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ENHANCEMENT OF STUDENT LEARNING AND FEEDBACK OF LARGE GROUP ENGINEERING LECTURES USING AUDIENCE RESPONSE SYSTEMS

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ABSTRACT

We studied the use of an Audience Response System (ARS) in large group lectures of a material science module in an engineering program. The aim of this study is to create a high level of activity in lectures through implementation of different teaching approaches supported by the use of ARS. The teaching approaches used in this study include long and short lecture sections, use of videos, peer interaction learning, and review lectures. We found that the use of ARS had no effect on student engagement if lectures were not broken into short sections. Results also show that when ARS are used in an active teaching environment, they improve the engagement of students and attendance, especially, when students are encouraged to discuss the topic with their peers before voting. In addition, quantitative results show that engineering undergraduate students taught with the support of ARS have improved performance on exams.

Keywords: *ARS, large group, Active Learning, student engagement*

1. INTRODUCTION

Large group lectures are still a major teaching approach in higher educational institutes. They are cost effective and efficient approaches of teaching and delivering knowledge. Additionally, they are not expected to be replaced with other methods in the near future. This is strengthened by the expansion in student enrolments while having limited resources. In the UK, The Higher Education funding system has undergone radical changes. For example, there is less funding for students from the Higher Education Funding Council for England (HEFCE) teaching grant and more graduate contributions through higher fee loans. In addition, in the last five years, the per-student funding in higher education decreased by about 10% in real terms from 2009 to 2014 [1].

One instant result of such changing in funding schemes is the increase in lecture size. Some lecturers considered such increase in class size to be better than repeating the same lecture many times. Students are also not so obviously against this type of teaching. Some students, for several reasons, may prefer large group lectures. In large lectures, there are more students to meet and to make friendships with. In addition, large lectures maintain a lower stressful atmosphere and provide an adequate independency during students learning and studying. Unfortunately, this does not seem to be the case as researchers reported a significant increase in the difficulties experienced by lecturers when teaching to large group of students. In many situations, lecturers have had to be trained to get innovative skills and approaches or modify their existing teaching styles in order to cope with large group lectures [2].

One of the key problems with large group lectures is that students get bored and are more likely to have a low level of engagement. As a consequence, much of criticism is generated as it affects student-learning performance and student feedback [3, 4]. In an earlier research by Tongue, the author tried to demonstrate the difficulties faced by an instructor teaching to a large group of students by comparing a large lecture class and a classical Greek theatre. In both situations there is an actor (or a teacher) speaking to a large group of people who are arranged in row upon row of seats looking down upon him. It has been emphasized that the actor has certainly an easier job of getting his audience engaged as he is usually presenting some sort of entertainment and the spectators are there in order to see it. On the other hand, the lecturer's job is much more difficult as the material he is delivering isn't usually exciting and most of the students are there only to fulfil their graduation requirements [3].

A significant challenge of the interactive approaches is to activate shy students, who often are discouraged by the language barrier as being international students, or when only few active students participate in lecture discussions and teachers cannot manage to encourage other students[5]. Students' attendance is another problem facing many lecturers when teaching to large groups. Many studies have found that students' absence becomes pronounced in large group lectures where students are mostly anonymous and taking attendance is usually intimidating, if not impossible [6, 7]. It is therefore important to retain high-quality learning against these challenges, which could be achieved through active learning. Active learning is a teaching approach, which involves a two-way interaction between the lecturer and the audience in a way intended to allow an increased discussion among the participants [8].

One approach to make a large lecture more interactive and engaging is to break the lecture into shorter sections of about 10-15 min each, separated by several activities to regain the students' attention and address learning outcomes. Any change of activity within a lecture may restore attention, as shown in Figure 1.. Short breaks may be in a form of discussion, a break to breathe fresh air, a short quiz or an example from life [9].

The "Flipped" lecture is a teaching method, which became popular in recent years especially in large groups. In flipped lecture technology format, students can watch the lecture on their own. They have the lecture materials in forms of a video, notes, or slides and they are able to pause, take notes, and revise it as many as they want to understand the contents. A quiz or relevant questions are usually included in the given lectures to ensure students' understanding of the material. Lecturers use the actual lecture time to apply the knowledge learned from the given lecture materials in an active learning environment. The advantage of this approach is to improve the student's problem solving skills and increase

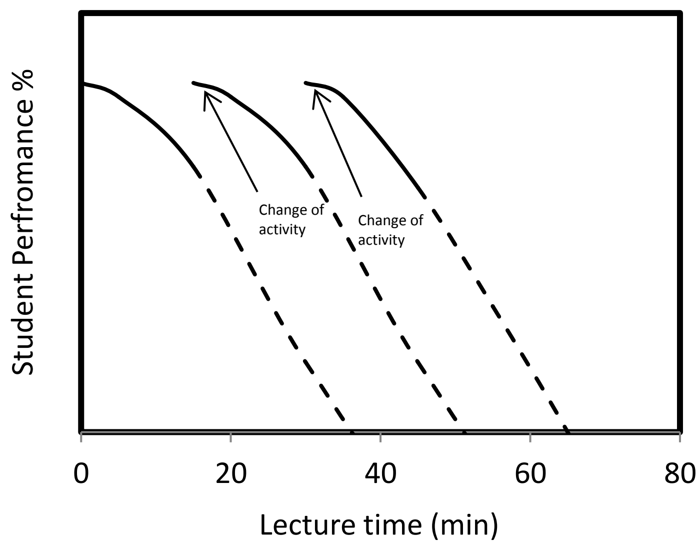


Figure 1. Influence of change in activity on learning [9].

student-teacher interaction. In addition, students are responsible for their learning while lecturers can guide and help to answer what students do not understand [10, 11]. Furthermore, Enquiry-Based Learning EBL is a teaching approach in which learning is triggered and stimulated by enquiry. The first step in EBL is to encourage individuals to share responsibilities for learning. This improves independent learning and team working skills [12].

