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A Reflection on Using an Audience Response System to Teach Business Mathematics

Abstract

In higher education, we are confronted with a number of challenges that will continue to grow in the near future. This includes an increasing diversity of students with respect to their basic knowledge, motivation and learning skills, just to mention a few. To overcome these challenges, we tried to change the instructional strategy from traditional lectures towards a more seminar-like format that actively engages students. The use of an audience response system helped to motivate students to get involved and to participate in the course.

In this paper, we will report on difficulties that arose when implementing an audience response system in a first-semester business mathematics course. We will identify appropriate solutions from a practical point of view and will also give an insight into how we redesigned the traditional lecture in order to successfully launch this instructional strategy. In particular, we will show the extent of the benefit gained by combining an audience response system with a peer-instruction phase. We will discuss advantages and disadvantages of this approach.

keywords

audience response system; peer-instruction; business mathematics; student activation; field report

1 Introduction

As part of the ongoing improvement of teaching at universities, especially in mathematics, numerous didactic concepts have been worked out, in terms of designing lectures. These concepts are primarily developed for lecturers to tackle challenges that universities are faced with and that have gradually intensified in the past years.

First of all, this includes dealing with heterogeneous learning groups, not only with respect to existing basic knowledge (such as converting products to sums, calculating with fractions, applying percentage calculation and dealing with linear and quadratic functions to mention a few) but also with respect to available learning skills (such as active reading and understanding, problem solving, arguing and explaining). Furthermore, challenges arise when being confronted with students' attention deficits (Gerbig-Calcagni, 2009; Hoppenbrock & Biehler, 2012). Besides, we observe that students are barely motivated to learn mathematics. This may also be a result of bad experiences they previously had in school. Students may find mathematics too difficult, too theoretic, or too abstract, and therefore even the smallest interest in mathematics is repressed (Farren, 2008; Lach & Sakshaug, 2005).

To improve students' motivation and stimulate interactivity, as well as to increase students' attention, we decided to implement an audience response system (ARS) in the business mathematics courses.

Such voting systems have been used at American universities since the late 1960s to support teaching. They have become increasingly popular in recent years. ARS's were first used in higher education in biology courses (e. g. Bessler & Nisbet, 1971; Hatch et al., 2005; Preszler et al., 2007) and chemistry lectures courses (e. g. Casanova, 1971; Hall et al., 2005). They were again used in combination with Mazur's peer-instruction method in the 1990s for physics instruction courses (see Mazur, 1997; Burnstein & Lederman, 2001; Sharma et al., 2005). This teaching-learning method provides for classroom interactivity by spurring inter-student discussions before and after responding to multi-choice questions (Mazur, 1997; Pilzer, 2001). Literature reveals the efficacy of ARS's in creating an active learning environment (Bruff, 2009). Other studies detect that learning effects can be achieved when an ARS is used with proper direction (Deslauriers et al., 2011; Hoppenbrock & Biehler, 2012).

In the last two decades, Mazur's pioneering work in physics has been successfully applied to other fields of science (e. g. Caron & Gely, 2004; Hinde & A., 2006; Moredich & Moore, 2007; Abdel Meguid & Collins, 2017). For a more detailed history of the ARS, refer to Abrahamson (2006). A current review of the literature in terms of the ARS can be found under Kay & LeSage (2009).

In this paper, we will show how we implemented the ARS and Mazur's peer-instruction method to a first semester business mathematics lecture. We will address challenges we were faced with and will show how we overcame them.

The plan of this paper is as follows: The section following this introduction is dedicated to a short description of the context in which we implemented the ARS. Section 3 deals with didactical challenges and how we tackled them. In Section 4, we discuss the design of our previous approach, and in Section 5, we conclude with a summary.

2 Context Analysis and Underlying Conditions

The ARS was implemented in a first semester business mathematics lecture that is part of a course of study in economics. We would like to note that this mathematics lecture was designed for non-mathematicians who were, by majority, minimally motivated and hardly engaged in learning mathematics.

The lecture was held for two student groups in two different courses of study (C1 and C2). Throughout the semester, both groups were divided into two classes (S1 and S2) consisting of 40 students each (for C1) and 36 students each (for C2), respectively. This means we instructed 152 students in total. All classes were taught by the same instructor during the whole semester, which covers a total of 14 weeks. During this time, we gave 28 lectures for each class. Each lecture takes one and a half hours.

