Advances in Medical Education and Practice

Dovepress

open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

Impact of Audience Response System in Enhancing Teaching of Anatomy and Physiology for Health Sciences Students at King Saud bin Abdulaziz University for Health Sciences

Ahmaed Baashar[1,2], Raju Suresh Kumar[1,2], S M Irshad Akhtar[1,2], Sarah M Alyousif[2–4], Abdulaziz I Alhassan[2,3], Nada Townsi[2,5]

[1]Department of Basic Science, College of Sciences and Health Professions, King Saud bin Abdulaziz University for Health Sciences, Jeddah, Saudi Arabia; [2]King Abdullah International Medical Research Center, Jeddah, Saudi Arabia; [3]Department of Medical Education, College of Medicine, King Saud bin Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia; [4]Department of Pharmaceutical Care, Ministry of the National Guard - Health Affairs, Riyadh, Saudi Arabia; [5]Department of Pediatric, Ministry of the National Guard - Health Affairs, Jeddah, Saudi Arabia

Correspondence: Ahmaed Baashar, Department of Basic Science, College of Sciences and Health Professions, King Saud bin Abdulaziz University for Health Sciences, Jeddah, Saudi Arabia, Tel +9661222 46666 Ext: 45529, Fax +96692000 8668 Ext: 45529, Email baashara@ksau-hs.edu.sa

Purpose: Instructional methods that offer students' opportunity for engagement are essential to develop an active learning environment. This paper aims (1) to assess whether the use of an Audience Response System (ARS) during anatomy and physiology lectures improves students' engagement, knowledge retention and academic achievement and (2) to evaluate the feasibility of introducing ARS as a formative tool from both instructors' and students' perspectives.

Materials and Methods: This quasi-experimental study was conducted across ten lectures for the second-year Pre-Applied Medical Science (PAMS) and Pre-Medical (PMED) students at the College of Sciences and Health Professions, King Saud bin Abdulaziz University for Health Sciences (KSAU-HS), Jeddah, Saudi Arabia. The ARS was integrated into five lectures, whereas the remaining were conducted without ARS. A comparison of the immediate post-lecture and prior laboratory session quiz scores between the lectures with and without ARS was performed using an independent sample *t*-test. An online survey was completed by the students as well as informal feedback was taken from the instructors to assess ARS usefulness.

Results: A total of 65 PMAS and 126 PMED students participated in the study. Students achieved significantly better scores for ARS lectures than non-ARS lectures: PAMS (p 0.038) and PMED (p 0.018). Students and instructors agreed that ARS was easy to use, allowing students to engage and actively participate in the teaching process by responding to questions and receiving instant and anonymous feedback about their learning progress.

Conclusion: Employing suitable interactive teaching methods facilitates students' learning and improves their retention of knowledge. Students and instructors positively view the ARS strategy as a means to promote learning in a traditional lecture setting. Increased practice on how to integrate its use into classrooms could lead to further utilization.

Keywords: active and engaging learning, knowledge retention, educational technology, formative assessment, medical students

Introduction

Anatomy and physiology are essential subjects for health sciences students in which the students learn about anatomical body structures and the physiological mechanisms of the human.[1,2] The students need to gain the core knowledge of anatomy and physiology subjects in order to build up a strong basis for the clinical path which, in turn, leads to professional physicians in the future.[1,3] However, an earlier study has shown that teaching such subjects is one of the challenges faced by teachers despite using effective educational strategies and approaches in learning and teaching.[4] Therefore, it is important for teachers to create a stimulating and encouraging environment for the students in order to

Received: 15 November 2022
Accepted: 9 April 2023
Published: 25 April 2023

enhance students' participation in the classroom, which could improve their educational outcomes that align with the overall educational goals that need to be achieved.[5]

Over the previous years, new instructional strategies and techniques have emerged incorporating technology. This technology assisted in making the learning environments more interactive (learner-centered approach) and attracted many students.[6,7] In medical education, for example, technology including e-textbooks, CD-ROMs, models and simulations has been utilized in classrooms and laboratories.[6,7] Although technology can help in delivering learning materials to students with various learning needs, it should be regularly assessed to ensure meant learning outcomes are successfully attained.[8]

The use of technology in education is an integral part of education research that would enhance the quality of teaching and learning process. Therefore, several educational programs and institutions have incorporated using technology in the classroom into their accreditation documents and future strategic plans.[8] The rapid evolution of technology in educational settings allows learners to have permanent access to the materials with diverse learning needs.[6] ARS, also known as classroom response system, is considered one of the educational technologies and most effective tool used by health professional educationists across the globe in order to obtain collective feedback from a larger group of students.[8–10] ARS works by allowing the instructors to pose questions to students in the form of multiple-choices developed via a PowerPoint interface. The students use individual response pads or keypads to select the answer they think is right. The percentage and number of the students selecting each multiple-choice answer is directly exhibited on the PowerPoint slide.[11]

Several studies have reported that the use of ARS promotes an active learning environment during classroom teaching activities that encouraged active student participation by providing a reflection about the content delivered during the lecture. Medina et al, for example, assessed the impact of ARS in a dual-campus environment for pharmacy students and reported that ARS increased instructors' ability to actively engage with the students on both campuses (onsite and distance site classrooms) and helped the instructors identify the course learning objectives that were not fully understood by the students.[11] An earlier study has also indicated the effective uses of ARS in getting rapid responses from students in face-to-face and distance education teaching modules.[12] In addition, a study conducted in physiological chemistry/molecular biology classes showed that ARS helped pharmacy students maintain attention during the lectures and motivate them to learn.[13]