The use of modern technology has a strong influence on improving education systems. In addition, communication technology has significantly influenced the way of teaching. Lecture theatres' infrastructure has changed dramatically to include digital and communication instruments such as PCs, mobile phones, whiteboard, laptops, Internet, and social media. This technology has influenced the way lectures are prepared and managed, and their interaction with students [13].

Audience Response System (ARS) is a robust type of communication technology that is aimed to improve students' engagement in different disciplines. Low cost ARS systems based on radio frequency (RF) technology have been commercially available in the market since 2005 and since then their performance in the educational process has considerably improved. Typically, students hold the ARS in their hand and can electronically submit their answers to multiple-choice questions (MCQ), presented by the lecturer. The submitted signal is received by a dongle/adapter/receiver on the lecturer's computer where the received data can be then displayed and analysed by the lecturer. In addition, students can also watch their answers, discuss them with the lecturer, and compare them with their peers. Other attempts have been performed using mobile phones as an alternative active learning tool, and are cost-effective when compared to ARS. However, one can see that mobile phones are not practical due to their diversity, which may be a barrier to improving the engagement of all students [14]. Many investigators have reported different studies concerning the application and evaluation of ARS in engineering disciplines. For example, Stehling and colleagues have studied the implementation of ARS for a very large group of students in classes of Information Technology at Aachen University. They addressed the advantages and disadvantages of using ARS for a class of about 2000 students'. The major difficulties reported involved the low number of participants due to the weak Wi-Fi signals, software problems and open-ended questions. Although such difficulties were faced in their first attempts, they managed to successfully use ARS for such a number of students [15]. The influence of the use of ARS on student learning performance has been an interesting point over the past 10 years. Bamberg and colleagues have used various learning approaches throughout a first year mechanical engineering course to overcome learning difficulties and student engagement accompanied with large group enrolment along with diverse students' backgrounds. Specifically, they used active learning as the main strategy to improve peer learning. They also used Computer Aided Design (CAD), Computer-Aided Engineering (CAE) software to improve mechanical engineering design practice [16]. In addition, others have introduced the use of ARS to improve undergraduates' and graduate students' understanding and promote active learning in the classroom [17].

The aim of this research is to overcome difficulties accompanied with large group engineering enrolment along with diverse students programs. Engineering is an applying area that depends on applying science, problem solving and critical thinking. While the majority of undergraduate engineering modules are taught through classical lecture, applying ARS methods can give students an opportunity to improve interaction with lecture and critical thinking skills through lecture activities. Here, it was planned to use ARS in teaching a Fundamentals of Materials B (FOMB) module. FOMB is set for first year students and the main aim of this module is to introduce various aspects of shaping materials into useful objects, and hence, to enhance students' understanding and knowledge of the manufacturing processes for metals, polymers and ceramics. In this module, there were about 140 students enrolled, coming from different study programs, specifically, Metallurgy, Nuclear Science and Materials, Sports and Materials Science, Biomedical Materials Science, and Mechanical and Materials Engineering. In addition, students came from national and international backgrounds. Such numbers and diversity in the classroom may cause teaching and learning deficiency. With these circumstances, it is becoming difficult to motivate large-group students to work and interact with their peers using traditional teacher-centred lectures.

The primary objective was to investigate the effect of ARS on education performance and to measure quantitatively the difference in student engagement and module score between classes taught using ARS and those taught using traditional lectures. In particular, we investigated the amount of interactivity in lectures between students and their peers and between the lecturer and students that comes from the employment of ARS. We compared the resultant interactivity in lectures, and how it affects student engagement and collaborative learning. To assess this proposal, we used ARS in both particular review lectures throughout the module semester and within standard lectures, which offers the chance to enhance students' attention and module understanding. We analysed actual data from undergraduate students in FOMB for the academic year 2013-2014, and studied the student feedback towards different approaches used within the ARS. We compared these results with those of the academic year 2012-2013 for the same module and same teachers but without the use of ARS. In this way, we would contribute to the existing learning in large-group lectures and improvement of engagement and student performance.

2. METHODOLOGY

We assessed the proposed use of ARS in a large group engineering course using a sample of 140 first year undergraduate engineering students for the academic year 2012-2013 and 97 students for the academic year 2013-2014 enrolled in FOMB at the University of Birmingham, UK. Students belonged to five different study programs, Metallurgy, Nuclear Science and Materials, Sports and Materials Science, Biomedical Materials Science, and

Mechanical and Materials Engineering. They attended two lectures per week for two hours during the term time. The course content, lectures, review lectures, and labs were similar for the two academic years, to ensure that all the lectures and the notes covered the same material in the same way [18]. Students also had similar assignments, and took similar quizzes and tests. The only difference was that in the academic year 2013-2014 ARS was employed in some lectures of the module and was used solely in the review lectures throughout the semester. An aspect that might affect the comparison between the two academic years was the change in student enrolment: In 2013-2014, there were 97 students, whereas in 2013-2014 there were 140 students. Student' attendance was recorded manually with paper forms throughout the two academic years under study.

ARS supplied by Turning Technologies (UK) was used in the study. In each lecture, 150 devices, also called clickers, were booked for students' use. Data received from students was collected by a dongle plugged into a PC at the front of the lecture theatre. In this technique, students were set to answer multiple-choice questions. After they voted, they were allowed to discuss with their peers. Discussions with peers are very important, and students can learn more from discussion with each other than by listening to lecturers, if the discussion is well organised [19]. During the semester, different approaches were used with the aid of ARS. Specifically, in one lecture, two long videos were played back to students explaining a topic of the module, followed by a quiz using ARS. In other lectures, short videos were used, followed by a question after each video. Re-voting after peer discussions was the next approach. After 5 minutes, they were allowed to re-vote on the same question again, and the lecturer displayed their voting results before and after peers' discussions for another discussion with him. Finally, one lecture at the end of the module was dedicated to a group competition. In that lecture, the lecturer prepared review slides and students were allowed to choose their groups. Multiple choice questions were displayed and students were allowed to answer. The results were calculated cumulatively for each team. Teams of students were given about 1 minute to discuss among themselves before answering each question. The answer was displayed after each question and the cumulative results of each team were displayed frequently to update the participants about their competitors.

