Phone-based audience response system as an adjunct in orthodontic teaching of undergraduate dental students: a cross-over randomised controlled trial

Fahad Alharbi
Prince Sattam bin Abdulaziz University College of Dentistry
Khulud Alazmi
Riyadh Elm University
Bashar R. El Momani
Queen Alia Military Hospital
Lubna Al-Muzian (drlibi@hotmail.com)
Glasgow Orthodontic Academy https://orcid.org/0000-0003-3136-1231
Mark Wertheimer
Private Orthodontic Practice
Anas Almukhtar
University of Glasgow School of Medicine Dentistry and Nursing
Mohammed Almuzian
The University of Edinburgh

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Abstract

Background: The advent of electronic teaching facilities improved tutor-student communication. This study aims to explore the effectiveness of Phone-Based Audience Response System (PB-ARS), as an adjunctive and interactive model to traditional pedagogy, on the retention of information by undergraduate dental students and to explore the students' perception and acceptance of PB-ARS.

Methods: This cross-over clustered randomised control trial was conducted with 34 final year undergraduate dental students, who were allocated to one of two event groups (G1 and G2) using computer-generated randomisation. Both groups simultaneously attended two different traditional lectures a week apart (L 1 and L2). During L1, PB-ARS was used as an adjunct to conventional presentation to teach G1 participants (PB-ARS group). In contrast, G2's participants acted as a control group (CG), and they were taught using the traditional presentation. In the second week (L2), the interventions were crossed. Participants from both groups completed pre- and post-lecture multiple-choice questions (MCQ) to assess short-term retention of information. They also filled post-lecture questionaries' to determine their perceptions of teaching delivery. Their performance in the final MCQ exam (10 weeks following L2) were used assess the long-term recall of the obtained knowledge.

Results: 29 and 31 participants from the CG and PB-ARS group completed this trial, respectively. Although 87.5% of students in PB-ARS group showed an improvement in their post-lecture scores compared to 79.3% for CG, it was statistically insignificant. Similarly, the intervention showed an insignificant effect on the long-term retention of the knowledge.

There was a mildly favourable attitude of students to the PB-ARS system; however, the difference in the overall rate of the level of satisfaction in both was statistically insignificant.

Conclusion: PB-ARS system has a minimal insignificant effect on short- and long term retention of knowledge of the undergraduate dental students, though it was a slightly more preferred adjunct to conventional classroom teaching. Due to the limitation of this trial, a long-term randomised controlled trial with a larger sample size is recommended.

Background

Undergraduate teaching has always been regarded as the core foundation in the development and maturation of undergraduate students [2]. Lecturing and learning are synonymous; hence, the underlying principles governing the appropriate teaching approaches are mainly aimed at encouraging student-tutor communications, enabling consistent feedbacks and establishing an interactive teaching model [2]. Other crucial pedagogical elements in any given course are to promote deep learning, though, most post-secondary educational courses rely on traditional teacher-centred and passive student participation approaches [3]. Evidence shows that didactic lectures require a high level of motivation and concentration, yet it yields low retention of the knowledge, approximately 5-50% of the taught subject [4]. On the other hand, interactive adult teaching enhances deep, self-directed and reflective learning [2].

Similarly, active question-based education stimulates and enhances learning more than didactic lectures [2].

An audience response system (ARS) is an electronic device introduced to be of value in teaching and education in parallel, as it transforms the traditional didactic lectures to a more interacting learning process (Miller et al., 2003). ARS was first used for education in 1991 by Rice University to teach statistics [5] The implementation of electronic wireless interactive technologies has gradually stepped into the educational paradigm acting as a novel pathway into a more developed student learning process; thus, prompting self-directed learning [2]. ARS also called personal response systems or “clicker” is an interactive method allowing the students to share their knowledge instantly; by electronically voting to an on-screen or on-handset set of questions [2].

The ARS can be hard-wired or wireless. Wireless ARS can either be a specific handset-based ARS connected via radio or internet to a master handset controller; or personal smartphone-based ARS using web poll, short message service (SMS) or direct wireless connection through smartphone applications. Most ARS systems allow the running of multiple-choice questions [6]; however, recently introduced ARS systems provide an additional option of running open-ended and dichotomous questions using either text or multimedia-based (pictures or video) questions.

ARS as a recent development allows instant evaluation of students’ response against their peers to confirm whether there is a need for further elaboration of the primary vital points thus, assisting tutors to redesign the method of learning materials delivery [7, 8]. Furthermore, students responses can be sent anonymously; this allows the student to answer in a non-threatening environment, eliminating the main barrier of active participation embarrassment [9].

A trial based in England showed that ARS could have a positive influence on students’ concentration levels resulting in a subsequent improvement to their knowledge retention when implemented in small group orthodontic seminars [6]. Another study showed that ARS promotes interactions during orthodontic lectures but with a little effect on the short-term information recall [10]. The same research has also shown that students would prefer using the response system while attending lectures and seminars as they may find it easier to understand, interact, and later, participate [10]. As a result, knowledge retention was expected to be more beneficial than using traditional teaching methods. A new likely advantage of the phone-based ARS (PB-ARS), in the current COVID-19 pandemic, is the versatility in engaging students during distant online teaching, building interactivity in the virtual classroom and possibly compensating the lack of face-face interaction.