A study by Ismaile and Alhosban found that implementing ARS in nursing courses encouraged peer discussions during the classroom and improved students' learning environment.[14] In line with previous studies, students and instructors for a study conducted in computer science classes stated that the interactivity of teacher–students and student–student improved using the ARS strategy.[15] Moreover, the residents who received ARS interactive lectures in family medicine, as well as obstetrics and gynecology programs, had considerably longer retention of the lecture material (scores of post-lecture tests) compared to their counterpart residents who taught the same material in a standard didactic lecture format.[16,17] Additionally, Alexander et al reported that undergraduate medical students in histology, anatomy and embryology courses scored significantly higher in the final examinations after employing ARS in classroom teaching activities.[18]

Studies by educators in other health professional institutes reported similar results that ARS offers a great amount of anonymity for the students and enables them in participating and answering the questions that are posted by teachers during lecture sessions without having a fear of public speaking.[18–21] "Clickers" have been widely used in many medical schools as a tool for ARS, but they are very expensive. A good amount of funding and infrastructure is needed to maintain clickers.[15] In the search for a cost-effective ARS tool, "Mentimeter" (www.mentimeter.com) was used as a tool for the ARS in this study. To the best of our knowledge, no studies have been published to date that investigated the implementation of ARS in classroom teaching for anatomy and physiology subjects in Saudi Arabia. Therefore, the aims of this study were first to compare the effect of introducing an ARS in improving overall students' lecture engagement, knowledge retention and academic achievement through utilizing post-lecture and pre-laboratory assessment and second to evaluate the feasibility of implementing ARS as a formative tool in education during lectures from both faculty members' and students' perspective.

Materials and Methods

Study Participants and Setting

The study was conducted at the College of Sciences and Health Professions, KSAU-HS Jeddah Campus. The study sampled all second-year male PAMS and PMED students who enrolled in anatomy and physiology courses and agreed to participate in the study. This course involves lectures and laboratory sessions delivering in four credit hours. The students were invited to participate in this study during the academic year 2022. There were no specific exclusion criteria for both PMED and PAMS students. The study was reviewed and approved by the Institutional Review Board (IRB) at King Abdullah International Medical Research Center (KAIMRC), Jeddah, Saudi Arabia (Study number: SP22R/212/09).

Study Design

This was a quasi-experimental (intervention) study conducted across ten anatomy and physiology lectures. The ARS was incorporated into five lectures, whereas the other five were conducted without the implementation of the ARS. A schematic diagram of the study design is displayed in Figure 1. The ten lectures were selected randomly from the topics mentioned in the course. The length of each lecture period was 60 minutes. PowerPoint slides addressing the learning objectives of each topic were uploaded to the Learning Management System a week in advance of the scheduled lecture.

For the five lectures with ARS, the instructors at interval times of the lecture (roughly every 15 minutes) provided students with the three lecture-based multiple-choice questions. Each of the questions had a unique numeric code that was generated using Mentimeter software (Stockholm, Sweden) and could be used once by each student. The students were trained to use Mentimeter software in four hours' sessions. They have also been asked to download the Mentimeter application (free of charge) in their smart devices (mobile phone, iPad or laptop). To select the answer, the students were asked to insert the code and access the question (three choices per question, single correct answer). The students answered the question anonymously, without help from classmates. The time for answering a question was set at 90 seconds. The participants' responses were collected and displayed as bars or percentages. The correct answer was highlighted and discussed with the students. The time allotted for students' discussion on ARS questions varied and depended on the subject area and complexity level of the question. No mark or bonus grades were given to the students who correctly answered the question. The effectiveness of introducing an ARS in enhancing interactive learning and improving overall students' engagement was assessed immediately after the lecture and prior to the laboratory session using lecture-based three multiple-choice questions. The time between the lecture and laboratory session related to the lecture's topic was about one week. As for the remaining five of the ten selected lectures, the students will be introduced to the same assessments described previously for the five lectures with ARS, but without asking questions during delivering anatomy and physiology lectures. In all ten selected lectures in the study whether with or without ARS, the students during the lectures were allowed to discuss any misconceptions with the instructors related to the delivered topics.

The sets of multiple-choice questions were developed by academic faculty members with more than five years of teaching experience in anatomy and physiology courses. Those members were also invited to be part of the study. The developed questions were internally validated by experienced faculty members and modified based on their comments and suggestions. All questions were directly related to the course learning objectives as outlined in the course syllabus. The questions were designed to test basic knowledge as well as complicated concepts. The faculty members were attended a full day workshop to train how to use Mentimeter software. They also monitored all lectures with and without ARS to solve any technical or logistics issues as well as to evaluate the interactions between student–student and student–teacher during the lectures.