Part of the data was collected to examine the students' feedback about the use of ARS and the advantages of using such technology. A questionnaire consisting of 22 items was prepared and given to students to complete. Out of 140 students enrolled in the course, 71 completed this special feedback form with a ratio of about 50%. The feedback' form included questions about the student's impressions about clickers such as (e.g.) easiness, enjoyment, usefulness, and the different approaches using ARS. In particular, feedback questions can be categorised according to the following: ARS's advantages and learning performance, different approaches used within ARS and module experience. In addition to the ARS feedback form, two overall module feedback data were received for the two academic years under this study. In the feedback form, students were requested to answer the questions with Strongly Disagree, Disagree, Neutral, Agree, or Strongly Agree. To quantify the results, one mark was allocated to Strongly Disagree, two marks for Disagree, and so on. Finally, module final scores of both years were also analysed. However, some focus was assigned to the exam multiple-choice questions (MCQ) scores, since they match the same style used in the dedicated review lectures using ARS.

3. RESULTS and DISCUSSION

Attendance data of both academic years 2012-2013 and 2013-2014 were gathered from the attendance paper forms, providing a record of the students' attendance per lecture. Those data were employed to estimate and compare the average student's attendance over the term time for both years. Attendance in the ARS lectures was slightly higher than for those lectures without the ARS. The average attendance in the academic year 2013-2014 was 94 students (68%) while it was 61 students (62%) in the academic year 2012-2013, with a small enhancement of the students' attendance of about 6%. In a previous study by Shapiro [7], the author improved his lecture attendance from 61% to 79% through the application of the ARS. This dissimilarity may be due the difference in the data collection method. In the current research, the data for both academic years were collected through a paper form as many of the lectures for the academic year 2012-2013 were conducted without the use of ARS. Hence, it was intended to get the attendance in a paper form through all lectures, while in the literature [7], the attendance data were collected through the ARS.

The student attendance does not contribute to the final mark, which might be another potential reason for the insignificant increase of the student attendance when an ARS was used. In a study by Greer and Heaney [20], benefits associated with the usage of ARS during the lectures of an Earth Science course at Penn State University were investigated. The authors reported a remarkable increase of the students' attendance from 40% to about 80% when ARS responses (regardless of correct/incorrect answers) were counted as 15% of the final grade. An increase in students' attendance when including the ARS participation with the final grade was also observed by Burnstein and Lederman [21], and Caldwell [22], although in the latter study the author suggested that 5% of a student's grade was a sufficient motivation to improve regular classroom attendance. It is important to emphasize that even though involving the use of ARS in the student mark may encourage them to attend lectures, they are not always pleased with this practice. The results by Greer and Heaney [20] showed that many students were unhappy about being obligated to attend lectures in order to gain academic credit for ARS participation. An earlier study suggested that when ARS questions were part of the grade, no significant evidence was found that students who responded to ARS questions in class did perform better on the corresponding exam questions than those who did not answer in class. This is often because students were answering in class only to get extra points for the ARS use, and not paying attention to the content [23].

The first observation was that most of the students seemed excited about using ARS. Students' feedback on how they felt about the use of Clickers is shown in Figure 2. As shown, 96% of students' answers were "strongly agree" or "agree", suggesting that most of the students found ARS easy and fun. Another important feedback about anonymity of ARS is shown in Figure 3. As shown, 4.42/5 of the students like the anonymity of ARS. In addition, more than 58% voted "strongly agree" with this question. These results support the assumption that the ARS encourages students for more participation and engagement with either their peers and/or the lecturer during large-group lectures.