The majority of the students (82%) was between 19 and 25 years old. But there were also students between the age of 26 and 35 (18%) who had already completed an apprenticeship or spent time abroad. This demographic makeup and different graduation qualifications (high school, professional school) have an impact on the learning biographies and personalities of the students. As a consequence, the learning groups were very heterogeneous with respect to learning skills, professional experience, basic mathematical knowledge, self-organization and capacity structured versus independent ways of working.

These challenges will probably increase since German universities and universities of applied sciences are requested to grant easier access to higher education for young people who have not passed their university-entrance exams (see Wielepp, 2013; Knauf, 2016). Therefore, it is inevitable to perceive this diversity as enriching by including it into the lecture. A benefit may be achieved when inter-student and instructor-student interactivity in class is ensured.

We would like to note that all observations and conclusions reported in this paper are based on empirical evidence gained from observing all four classes throughout the whole semester. Nevertheless, we were able to confirm our initial observations with a survey of the students, conducted at the end of the semester (see Figure 2, Figure 3 and Figure 4).

3 Didactical Challenges and Solutions

To recognize the existing diversity of students as an opportunity, we are obligated to use it rather than to fight it. To achieve this objective, we need to invest time in lectures. Students can, for example, benefit from professional experiences of other students. Furthermore, those who have already gained practical know-how can act as experts in their field. But it is clear that there is a need for an adequate learning environment to support lively exchange and interaction. With this, students integrate more easily into the course and will probably experience success which, in return, is expected to raise motivation.

It is well-known that various classroom activating techniques (CAT's) exist, such as, for instance, brainstorming, inside-outside circles or Think-Pair-Share (see Brinker & Schumacher, 2014; Hoffmann & Kiehne, 2016 and references therein). Although these methods usually can be used without major preparation, we observed that they were either hardly applicable to a mathematics lecture or that they did not arouse students' interest in participating. We not only tried to activate the class via buzz groups and quizbowls, but also with a Taboo game and traffic light polling. In regard the latter, students voted using green, yellow, and red cards to signal which answer they chose to an issue previously raised. None of the strategies met expectations when it came to stimulating interaction, whether because of minimal engagement of students for fear of embarrassment, or because students preferred taking a break to participating, or because it was difficult for the instructor to evaluate the students' responses.

It was only when the ARS was introduced that students' enthusiasm increased. The objective was to adopt this instructional method so that, on the one hand, it would preserve the advantages of other didactical methods, such as easy handling and offering of learning support for students, and, on the other hand, it minimizes disadvantages, such as a lack of intrinsic student motivation and problems in terms of promptly getting and evaluating feedback. In order to achieve didactical surplus in activating students via an ARS – and not only to gamble in class – different challenges needed to be met.

Right now, there are several approaches to implementing an ARS in classes; these approaches have been developed at universities mainly motivated by their own desire for implementation. First off, there is polling via phones using text messages (e. g. "Invote" from the Technical University of Dresden). Secondly, there is voting using phones, tablets, or laptop computers via the internet (e. g. "FreeQuizDome" from the University of Bielefeld). Thirdly, there is voting with electronical handsets based on radio transmission (e. g. "TurningPoint" system by Turning Technologies).

Although students nowadays have mobile phones at their disposal, we decided not to use the first alternative. This is due to the fact that, as far as we experienced, mobile phones distract learners' attention and concentration (see also Kuznekoff & Titsworth, 2013). Allowing mobile phones or smartphones for polling purposes would hence be counterproductive. So, we strictly excluded these devices from the lectures by mutual agreement with the students. For the same reasons, polling via internet was not practicle. Even though the initial cost of the devices is high, we decided to take the third alternative into consideration, i. e., electronic handsets.