Student Surveys

A week after the last lecture conducted in anatomy and physiology course, students in both PAMS and PMED groups were asked to voluntarily complete an anonymous online survey developed by the assistance of external experts (Appendix A). The survey was created using Google Forms to assess the impact of ARC technique on students'

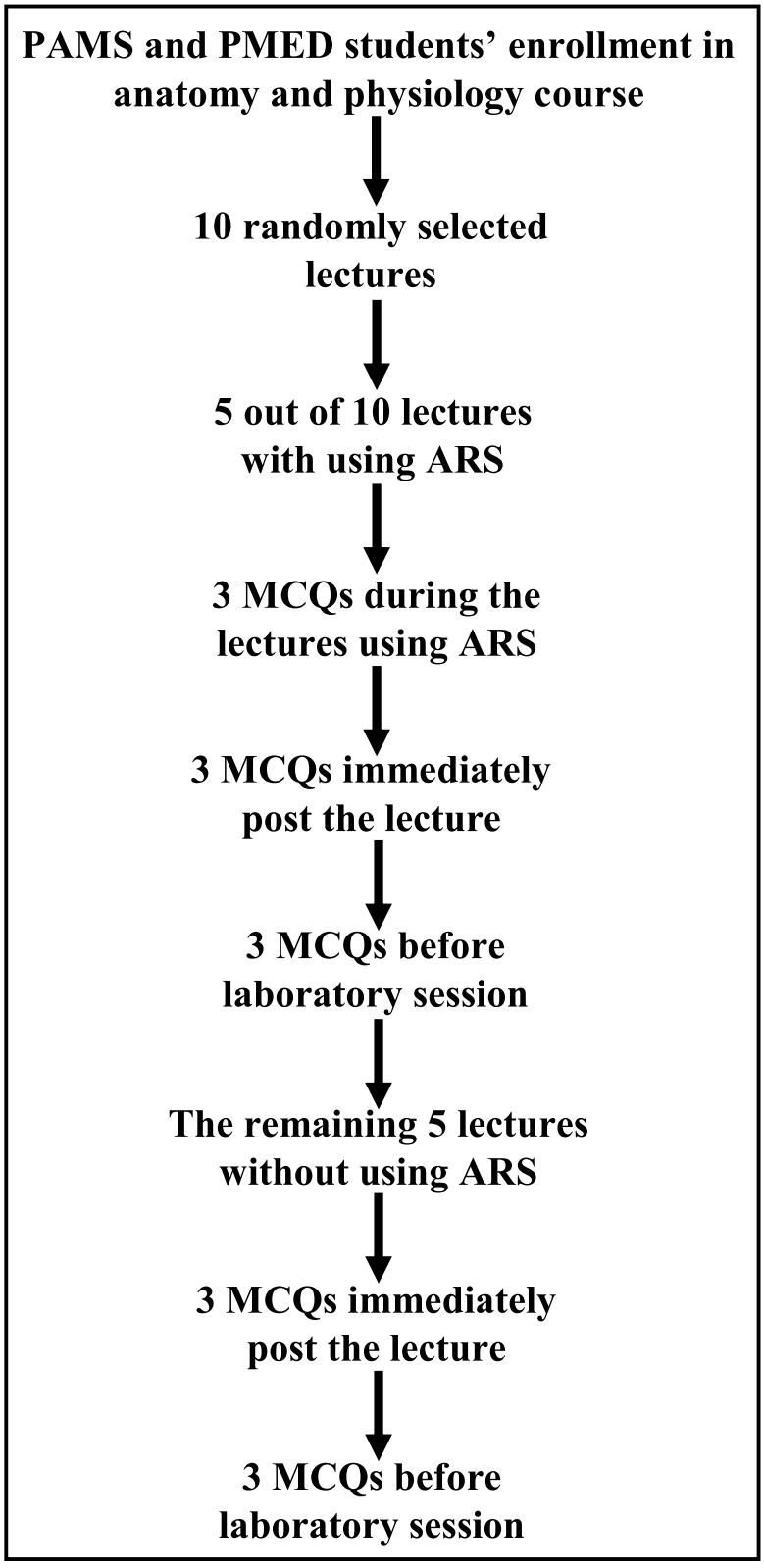

Figure 1 Schematic representation of the study design.

perceptions, satisfaction and engagement with the instructional strategy. The survey involved 12-item that were answered on a 5-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree. The students were also provided with an optional open-ended question to summarize their experiences, suggestions and

recommendations about whether they preferred to continue using the ARS strategy in the upcoming academic year for the same or future courses. Informed Consent (E-format in Google doc) was posted to the PAMS, and PMED students and consent was taken from those who were willing to participate in this study.

Statistical Analysis

Descriptive data were reported using frequency (percentages) for categorical variables and mean (standard deviation, SD) for numerical, continuous variables. Independent sample *t*-tests were used to assess the difference in the students' mean scores at two time points; immediately post lectures and prior laboratory sessions across the lectures with and without ARS. Students' satisfaction with the introduction of ARS and its impact on their engagement in the lectures was assessed using 5-point Likert scale, and the overall satisfaction and engagement was reported using mean and SD. Thematic coding was used to assess the responses acquired from the participants who responded to an open-ended question at the end of the online survey. The level of significance (α) in the study was set at 0.05. The p-value <0.05 was taken as significant. All the statistical analyses were carried out using SPSS (V.25; IBM, Chicago, IIIinois, USA) for data analysis.

Results

Student Demographic

A total of 191 students participated in the study. Sixty-five (34.03%) of the students were PAMS students and 126 (65.97%) were PMED students. All participants were second-year students taking anatomy and physiology courses.