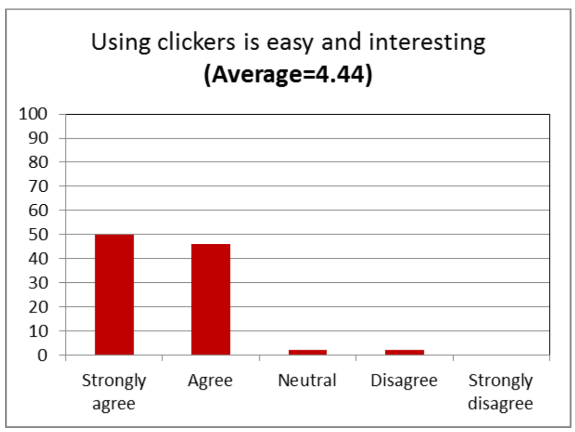


Figure 2. Students' feedback on how easy and fun are the ARS

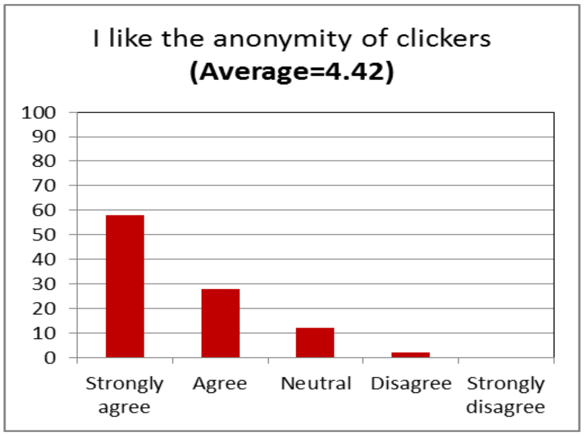


Figure 3. Students' feedback on anonymity of ARS

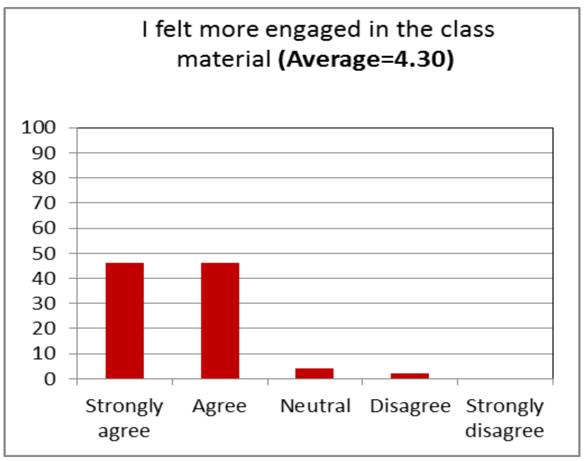


Figure 4. Student engagement when using ARS

As for student engagement, students thought they were more engaged when using ARS in a lecture, (see Figure 4). About 4.3/5 of students think they were engaged with the lecture. No one voted as "strongly disagree" with this feedback. This result was in agreement of research published by Everett and colleagues [24]. These findings also supported the results by Hu and co-authors [25], which showed that the students, especially those who are from overseas, liked to participate and respond to lecturers' questions using ARS within a large lecture class rather than if they were required to answer orally. In addition, this also agreed with the results of the study carried out to assess the effectiveness of the use of ARS in six biology courses at New Mexico State University [26].

As described, different approaches were employed with the aid of ARS, and their effect on students' understanding of the lecture concepts was assessed by analysing student responses. This was achieved by counting their correct and incorrect answers to a number of questions using ARS. The first approach used was the employment of long videos presenting a certain amount of information followed by an assessment of the students' understanding through multiple-choice questions using ARS. This was applied to a lecture about casting of metals. Two long videos, each of about 25 minutes length, were played. Afterwards, multiple-choice questions and slides were displayed, and students were asked to answer them one by one with the aid of ARS. Each question was followed of an explanation of the topic under investigation. For advanced questions, which require deep understanding of the content and need more thinking to relate what has been displayed in the video and what is shown in the question, only 40-50% of students answered this type of question correctly. One negative observation in this approach was the obvious boredom of many of students after about 10-15 of playing back of the videos. Students started to chat with each other and a couple of students at the back leaned their head on the desk. This might be due to the length of the video. It could be seen clearly that playing relatively long videos was boring to students. Students can typically recall most of the information in the first ten minutes; later on, their focus drops very quickly [8]. Apparently, this also applies for long videos. It could be concluded that videos' duration should be shorter, or at least they could be divided into sections separated by discussions or review questions using ARS. With the aim of improving student engagement and killing boredom during video lectures, short videos with the aid of ARS were used to stimulate students to focus on the videos' content. Questions were asked using ARS, with a hint that the answer lies in the coming short video. This approach helped to enhance active learning and engagement. One could see that most of the students paid attention during the video and voted towards correct answers. Student feedback regarding this technique is shown in Figure 5. A fair proportion of students found this technique helpful in increasing their focus on video content. Only 6 % "disagree" or "strongly disagree" with this technique.

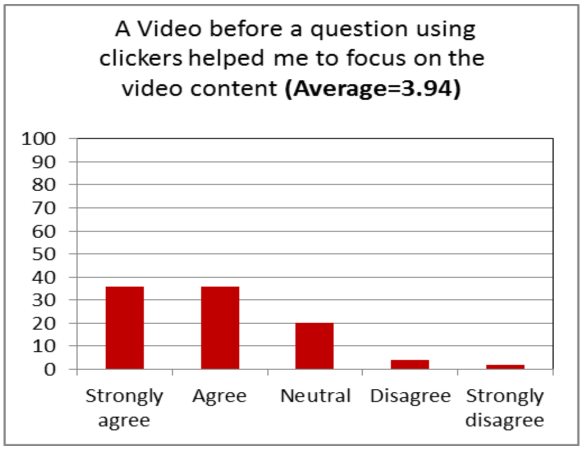


Figure 5. Students' feedbacks on displaying a video using ARS.

Re-voting after peer discussions was an approach used with the aid of ARS. In this technique, students were asked to answer multiple-choice questions. After voting, they were allowed to discuss the question with their peers. Discussion with peers is very important, and a student can learn more from such discussions than from listening to lecturers, if the discussion is well organised [19]. After 5 minutes, they were allowed to re-vote the same question again and the voting results before and after peers' discussions were displayed to students. It could be clearly seen how the answers shifted towards the right one after peer discussions, as shown in Figure 6.

The students' feedbacks about peer discussions before the ARS are shown in Figure 7. Most of the students found that it helped them to achieve better understanding of the course material. No one "strongly disagreed" and only 8% "disagreed" with this technique.

These results were consistent with the inferences drawn by many researches regarding the impact of using ARS on several learning benefits such as the students' interaction and

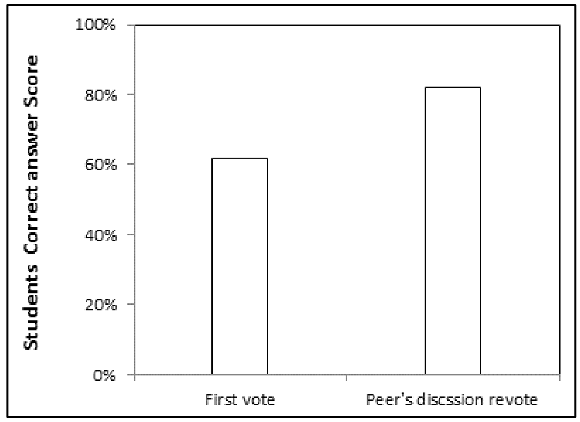


Figure 6. Students' correct answer score before and after peers' discussion

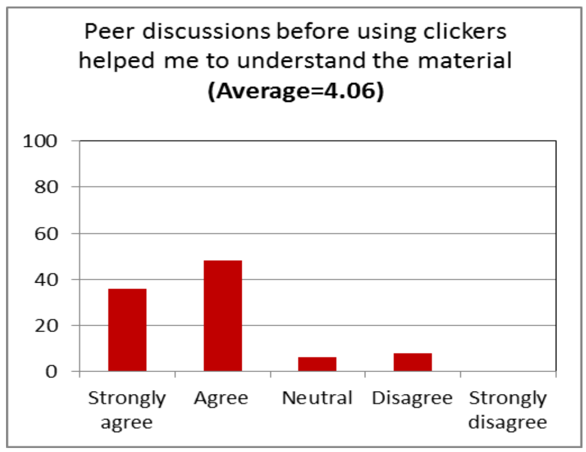


Figure 7. Students' feedbacks on peers' discussions using ARS.