Challenges of introducing the ARS in the course occurred at different levels. First of all, the technical challenges need to be identified. It must be guaranteed that the receiver and the handheld key pads are available in sufficient quantity. Additionally, it is necessary to ensure that the handsets do not get lost during the semester and that they are ready for use at each lecture. There are two ways to overcome this last technical challenge. On the one hand, handsets can be distributed to learners for a rental charge that will be returned after receiving the handsets at the end of the semester. On the other hand, handsets can be distributed before and can be collected after each course. This can be done by the learners themselves so that no course time is lost. Since we implemented an ARS in four groups simultaneously without having enough devices for all groups, we selected the latter strategy. In doing so, the risk for students of being excluded from participating because of lost or forgotten handsets is minimized, too (Caldwell, 2007; Draper & Brown, 2004). We equipped 152 students in total for four semesters and, during this time only one handset was lost. It is important to note that the instructor has to take particular care not to lose the receiver, which is the most cost-intensive part of the ARS technology.

Furthermore, challenges on the instructor's level must be considered. The effective use of an ARS in lectures requires a lot of experience. Being familiar with the use of ARS's not only helps to create an atmosphere which encourages students to give feedback, it also helps to evaluate the students' responses and to react accordingly to them during the course. Applying an ARS, responses are predominantly queried by the answer options of the multi-choice questions asked. That is why the quality of the feedback is closely related to the quality of the questions and their answers. Aspects of formulating good questions can be found in Miller et al. (2006), Beatty et al. (2006), Caldwell (2007). Unfortunately, only a few comprehensive libraries of questions suitable for ARS's are available, mainly for physics teaching. First Pilzer & Hughes-Hallett (2003) and later Miller et al. (2006) also developed questions for calculus courses. Since we implemented the ARS in a business mathematics course at a university of applied sciences, we decided to create our own questions that are more application-oriented and hence adapted to the needs of this course of study.

Creating adequate, customized, and high-quality didactic questions is a very time consuming process that also includes phases of adjustment and correction. Thus, we started formulating questions six months in advance. Adjustment, correction, and extension of the collection of questions is still ongoing. This process is also influenced by students' approaches to the questions and students' ideas. Figure 1 shows a sample question. We will use this question as an example to illustrate how to derive feedback from the audience. It gives an impression of how we use the ARS to check students' comprehension of material, how we use it to identify misunderstandings of the concept and how it helps to uncover flawed thinking in order to remedy it immediately, if needed.

The parameters p_{ij} describe the number of patients being hospitalized in month i at section j. In this context, what is being counted by the sum $\sum_{j=7}^{9} p_{j4}$?
(A) The number of patients hospitalized from July to September; (B) the number of patients hospitalized in April at sections 7, 8 and 9; (C) the number of patients hospitalized in section 4 during the third quarter; (D) nothing is described in this factual context; (E) I cannot decide.

Figure 1: Sample question illustrating a general question design

Questions are designed in a way such that common, frequently-made errors are caught by distracting response options. This enables the instructor to detect critical points and to initiate appropriate corrections. Here, we were able to draw on experience of previous semesters.

In the particular case of Figure 1, the feedback is coded as follows: Answer (A) shows that students absorbed the possibility to name indices differently, but that students did not take the double indices into consideration. Difficulties arise because the second index is simply ignored or regarded as unimportant. It is also possible that the index is considered by the students but cannot be interpreted.

Answer (B) shows that students understood the concept in general. Nevertheless, they did not pay attention to the fact that the order of indices is not exchangeable. The peer-instruction phase that follows the questioning (see Section 4) may reveal this misconception. Additionally, specific mistakes should be explicitly addressed when the question is finally solved in class (after the second questioning phase).

Answer (C) shows that students are able to apply the concept correctly. Answers (D) and (E) show deeper problems of comprehension. If students are not able to clarify the point while discussing them among peers, we recommend that the instructor focuses on individual difficulties and explains the content once again before continuing the lecture. Moreover, answer (E) is the last alternative for all questions we created. It allows students that have no ability to find the solution to participate in the voting process without being forced to guess. In doing so, we avoid feedback that misleads the lecturer. Additionally, the number of answers is always limited to five. This ensures that reading the questions and the answers doesn't take too much time in order to provide sufficient time for the peer-discussion phase. We will focus on how we included voting phases and peer-instruction phases into the lecture in Section 4.