Impact of Audience Response System on the Lecture

The impact of ARS on improving students' engagement during the lecture and knowledge retention of the lecture contents were assessed using three anonymous lecture-based multiple-choice questions completed by the students at the end of each lecture and prior to the beginning of the laboratory sessions. The response rate was significantly higher among PAMS students (mean response rate ± SD; 62.0 ± 13.1) compared to PMED students (mean response rate ± SD; 55.6 ± 13.8; *p* 0.010). The overall students' mean score was significantly higher among the ARS lectures compared to non-ARS lectures in both PAMS (Mean ± SD for ARS lectures: 24.7 ± 10.5 vs Non-ARS lectures: 19.3; 9.14; *p* 0.038) and PMED (Mean ± SD for ARS lectures: 58.6 ± 16.5 vs Non-ARS lectures: 31.6 ± 11.1; *p* 0.018), which shows a 27.9% improvement in the score of the lectures with ARS compared to non-ARS lectures for PAMS students, and an 85.4% improvement for PMED students (Table 1). These results demonstrate that introducing ARS during the lectures had significantly improved students' retention of the lecture material compared to non-ARS lectures (*p* 0.038 for PAMS students and *p* 0.018 for PMED students).

Student Survey Results

The usage of ARS during the lectures was evaluated using an anonymous survey, scored along a 5-point Likert scale (from 1 "strongly disagree" to 5 "strongly agree"). Out of 191 PAMS and PMED students, 126 completed the survey with a response rate of 66%. Thirty-seven of the respondents (29.4%) were PMAS students and eighty-nine (70.6%) were PMED students. Table 2 includes a detailed percentage and frequency of the survey items completed by PAMS and PMED students. Overall, the students commented positively on employing ARS in anatomy and physiology lectures.

Table 1 Students' Man Scores and SD for the Lectures with and without ARS

	Five Lectures with ARS (Mean ± SD)	Five Lectures Without ARS (Mean ± SD)	*p*-value
PAMS No. = 65 students	24.7 ± 10.5	19.3 ± 9.14	0.038
PMED No. = 126 students	58.6 ± 16.5	31.6 ± 11.1	0.018

Table 2 Students' Responses to the Survey Items Regarding Use of an ARS in Anatomy and Physiology Course (No. = 126)

Survey Items	Strongly Disagree No. & (%)	Disagree No. & (%)	Neutral No. & (%)	Agree No. & (%)	Strongly Agree No. & (%)
1. The use of an ARS encourages you to participate	1 (0.8)	6 (5.4)	27 (21.6)	52 (41.3)	40 (31.7)
2. ARS assists in making the lecture more understandable	1 (0.8)	11 (8.9)	20 (15.9)	57 (45.2)	37 (29.4)
3. By including an ARS, it allows you better engagement during the lectures	1 (0.8)	8 (6.3)	26 (20.6)	55 (43.7)	36 (28.6)
4. Use of ARS makes the lectures more interesting	1 (0.8)	9 (7.1)	25 (19.8)	51 (40.5)	40 (31.7)
5. Faced difficulties dealing with the ARS as an educational tool	15 (11.9)	55 (43.7)	21 (16.7)	26 (20.6)	9 (7.1)
6. The use of an ARS encourages the students to participate without having the fear of embarrassment	2 (1.6)	11 (8.7)	11 (8.7)	43 (34.1)	59 (46.8)
7. Recommend implementing the audience response system in the other courses	2 (1.6)	9 (7.1)	30 (23.8)	45 (35.7)	40 (31.7)
8. The use of the ARS help in making the learning interactive	0 (0)	9 (7.1)	16 (12.7)	58 (46)	43 (34.1)
9. The use of the ARS helps in paying more attention during the lectures	2 (1.6)	13 (10.3)	19 (15.1)	43 (34.1)	49 (38.9)
10. The ARS helps the instructor to get instant feedback on students' understanding	3 (2.4)	9 (7.1)	18 (14.3)	39 (31)	57 (45.2)
11. The use of the ARS was a distractor during the lecture	16 (12.7)	40 (31.7)	37 (29.4)	22 (17.5)	11 (8.7)
12. Using the ARS, a week after the lectures helped in evaluating my understanding of the topic	2 (1.6)	11 (8.7)	33 (26.9)	54 (42.9)	26 (20.6)

Students stated that they felt more encouraged to participate when utilizing ARS than they commonly did in non-ARS lectures (73%, No. = 92). Students also reported that ARS made the topic of lecture more understandable (74.6%, No. = 94) and interesting (72.2%, No. = 91) by created interactive learning experience (80.1%, No. = 101). 55.6% (No. = 70) of the surveyed respondents did not confront any technical issues dealing with ARS as an educational tool. Using this tool periodically through a class lecture did not distract many of the students (44.4%, No. = 56). Therefore, many students agreed with the notion that ARS assisted them to maintain attention (73%, No. = 92).

Approximately 72.3% (No. = 91) of the students indicated that introducing ARS gave them the opportunity to engage with and respond to the course materials. ARS allowed students overcome the fear of participating in a large classroom because of the anonymity approach (80.9%, No. = 102). As a reason for this preference, students (67.4%, No. = 85) preferred to incorporate ARS into other course lectures. 63.5% (No. = 80) of the students reported that ARS helped in achieving a better retention of the lecture contents compared to those lectures that did not use ARS. Students (76.2% No. = 96) also reported that the ARS question and answer method helped instructors obtain immediate feedback about their understanding of the lecture objectives. Figure 2 includes the mean and standard deviation (SD) of individual 5-point Likert scale survey item for the surveyed students.