discussions. In a study by Beatty [27], the author followed a similar approach in his lecture as he was giving his students a question or a problem and asking them to individually-answer via a clicker. Then, he displayed their answers on a screen in the form of a histogram. Afterwards, students were allowed to discuss the problem among them for some time before being given a second chance to answer the question. The author suggested that the application of ARS helped him to implement what is called "*think-pair-share*" education model, usually associated with small classes, in the large lecture hall, which in turn enhanced the students' performance and satisfaction during the lecture. Other researchers also signified a significant improvement of the quantity and quality of peer discussions during classes when ARSs were used [22, 28].

An important outcome of the application of ARS was the improvement of students' performance on exam questions of the FOMB course. As shown in Figure 8, the use of clickers significantly decreased the percentage of failed students from 29% to 17% while increasing the percentage "D" and "C" students from 28% to 40% and from 24% to 29%, respectively (Figure 8 (a). However, the use of ARS seems to have no effect on the percentage of "A" students. In addition, and regarding the MCQ question, which was out of 15, the use of ARS decreased the percentage of students who obtained "Zero" in this question from 6% to only 2%. In addition, the number of students scored less than (8/15) was dramatically reduced (by a factor of about 50%).

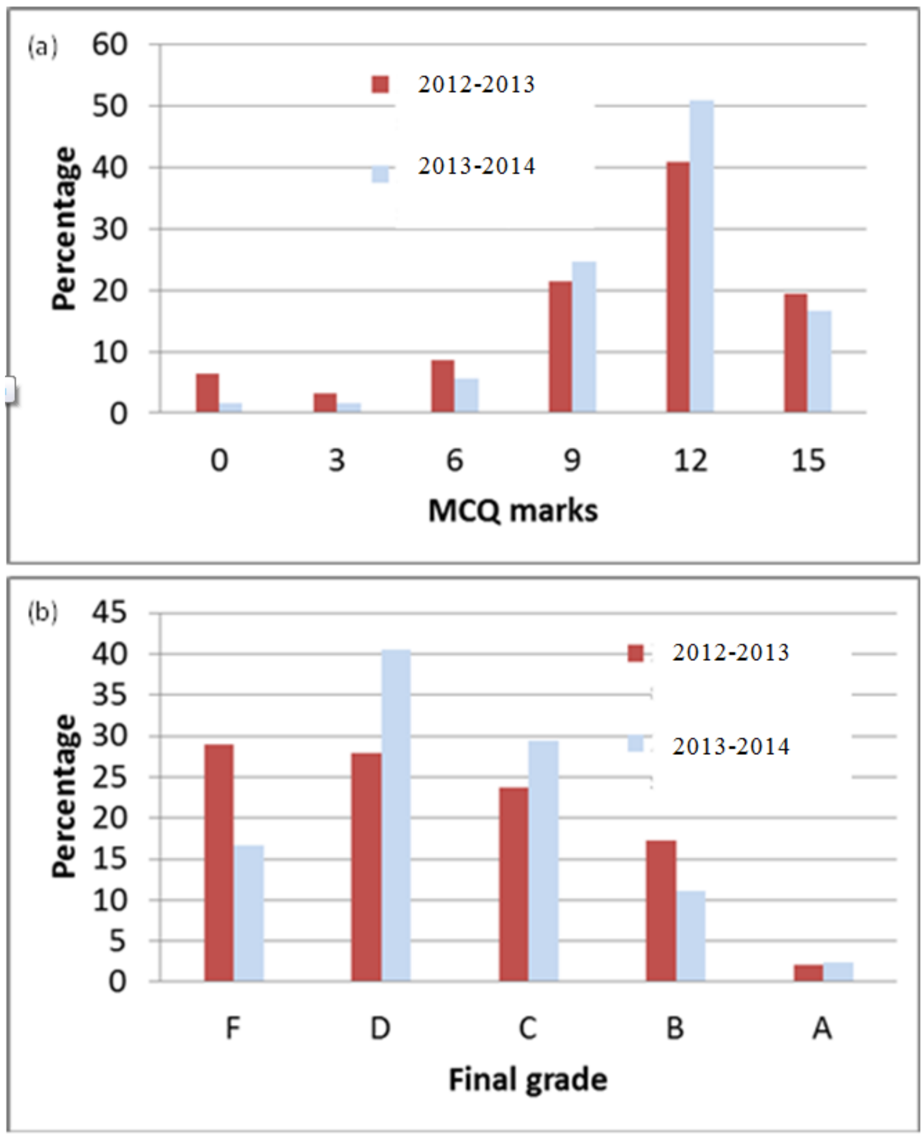


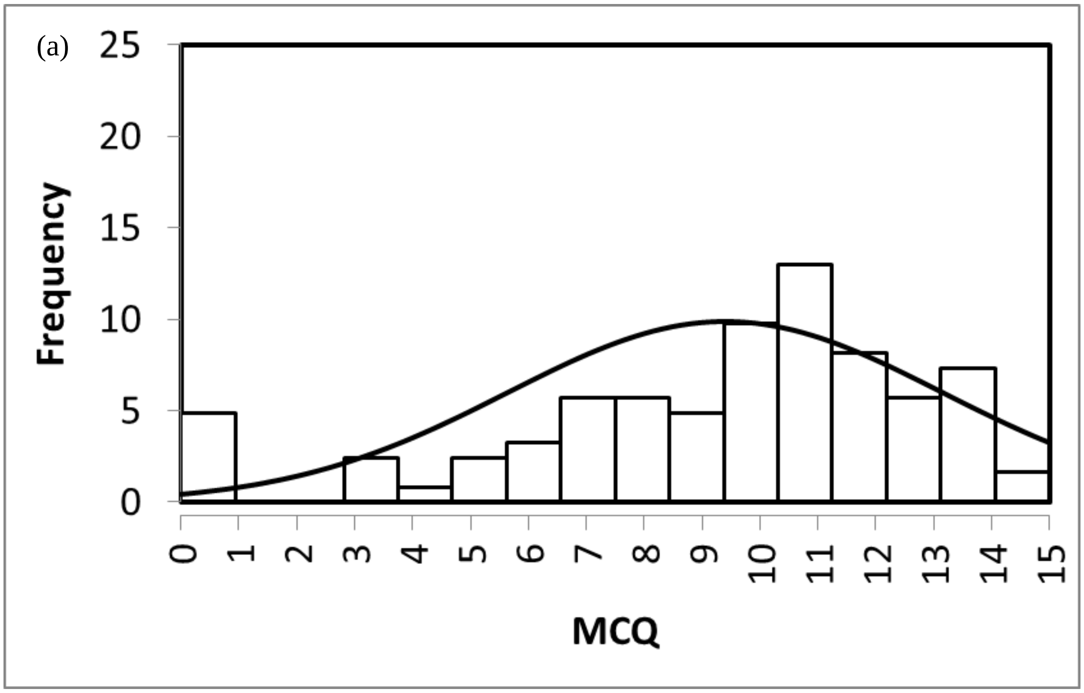
Figure 8. Effect of clickers on grade distribution of the FOMB course at the University of Birmingham for two academic years 2012-2013 and 2013-2014 (a) Final module grades, (b) MCQ question score

These results could be an indication that the enhanced class participation associated with the use of clickers had a positive impact on the grades at least for some students, while it prevented others from failing the course. The results are consistent with the results by Caldwell in his study of the effect of using clickers in a trigonometry course with classes of about 200 students at West Virginia University [22]. His results indicated an increase in the percentage of students who obtained an “A” grade by about 5%, as well as a decrease in the percentage of “F” and “D” students by about 4%. However, in the current work, although the use of clickers seems to have no influence on the percentage of the “A” students, it showed remarkable impact on reducing the failed students by a half. This might be a suggestion that the active educational performance, usually associated with the use of ARS, is more beneficial in attracting shy and low performance students, encouraging them to attend, focus and respond to lecture questions. This in turn might enhance their learning attitude and allow them to avoid failing the course.