Another challenge on the instructor's level deals with the fact that the implementation of an ARS also takes time in the lecture which cannot be used to transfer content. Therefore, it is inevitable that the teaching material must be reduced (Knight & Wood, 2005; Caldwell, 2007). To overcome this challenge, we concentrated on the content that was of major importance for the students during their study. The reward was twofold. By concentrating on the reduced lecture content, students obtained a better understanding of the content in general. At the same time, this enabled the instructor to motivate students to learn, by pointing out where exactly in the future of their studies the course content can be applied (Caldwell, 2007; Elliott, 2003).

Finally, challenges on the students' level were encountered as well. The course addresses first-semester students that are not yet familiar with academic teaching. This open-mindedness helped to implement the ARS. In the inaugural lesson, we introduced the ARS by emphasizing the rules of its application in class and related educational objectives (see Section 4). In a test vote we then practiced the handling of an ARS to accustom students to both the handsets and courses of action. Spending time on making the new teaching method transparent provided the benefit that the ludic aspects did not displace the serious aspects. Even though there was a possibility to personalize keypads, we stressed we wouldn't use this feature and so that anonymity was guaranteed during voting. As a result, the acceptance threshold was low and students responded to the questions, almost without any fear of embarrassment.

4 Design and Discussion

According to Clark (1994), it is not the instructional technology itself but the instructional design that influences students' learning. The study reported in Van Dijk et al. (2001) shows that interaction in the classroom will not mean, as a matter of fact, that students are more engaged compared to traditional lectures. On this account, the following is devoted to show how the ARS has been successfully embedded into the lectures.

First, we note that in the inaugural lecture, didactical objectives and reasoning linked to the application of an ARS, as well as the rules and the ways of using an ARS in the lectures were outlined in a proactive and transparent manner. This strategy made students aware of the fact that the use of an ARS is less a quiz show in class, but rather a supportive method of learning through providing prompt feedback. To preserve seriousness, we not only employed the ARS selectively and sparingly but we also associated the use of ARS with detailed routines. The latter helped, thanks to the repetition, to focus students on the lecture. This included independent distribution of handsets to students when entering the lecture hall and autonomous and silent reading of presented questions.

It was not easy to decide when to stop the time for reflecting on the questions. As the seminar groups are heterogeneously composed, students answered questions at different speeds. We waived the possibility of a specifically fixed time period to answer the questions, since we had designed questions with different levels of complexity. Therefore, it was challenging to estimate an appropriate time limit for each question a priori. In practice, we pursued the strategy of announcing the remaining time of five seconds by counting the seconds down vocally and gesturally once more than half of the group had voted. This ensured that most of the students reflected the question and made a decision with good reason. A survey among students at the end of the semester concerning this time management revealed that a vast majority considered it as reasonable (see Figure 2). They agreed across all seminar groups and across both programs of study. This confirmed that the chosen approach to time management was perceived to be reasonable by a vast majority of students.