Student Overall Feedback

At the end of the online survey, the students were asked an open-ended question to obtain their overall impressions of their experience with the ARS strategy (Table 3). In general, students reported favorable remarks about implementing ARS into classroom teaching activities. Students stated that the ARS permitted them to participate in a competitive and

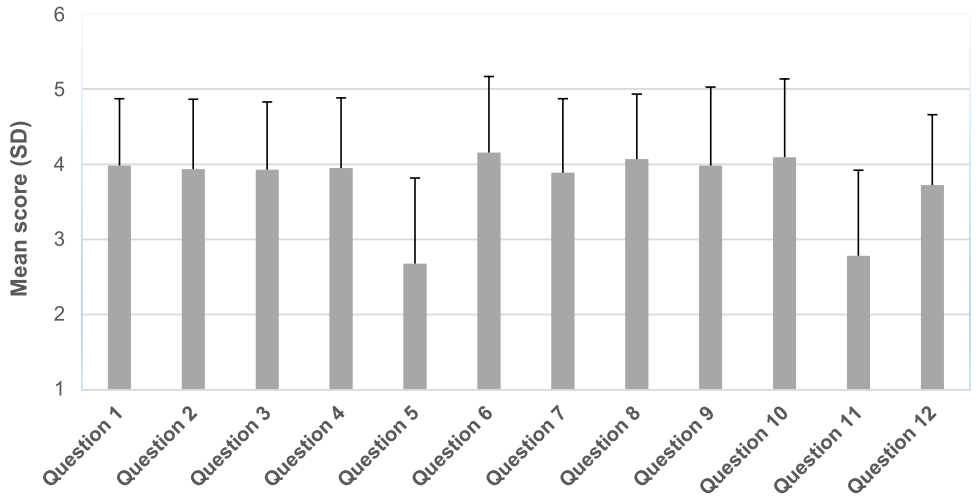

Figure 2 Mean and SD of students' experiences with ARS for individual survey item, where 1= strongly disagree, 2 = disagree, 3 = neutral, 4 = agree and 5 = strongly agree, no. 126 students). More details about questions 1–12, find Appendix A.

entertaining environment as well as motivated them to ask the instructor questions during the lecture. Students further appreciated the anonymity approach taken when answering the questions by only showing the number and percentage of the participants. Also, students felt that ARS (ie, Mentimeter software) was easy to use, and they considered it as the best instructional strategy used for longer retention of knowledge. Some students reported that ARS made attending the lectures worthwhile and expressed a preference for implementing the ARS in other courses. Students also indicated that ARS was a useful feedback tool that tested their attention to and comprehension of the lecture materials. In addition, students valued the time taken by the instructors to discuss questions that were not correctly answered or not fully understood by many of them. Therefore, some students revealed that ARS enhanced interactions between instructors–students and students-–students during and after the classes, which gave them the opportunity to reflect on their understanding. Many students also commented on the multiple-choice questions and that the questions were well written and covered the main objectives of the lectures.

Students also illustrated the challenges and drawbacks that they encountered using the ARS strategy. Firstly, a few students encountered some technical issues when inserting the code of the questions in Mentimeter software, but those issues had been solved by the instructors. Secondly, some students mentioned that ARS distracted them from paying attention during the lecture. Thirdly, students pointed out that the time assigned to answer the questions (90 seconds per question) is not adequate and suggested to increase it to 3 minutes instead. Therefore, they suggested to increase the time and number of the questions to cover all the lecture learning objectives and thus facilitate their preparations for the exam. Fourth, students stated that once they answered the question, they were unable to review it and change their answers, suggested to allow them changing their responses within the limited time allocated for each question. Finally, one major

Table 3 Feedback from Open-Ended Question

Benefits of ARS	Drawbacks and Challenges of ARS
• Competitive and entertaining environments • Participation encouragement • Anonymity strategy • Knowledge retention • Worth attending • Maintain attention • Instant feedback • Increased interactivity • Preparations for the exam	• Technical issues • Distraction strategy • Inadequate answering time • Incapable changing their answers • Obtained answers from each other.

drawback mentioned that some students get help from others in answering the questions although the questions were not graded. Thus, they suggested that the instructors should keep reminding the students about the main aim of introducing ARS in anatomy and physiology classes.

Instructors Self-Reflection

Informal feedback was taken from the teaching faculty who adopted the Mentimeter as the ARS during their teaching sessions. In general, the overall feedback on ARS from the faculty side was positive. Faculty members agreed that the setup and organizing of the sessions using ARS was quick and efficient and the software used (Mentimeter) was user-friendly. Faculty members believed that the number of correct responses made by the student during the ARS evaluation would be an indirect reflection of the student's understanding of the topic. The majority of the faculty members who took part in the survey presumed that ARS can also provide room for further discussions or clarifications on those topics which are not clear to the students. They believe that ARS could be used as an effective tool for getting instant reflective feedback on their classroom teaching. Some faculty members opinioned that ARS helped them in breaking the monotony of regular didactic lectures.

In addition, the instructors felt that the students were paying more attention during their lectures where ARS was used, as prior instruction was given to the students that they will be tested using ARS. The faculty also felt that there was a good amount of student participation in the lectures where ARS is implemented. Students showed a high amount of enthusiasm by responding to the questions displayed to them within the given time frame. The instructors also believed that the student's test scores obtained from ARS after one week after the individual lectures would be an indicator of student understanding as this task needs the students to recall the topic that was taught one week ago. Therefore, the instructors felt that this exercise might also help the students in reinforcing their memory.

When it comes to the cons of ARS, some of the instructors felt that ARS can take away some amount of lecturing time as they must wait for the students to answer the questions that were displayed. Therefore, some of the faculty members opinioned that it may affect the continuity of the lecturing, when the ARS questions are displayed in between the lecture slides.