Figures 9 and 1**0** show the distribution of the MCQ mark and the final module mark of the academic years 2012-2013 and 2013-2014, respectively. The distribution of both marks showed a good fit with the normal distribution. In the academic year 2012-2013, the mean value of the MCQ mark and the final mark was 9.4 and 57, respectively. However, the implementation of ARS technology in the academic years 2013-2014 boosted the average scores to 10.3 and 60, respectively. This also reflects a positive impact of such strategy on the learning-outcomes.

These findings are supported by the results reported by Yourstone *et al.* who investigated the substantive difference in learning outcomes between traditional classrooms and classrooms using clickers during an Operations Management course [18]. In this study, the authors were intended to quantitatively determine whether the students who were being taught using clickers had better fulfilment of their learning outcomes than those taught using traditional paper quizzes. In other words, and in terms of examination scores, will the immediate electronic response feedback (provided via the ARS technology) allow students to learn more than those students who receive delayed paper feedback. Their findings showed that the class that was taught using clicker had a significantly greater increase in the average examination scores than the non-clicker class by about 8%, which could be sufficient evidence that the use of instant feedback associated with the use of ARS technology can have a positive impact on student learning. The implementation of ARS technology in an introductory manufacturing course at Texas A&M University was also found to raise the average test score from 80.3 to 95.7 [17]. Figure 11 shows plots of the sorted scores, ranging from the lowest to highest, of both the MCQ question and the final module grade for all students in the academic years 2012-2013 and 2013-2014. It could be indicated that the application of ARS resulted in an enhancement of the success rate of both the MCQ question from 81% to 93%, and the overall module final score from 75% to 88%.

In a research by King and Joshi [23] regarding the use of clickers in a chemistry course for engineering majors at Drexel University, the authors found strong evidence that class participation, associated with the use of ARS, had improved the students’ final grade. In addition, a significant correlation between the response to clicker questions in lectures and the enhancement of students’ performance in similar exam questions. Fang [29] also reported statistically significant correlations between clicker performance and exam performance. Therefore, the results of the current research, in which the use of clickers was demonstrated to boost not only the students’ scores in the exams but also their performance in the MCQ questions closely imitating the ARS questioning style, could be a confirmation of the findings by Fang [29], and by King and Joshi. Finally, Preszler and his colleagues reported a positive impact from the application of ARS on students’ exam scores in biology courses at New Mexico State University [26]