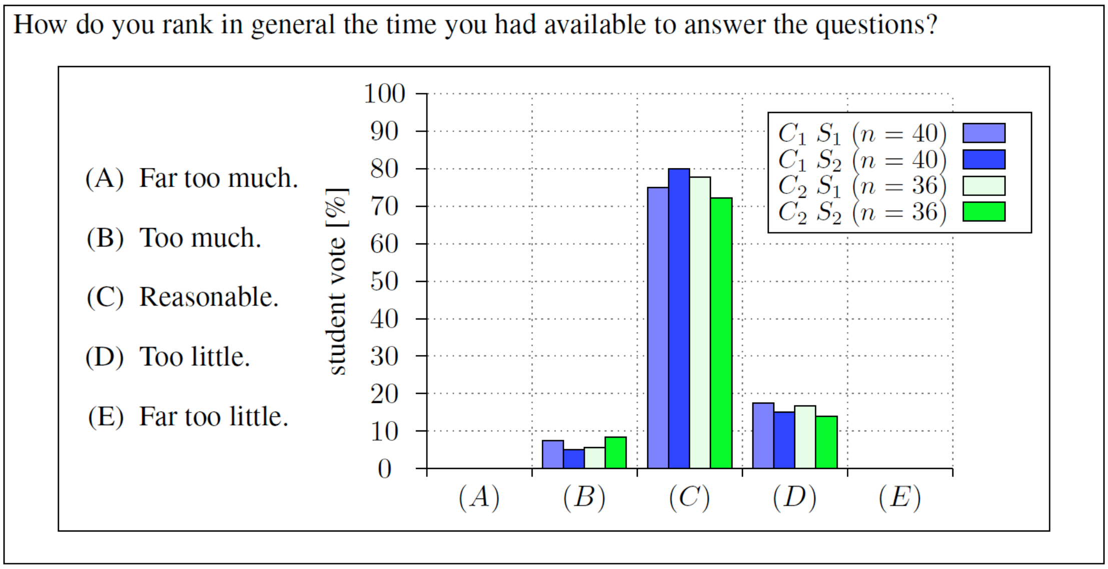

Figure 2: Results of survey relating to time management of answering questions.

The voting procedure was followed by a peer-instruction mode (Mazur, 1997; Crouch & Mazur, 2001). After the students had voted, we revealed a bar plot showing the distribution of the votes. At this time, we neither solved the question nor gave any hint to the solution. Subsequently, students formed little groups consisting of two or three neighbors to discuss their individual results. For this discussion among peers, we provided two to five minutes, according to need. Argumentatively, they tried to explain their choices and to convince others of its correctness, or they tried to reject other approaches. Finally, they converged on a more widely-accepted solution. This being the phase engaging students the most, students could adjust their results and verify their understanding of specific concepts. We observed that this peer-instruction phase motivated already active students to play an active part in their peer group. It was not rare to see that they were successful in involving shy students in the discussion. This is an advantage over lectures without peer-instruction since one hardly reachs those who are only silent observers of the lecture. If there were students without neighbors or students who did not want to participate in the discussion, we encouraged them to join a team. During this peer-instruction phase, we left the central position at the head of the classroom to circulate and adopt an observing role. Interestingly, this allowed us to follow discussions of the peer groups. Doing so, we were able to detect individual problem-solving strategies and different ways of thinking. We were able to address this insight in class at a later time and, furthermore, this insight helped to create new "distractors" for further questions. Beyond that, another side effect arose: when arguing and explaining, students gained confidence in their abilities. Such positive experiences had a motivating effect.

We only initiated this peer-discussion phase when less than 50% of the students voted for the correct answer. This was due to the fact that we recognized early on that students otherwise barely exchanged thoughts on the issue and instead tended to talk about other things.

In practice, students often did not think strictly on their own about the question asked in the first voting phase, nor we did not insist on that. They rather started discussion in small teams, whether in order to get access to the solution, or in order to reassure themselves of their own decision. We note, that this did not make the following peer-instruction mode unnecessary because then students often formed other groups and hence, initiated fruitful discussions anew. Nevertheless, this pre-discussion also enabled students to solve the question on their own, if desired.

Following the peer-instruction phase, we showed the new distribution of the votes and asked a student that had changed his or her answer to explain why the new decision is correct. If needed, further questions from the audience were answered either by students or by the instructor. In total, this strategy took an average of 15 minutes per question.

We collected all the questions asked in the lecture in an online learning platform together with other lecture materials. We used this opportunity to outline the correct solution, to give references to other lecture content or to point out important items. A general survey as to the overall lecture at the end of the semester revealed that this was welcomed by the students as a method of support in preparing for the final exams. Contrary to what was explained, for example in Cain et al. (2009), the results of the votings were by no means used to influence final examination results.

In class, at the end of the semester we asked students how they experienced this learning method, i. e., the blend of answering questions and consulting peers, and how this helped them to understand the lecture content. Figure 3 shows the results of this survey. It is clear that according to the students, an ARS and peer-instruction supported the learning process. We emphasize that in none of the seminar groups was this instructional strategy evaluated negatively in terms of learning success.

In the context of including an ARS into the lecture, two major issues needed to be resolved. First, we had to be aware of how many questions we would like to ask in one lecture. Second, we had to decide how to integrate them into the lecture.