Discussion

The results of the present study demonstrate that the use of ARS during delivering anatomy and physiology lectures to PAMS and PMED students created an active learning environment which resulted in improved students' engagement during the classroom teaching and increased retention of the learned materials. The study also provides additional information about the satisfaction of both students and instructors in introducing ARS into classroom teaching. The findings of the current study are consistent with other studies that were conducted in several colleges of health professions.[11,13–21]

Health professions students in their early studying years often receive information in a traditional lecture format (teacher-centered approach), without actively participating in the learning process.[13,18,19] Active learning has a great influence on students' learning success and their performance in assessments.[22] The key components that are essential for active learning are intentional engagement, purposeful observation and critical reflection.[23] One of the major advantages of utilizing ARS in teaching is the commitment of the students to engage in an individual response, which could ultimately help improve students' learning experiences. In the current study, the students were observed to be more attentive and active throughout ARS lectures compared to non-ARS lectures. These results are in line with earlier studies that had introduced ARS in different teaching modalities like lectures,[19] case-based discussions[24] and seminars.[10] As has been seen in other studies,[8,19,24] the participation of the students also increased when ARS was introduced into anatomy and physiology lectures. This could be because the use of ARS enhanced students' self-confidence and allowed them to gauge their abilities in comparison with their classmates.

Another important characteristic of ARS as indicated by the students in this study and could further improve students' participation is the anonymity of respondents. This feature allowed students to overcome their fear of participation, as demonstrated by several researchers.[10,19,24] Moreover, the immediate discussion of the students' answers in classroom provided the students with individualized and quick formative feedback during the learning process and about their

learning progress compared to their classmates. The instant feedback, as shown in this study and in other studies, also allowed the instructors to clarify, repeat and rephrase the key points and/or concepts that students misunderstood the most during lectures.[10,11,24] Therefore, the instructors can employ the time of the class more effectively by spending more time reviewing the points and/or concepts that appear to be misunderstood by many students instead of responding to questions raised by individual students. Without ARS, the instructors might imprecisely estimate which lecture objectives require further and immediate review till the lecture is completed or the exam is conducted.

In the current study, peer interaction also seemed to be enhanced after introducing ARS into classroom teaching activities, which is consistent with earlier studies.[11,19,24] The students were seen spontaneously communicating with each other after entering their responses to a multiple-choice question. This interaction, based on the instructors' observation, was more apparent when students had chosen all correct and incorrect options for a given question. These findings would promote students' abilities to auto-evaluate and critically reflect their abilities to what extent the concepts were comprehended.[24,25]

In addition, the use of ARS as an instructional tool in this study motivated the students to learn and engage them in others' thinking paths in a fun, interesting and competitive environment compared to the traditional lectures, which is also in agreement with the report of previous studies.[19,24,25] When instructors encourage learners to actively participate in classroom teaching activities, the students feel more motivated to learn, considered as an essential factor for effective learning.[24] These findings suggest that ARS can enhance students' learning, although additional studies are needed to quantify the actual impact of ARS on students' learning. In a traditional lecture, it has been shown that the students' attention substantially decreases after 20–25 minutes,[26] requiring an intervention such as posing lecture-based questions using ARS to get back the class' attention.[10] Therefore, the current study, like others, found the ARS to be an efficient tool for getting enhance students' attention.[13,18,19] This would help in providing the perceived benefit of learning and assisting students to retain their learning.[16,17]

The significance of the current study also showed improved knowledge retention among the second-year health professions (PAMS and PMED) students via using an ARS-enhanced lecture format versus a non-ARS lecture format. This effect seemed to be long lasting with knowledge retention in ARS lectures compared to non-ARS lectures. In particular, the students' mean score for ARS lectures was better than those lectures that were delivered without this additional interactive part for both PAMS students (ARS lectures: 24.7 vs Non-ARS lectures: 19.3) and PMED students (ARS lectures: 58.6 vs Non-ARS lectures: 31.6). Remarkably, the interaction of instructors with the students in the context of highlighting the key fundamental concepts of the lecture by presenting lecture-based questions using ARS plays an essential role in improving the scores of post-lecture questions compared to the lectures where ARS was not used. This finding is broadly aligned with the studies of Schackow et al,[17] and Pradhan et al,[16] who confirmed a positive effect of using ARS on retaining the learned concepts.

Schackow et al compared the quiz score of traditional lectures (ie, non-ARS) with ARS-enhanced lectures (post-lecture as well as one month after the lecture) for 24 family medicine residents.[17] They found that the residents' average quiz score of the traditional lecture (post lecture: 61% and one month after the lecture: 48%) was lower than those having attended ARS lecture (post lecture: 96% and one month after the lecture: 67%). In another study, Pradhan et al conducted their study on 17 obstetrics and gynecology residents and reported that residents who experienced ARS lecture had significantly better results for knowledge retention than those who attended traditional lecture.[16] However, it is essential to note that both studies had included very small sample sizes in comparison to our study that involved large sample sizes (191 participants). In line with these results, several studies found that the use of ARS also improved the scores of final examinations.[13,18,24]

The question of the current study "Did the ARS strategy used in anatomy and physiology lectures directly or indirectly affect students retain learned material?" may have two possible explanations. The first explanation is that ARS strategy in itself had a positive impact on students' knowledge retention through their active participation in the lecture process. This suggests that the ARS could be a valuable instructional strategy for health professions students. The second explanation is that the novelty of the experience might have led to modifications in teaching styles and the primary teachers' behavior, which ultimately helped in increasing students' attention to the lecture, a phenomenon known as the Hawthorne effect. To shed light on this possibility, Pradhan et al suggested to implement ARS into many lectures on the

same day and also compared the quiz scores before and after the lectures delivered.[16] They claimed that students' knowledge retention would not be the same for all lectures despite using ARS strategy in teaching activities. Therefore, further investigation is needed to establish the direct and indirect effects of ARS strategy on students' factual retention.