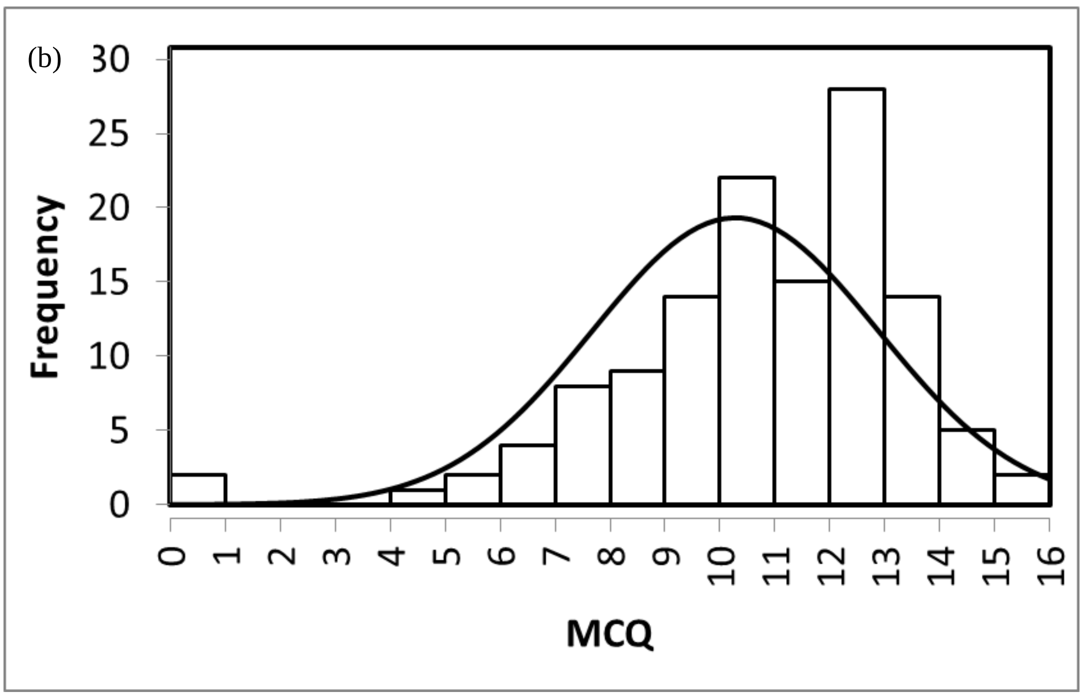


Figure 9. Distribution of the students' MCQ marks. (a) academic year 2012-2013, and (b) academic year 2013-2014.

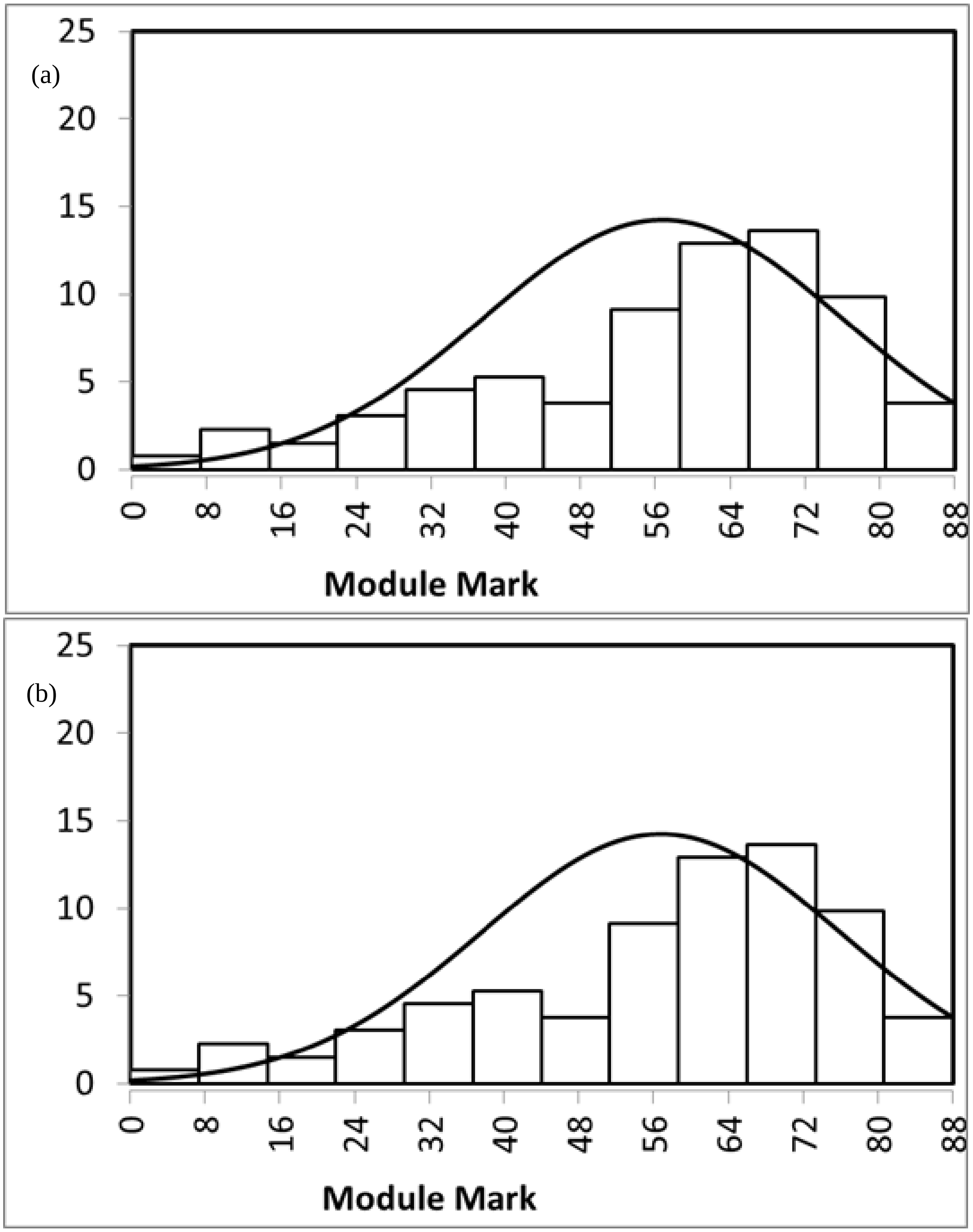


Figure 10. Distribution of the students' final module marks. (a) academic year 2012-2013, and (b) academic year 2013-2014.