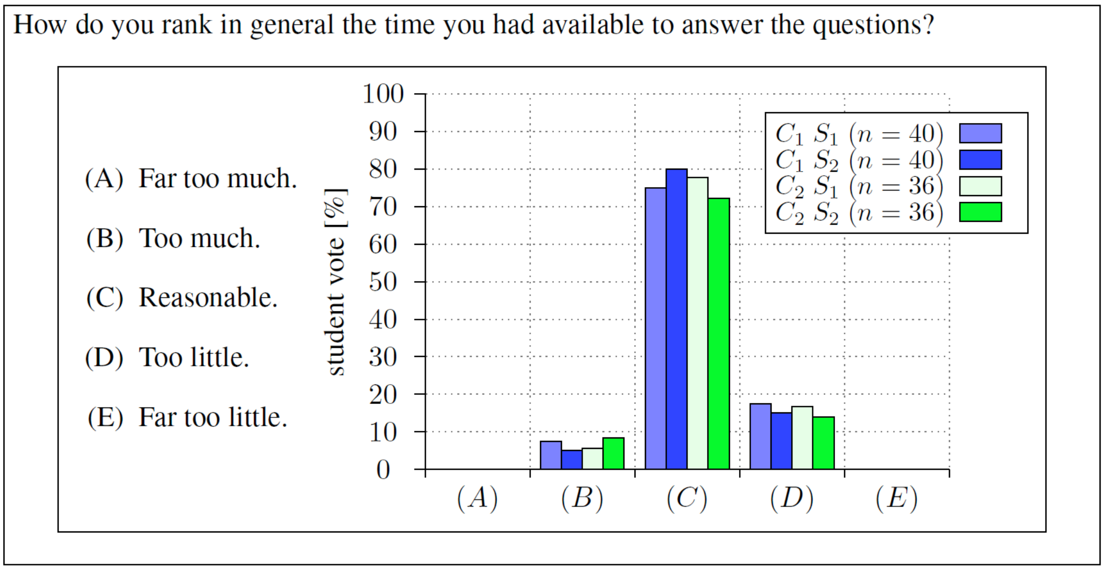

Figure 3: Results of survey relating the helpfulness of an ARS to the learning process.

Due to temporal restriction but also to ensure more varied instruction, in general we recommend to ask one question per lecture, and, rarely, two questions. This is because we realized that regardless of the seminar group, the level of concentration declined as the number of questions increased. There were three different strategies in terms of temporal placement of the questions that we employed without preference. In the first strategy, we used questions to start lectures. This provided the advantage that students' attention and concentration were immediately focused on the lecture. In this way, we could get feedback on students' state of knowledge and equally recall the material of the last lecture.

It is well-known and empirically supported that the average time span of an adult's concentration has a length of about 20 minutes (see Burns, 1985; Middendorf & Kalish, 1996 or, for a detailed discussion, see Bligh, 2000). Taking this fact into consideration, we also used the questions as means of breaking long talks into shorter segments. This helped students to refocus on the topic and increased their attention. Furthermore, by interspersing questions in the lectures, we also could detect conceptual difficulties and problems with understanding. We then adapted the lecture's speed and content in time, if required. Time that students spent reflecting on lecture's content could be saved, as we were no longer forced to constantly repeat material – thanks to a better comprehension.

We also used questions to end lectures. Here, monitoring the progress of learning laid in the foreground. This gave a good opportunity to reflect on content material and to highlight important issues. Surprisingly, several times students even preferred answering a question at the end of the lecture rather than ending it early. This was interpreted as an indication that students were motivated to learn. Nevertheless, we note that it is necessary to have enough time left to answer and discuss the question. In case of time constraints, we suggest skipping lecture content rather than interrupting the peer-instruction phase or rushing through.

In addition, to activate students within the lecture, we tried to engage students between the lectures as well. Students were asked to create their own questions that we promised to present in class. The objective of this approach was to motivate students to study lecture content at home and to add an additional period of reflection. As a result, in total, we received five questions from four students that belong to two different seminar groups in the whole semester. The ways that they formulated the questions and the degree of complexity they used provided supplementary feedback.