Earlier studies on the impact of ARS on knowledge retention and assessments also showed contradictory findings to the current study results. Doucet et al introduced ARS into a large group of participants during case-based discussions and found that long-term retention was not significantly different between the participants who attended ARS case-based discussions and those who attended the discussions without the additional interactive part.[24] Additionally, Schmidt et al implemented ARS into a large group of students during a seminar series and could not confirm a positive effect of using ARS on knowledge retention and assessment results.[10] Both studies' findings may be explained by the fact that case-based discussions and seminars were adequately interactive teaching modalities. Thus, any further activation via using ARS had no additional impact since the students had already reached the highest interactive level of learning.[10,24]

The majority of the surveyed students in this study, as in others, rated ARS as a beneficial instructional tool in maintaining their attention, increasing their classroom interactivity and providing instant feedback about their learning progress compared to their colleagues.[11,13,18,19,24] Like other health professional studies,[10,11,24] numerous students in the current study mentioned that the use of ARS during the lectures motivated them to study and review the learning objectives of the lecture that required further attention as reflected by their ARS scores. Importantly, the students reported that introducing ARS into classroom teaching improves their knowledge retention, which is consistent with the reported data of our study. As reported in the study by Cain et al, many students in the current study cited that adopting ARS encouraged them to attend the class and actively engage with the instructors during the lectures.[13] Students finally reported the ARS as an effective tool that helped them prepare for the exams, as had been documented in the studies of Cain[13] and Alexander.[18]

The instructors also cited that Mentimeter software was easy to learn and use, with no additional cost to the students. They used it as a reliable instructional strategy to measure students' understanding of the delivered lecture and monitor their learning progress. ARS was also used as formative feedback in anatomy and physiology courses for their own instruction. In addition, instructors stated that ARS was well received by students. This favorable reception agrees with the earlier studies that used ARS with health professions students.[11,13,18,19,24]

The current study reported a positive impact of using ARS strategy, yet it has limitations that should be addressed. Firstly, ARS testing was done during the lectures, end of lectures, and in the laboratory where all students were sitting together. We believe that it might give room for the students to discuss each question with their peers before they choose the correct option. In spite of proper instructions to the students, to a lesser extent, this factor could also have contributed to the observed number of correct responses from the students during each ARS session. Bringing more invigilators during the ARS sessions is one way by which we can prevent peer discussion. Secondly, the preparation time for designing the subject-specific questions for this study was a laborious task. The teaching faculty had to spend more time making these questions. Also, the level of questions asked during our study evaluated the knowledge level (knows) of anatomy and physiology. The study did not test the levels of skill acquisition (know-how) of the students. This would be a limitation of this study as we were not able to evaluate the extent of their understanding.

In addition, in anatomy questions, no pictures were used along with the questions in order to test the anatomical knowledge pertaining to each organ that was taught in the lecture. Including pictures along with the questions is one area, we would like to improve in our future study. Moreover, we had time constraints due to the limited lecture duration, each lecture was for a duration of an hour. Delivering the lecture and conducting the ARS along with clarifying the questions as per the student's responses in ARS took a lot of time. It would be a good idea to discuss the questions that had low correct response rate in a small group sessions or during tutorial hours when the students are available. Finally, in this study, we had limited only to anatomy and physiology courses. If we had extended this study to other subjects, it would definitely give us a better understanding of how ARS impacts student learning and to know if there are any variations according to the subject specialty.

The future application of ARS is likely to be more engaging and gauging for the students. This study will be looking to involve female students in the future which will provide another dimension to its application. The study will also compare the final exam grades of the present study participants with the previous year's batches where ARS was never

applied to get any differences. Appropriate feedback from student focus groups and scoring students' responses will be considered in the future studies as well.

Conclusion

The use of ARS strategy in a large group of undergraduate health professions students in anatomy and physiology lectures was effective in enhancing an active learning environment. The strategy allowed students to engage with the course contents and motivate them to actively participate in responding to ARS question, made the majority of the students' thinking more observable. Implementation of ARS into classes also enhanced students' attention during the lecture and provided instructors timely feedback about the students' comprehension of the lecture materials, which offers an opportunity to reinforce understanding and remediate misconceptions. In addition, ARS strategy improved students' factual retention through their good performance in post-lecture quizzes, both immediate and a week after the lecture presented, indicating the importance of utilizing ARS in other health science courses.

Abbreviations

ARS, Audience Response System; PAMS, Pre-Applied Medical Science; PMED, Pre-Medical; KSAU-HS, king Saud bin Abdulaziz University for Health Sciences, SD, standard deviation.

Acknowledgment

This study was supported by King Abdullah International Medical Research Center, under the supervision of the Department of Medical Education, College of Medicine, KSAU-HS, Ministry of National Guard-Health Affairs, Saudi Arabia. The authors would like to express their deep gratitude to all students of the KSAU-HS, Jeddah campus, who proactively participated in this study.

Disclosure

The authors declare that they have no conflict of interest relevant to this work.