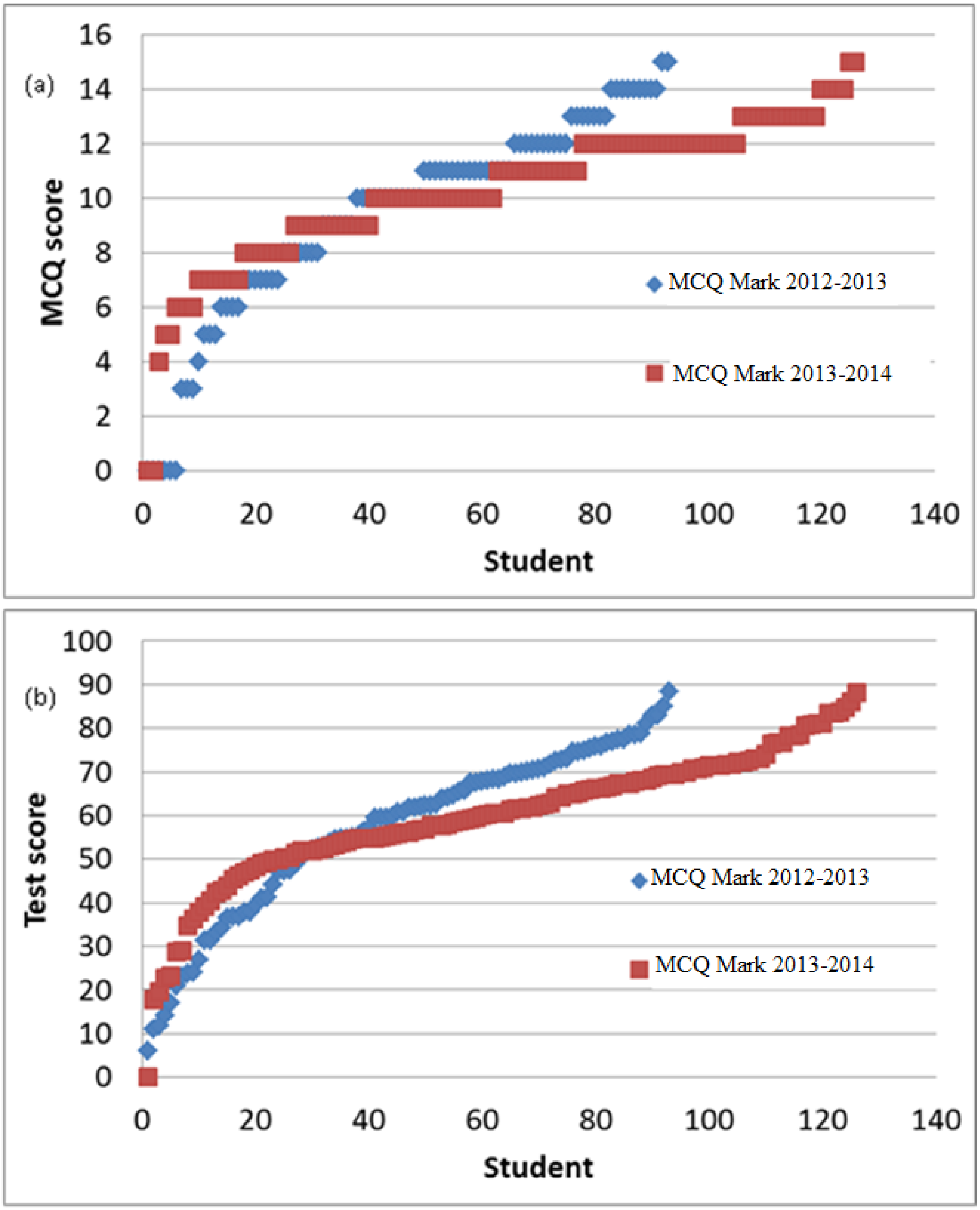


Figure 11. Test score comparison of the academic years 2012-2013 and 2013-2014.
(a) MCQ question, and (b) final module grade.

4. CONCLUSIONS

An audience response system was applied in a Fundamentals of Materials module during the academic year 2013-2014, to improve student attendance, motivation and participation during class, and provide immediate feedback to the lecturer about student understanding of lecture content. From this work, a number of conclusions can be drawn;

Firstly, the implementation of ARS technology showed a positive impact on the overall student attitudes. The results indicated that students had positive perceptions of such technology. In addition, the majority of students reported that the technology was interesting, exciting and enjoyable to learn and use.

Secondly, the anonymity associated with the use of clickers was viewed as favourable by students. Learners can respond to ARS questions without a fear of being criticized by their colleagues or the lecturer. Such anonymity allows all students to be active members in the lecture theatre and participate in the learning process without accusation. In addition, students' feedback suggested that the use of ARS increases student participation when compared to that shown in lectures where an ARS was not used.

Thirdly, the most outstanding goal related to the use of ARS is the enhancement of students' attention, interaction, participation, engagement and class discussion. According to student feedback, asking periodic questions throughout lectures using clicker accomplished such objectives. Student attention usually drops in less than half an hour from the start of the lecture. Therefore, introducing ARS questions during lectures was found helpful restoring their focus. In addition, significant evidence from the students' feedback indicated that using an ARS increases their participation and engagement when compared to lectures where an ARS was not used, most likely because of the feeling of more active participation in the learning process. The peer discussion environment encouraged by the use of ARS is another learning benefit as many students expressed their pleasure in being able to discuss and gauge their understanding of the lecture topic when peer discussions were employed.

Fourthly, when used in classes, ARS was proved to have a positive effect on student performance on exams. The results of the present study provided considerable evidence that the instantaneous feedback offered by clickers can have a substantial influence on student learning as measured by test scores. This was expressed by the significant reduction of the percentage of students failing the course, by up to 50%, and the increase in the average final module mark by about 5%, and the remarkable boost of the success rate of the course by about 17%.

Overall, ARS has the potential to develop the educational environment, particularly in large lectures. Students find its use stimulating, revealing, motivating, and enjoyable.

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