5 Summary

Giving lectures at universities becomes more and more challenging because an increasing heterogeneity of study groups can be expected. The challenges lie in considering different prior knowledge, developed learning skills, speeds of learning, and professional experiences of teachers. To get meaningful feedback from the course, it is necessary to create a friendly learning atmosphere that encourages students to interact with the lecturer and other students. In this article, we illustrated how we implemented an ARS combined with a peer-discussion phase in a first-semester business mathematics course. During the questions asked in the lectures, we observed an average participation rate of 98% of the students. Since answering the questions in general required a discussion of the mathematical concept behind them, we deduced that, at least at this state, students' motivation and participation increased. We also observed that students were more engaged to ask questions about the lecture content than we experienced in lectures without an ARS.

As a result, we were able to receive and assess feedback. We used this feedback to adapt the lecture constantly and group-specifically with respect to speed and content. Although we invested plenty of time and effort not only in preparing the lecture but also within the lecture itself, we were able to achieve didactic benefit. Now that the major effort is done and that we are more familiar with the instructional strategies of using an ARS and peer-instruction, we expect that we can pay more attention to fine-tuning adjustments and that we can further improve this approach.

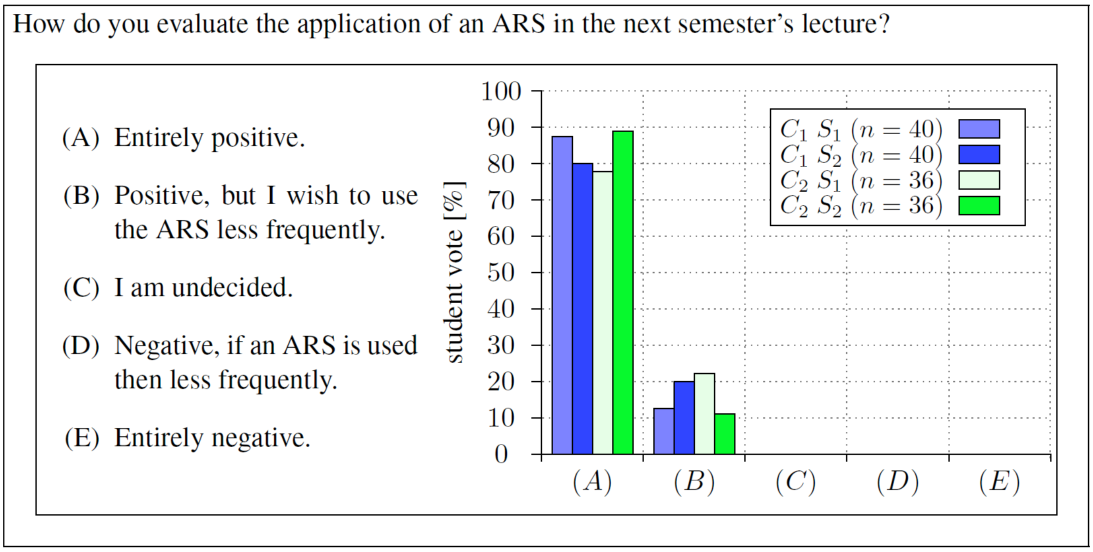

Figure 4: Results of survey relating to further use of ARS.

Even though major problems were avoided and negative experiences were rare exceptions, it became clear that the use of ARS without further considerations could also lead to undesired side-effects that can be counter-productive to students' learning success. That is why careful planning in terms of the application of the ARS is crucial. This includes the preparation of educational questions to be asked in class as well as the time in which they are to be posed.

In conclusion, we stress that the students enjoyed the variety which was brought into the course through the engagement via the ARS. This perception is underlined by the survey presented in Figure 3. There, students voted that they find the use of the ARS very helpful and that they think it contributed to their learning. Instructors' practical experiences reflected in higher student motivation correspond entirely with these positive results.

Although some literature reports a positive impact regarding performance during final exams (e. g. Kyei-Blankson, 2012), we can neither confirm nor deny this observation. On average, our students achieved better final exam results than those of previous years - when the ARS was not included in the lecture. Since there is no control group or reasonable comparison with which to attribute a statistically significant difference to the use of the ARS, future investigation into the possible causes is needed.

We would like to end this section by presenting a survey that we carried out at the end of the semester (see Figure 4). This survey emphasizes that the students take positive stance towards the instructional strategy of combining an ARS and peer-instruction methods in the way reported in this paper. This, in turn, motivates us to continue improving our approach.

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