References

1. Michael J. What makes physiology hard for students to learn? Results of a faculty survey. *Adv Physiol Educ*. 2007;31:34–40. doi:10.1152/advan.00057.2006
2. Singh K, Bharatha A, Sa B, Adams OP, Majumder MAA. Teaching anatomy using an active and engaging learning strategy. *BMC Med Educ*. 2019;19:1–8. doi:10.1186/s12909-019-1590-2
3. Tubbs RS, Sorenson EP, Sharma A, et al. The development of a core syllabus for the teaching of head and neck anatomy to medical students. *Clin Anat*. 2014;27:321–330. doi:10.1002/ca.22353
4. Tworek JK, Jamniczky HA, Jacob C, Hallgrímsson B, Wright B. The LINDSAY virtual human project: an immersive approach to anatomy and physiology. *Anat Sci Educ*. 2013;6:19–28. doi:10.1002/ase.1301
5. Guimaraes B, Durado L, Tsisar S, Diniz JM, Madeira MD, Ferreira MA. Rethinking anatomy: how to overcome challenges of medical education's evolution. *Acta Medica Port*. 2017;30:134–140. doi:10.20344/amp.8404
6. Al-Hariri MT, Al-Hattami AA. Impact of students' use of technology on their learning achievements in physiology courses at the University of Dammam. *J Taibah Univ Med Sci*. 2017;12:82–85. doi:10.1016/j.jtumed.2016.07.004
7. Kurt E, Yurdakul SE, Atac A. An overview of the technologies used for anatomy education in terms of medical history. *Procedia Soc Behav Sci*. 2013;103:109–115. doi:10.1016/j.sbspro.2013.10.314
8. Hussain FN, Wilby KJ. A systematic review of audience response systems in pharmacy education. *Curr Pharm Teach Learn*. 2019;11:1196–1204. doi:10.1016/j.cptl.2019.07.004
9. Caldwell JE. Clickers in the large classroom: current research and best-practice tips. *CBE Life Sci Educ*. 2007;6:9–20. doi:10.1187/cbe.06-12-0205
10. Schmidt T, Gazou A, Rieß A, et al. The impact of an audience response system on a summative assessment, a controlled field study. *BMC Med Educ*. 2020;20:1–8. doi:10.1186/s12909-020-02130-4
11. Medina MS, Medina PJ, Wanzer DS, Wilson JE, Er N, Britton ML. Use of an audience response system (ARS) in a dual-campus classroom environment. *Am J Pharm Educ*. 2008;72:1–7. doi:10.5688/aj720238
12. Harris ST, Zeng X. Using an audience response system (ARS) in a face-to-face and distance education CPT/HCPCS coding course. *Perspect Health Inf Manag*. 2010;7:1–10.
13. Cain J, Black EP, Rohr J. An audience response system strategy to improve student motivation, attention, and feedback. *Am J Pharm Educ*. 2009;73:21. doi:10.5688/aj730221
14. Ismaile S, Alhosban F. Students perceptions of audience response system in classroom feedback: a qualitative study. *Int J Adv Appl Sci*. 2018;5:67–72. doi:10.21833/ijaas.2018.04.008

15. Aljaloud A, Gromik N, Kwan P, Billingsley W. Saudi undergraduate students' perceptions of the use of smartphone clicker apps on learning performance. *Australas J Educ Technol*. 2019;35:85–99. doi:10.14742/ajet.3340
16. Pradhan A, Sparano D, Ananth CV. The influence of an audience response system on knowledge retention: an application to resident education. *Am J Obstet Gynecol*. 2005;193:1827–1830. doi:10.1016/j.ajog.2005.07.075
17. Schackow TE, Chavez M, Loya L, Friedman M. Audience response system: effect on learning in family medicine residents. *Fam Med*. 2004;36:496–504.
18. Alexander CJ, Crescini WM, Juskewitch JE, Lachman N, Pawlina W. Assessing the integration of audience response system technology in teaching of anatomical sciences. *Anat Sci Educ*. 2009;2:160–166. doi:10.1002/ase.99
19. Al Basheer A, Almazrou S. Assessing female pharmacy students' satisfaction with active learning techniques at King Saud University. *Adv Med Educ Pract*. 2021;12:319–327. doi:10.2147/AMEP.S284415
20. Beekes W. The 'Millionaire' method for encouraging participation. *Act Learn High Educ*. 2006;7:25. doi:10.1177/1469787406061143
21. Cain J, Robinson E. A primer on audience response systems: current applications and future considerations. *Am J Pharm Educ*. 2008;72:1–6. doi:10.5688/aj720477
22. Freeman S, Eddy SL, McDonough M, et al. Active learning increases student performance in science, engineering, and mathematics. *Proc Natl Acad Sci*. 2014;111:8410–8415. doi:10.1073/pnas.1319030111
23. Graffam B. Active learning in medical education: strategies for beginning implementation. *Med Teach*. 2007;29:38–42. doi:10.1080/01421590601176398
24. Doucet M, Vrins A, Harvey D. Effect of using an audience response system on learning environment, motivation and long-term retention, during case-discussions in a large group of undergraduate veterinary clinical pharmacology students. *Med Teach*. 2009;31:570–579. doi:10.3109/01421590903193539
25. Slain D, Abate M, Hodges BM, Stamatakis MK, Wolak S. An interactive response system to promote active learning in the doctor of pharmacy curriculum. *Am J Pharm Educ*. 2004;68:1–9. doi:10.5688/aj6805117
26. Kadmon M, Strittmatter-Haubold V, Greifeneder R, Ehlail F, Lammerding-Köppel M. The sandwich principle – introduction to learner-centred teaching/learning methods in medicine. *Z Evid Fortbild Qual Gesundhwes*. 2008;102:628–633. doi:10.1016/j.zefq.2008.11.018