On the other hand, there are generic obstacles in the uses of ARS such as subscription rate, maintenance, training, troubleshooting and technical support. Also, it seems that there is conflicting evidence regarding the effectiveness of ARS. Robson and colleague found that the benefit of the ARS system is insignificant; nevertheless, there was a small improvement in knowledge gained for the ARS group compared to the control group [10]. Hence, it is essential to reach a consensus regarding the effectiveness of ARS in orthodontic pedagogy.

The aim of this cross-over randomised controlled trial (RCT) was (1) to investigate the effectiveness of PB-ARS using text- and multimedia-based questions on the retention of information by male undergraduate dental trainees; (2) to explore the students' perception and acceptance of PB-ARS. The null hypothesis stated that there is no difference in terms of knowledge retention and student perception when PB-ARS is used as an adjunct to didactic orthodontic teaching of undergraduate dental students.

Methods

Funding, ethical considerations and registration: This trial was a self-funded study approved by the local committee of research at the College of Dentistry at Prince Sattam Bin Abdulaziz University (PSAU) (1439-03-001). The trial was registered with ClinicalTrials.gov Protocol Registration and Results System (NCT04336813), and the protocol was not published before.

The authors declare that there is no financial interest or conflict of interest in this trial.

Study design: The trial was designed as a cross-over clustered randomised control trial (each group was a cluster) so that each group acted as their control for their knowledge's retention and perception.

Setting and consent: The study was commenced at the College of Dentistry, PSAU in Alkharj city in Saudi Arabia. Written consents obtained from all participants before starting the trial.

Participants: The eligibility criteria included undergraduate students in the fourth year of their dental training with no prior orthodontic education. Students who were registered in the course for the second time were excluded to lessen the bias associated with increased knowledge. The cohort of the trial involved the whole fourth-year undergraduate class (34 undergraduate dental students).

Randomisation: Participants were allocated to one of the two even groups using computer-generated randomisation. Participants in the control group (CG) were taught through the conventional model of power-point presentation. Participants in the intervention arm used phone-based audience response system (PB-ARS group) as an adjunct during the presentation. The sequence of random allocation was concealed from the researcher who recruited the participants. Each group consisted of 17 male students.

Intervention

<u>Lectures:</u> Simultaneously, CG and PB-ARS group attended two lectures, the first lecture (L1) titled "Management of Class III malocclusion" while the second lecture (L2) titled "Management of open bite and cross-bite". L1 and L2 were delivered at the main campus of PSAU College of Dentistry. L1 and L2 delivered identically in all aspects, including

- The presentation platform (PowerPoint, Microsoft Corp, Redmond, WA),
- The lecturer (both L1 and L2 were given by the one registered specialist orthodontist (F.A.), and
- The duration of the lectures which was 60 min.

Learning outcomes of the delivered lectures were based on learning objectives and outcomes as specified by the National Commission for Academic Accreditation and Assessment in Saudi Arabia.

Before L1, students were instructed to register with the PB-ARS and to download its application (Poll Everywhere, San Francisco, California, USA,

https://www.polleverywhere.com). Polleverywhere is a smartphone application that has a feature enabling the administrator to launch open-ended and dichotomous questions using either text or multimedia-based (pictures) materials, and then collects and analyses the answers from the users (students) instantly.

Extra smartphones were accessible to students who did not have smartphones at the time of the lecture. Students were blinded from their allocations until the beginning of L1.

Before the lecture, both groups completed a validated multiple-choice question (MCQs) formative assessment. During L1, the participants of the PB-ARS group had access to an interactive poll of new questions regarding the taught topic, via their smartphones. The participants of the PB-ARS group were allowed to read the questions and answer them. Participants in CG were blinded from those questions. At the end of L1, both groups re-sat the same pre-lecture MCQs assessment. A similar protocol was undertaken during L2 a week later, except that groups were crossed-over. Hence, the group which had had PB-ARS integrated during L1 were blinded from the poll of questions during L2, and vice versa. At the end of L1 and L2, participants of PB-ARS and CG groups filled a set of questions regarding their experience with the lecture.

Formative MCQs formative assessment

MCQs formative tests consisted of 20 questions related to the taught topics during L1 and L2. The maximum achievable score was 20. To reduce the carry-over effect, the PB-ARS questions during the lectures were different to the MCQs formative exam sheet. Two authors piloted the bank of questions to ensure its content validity and reliability. Content validity was tested using test matrix and expert judgment. The test reliability was estimated using inter-rater reliability, a correlation of more than 0.7 was considered acceptable. Appendix 1 and 2 include the poll of questions for L1 and L2.

Summative exam

Both groups attended their final written summative exams ten weeks after L2. The final exam was in MCQ format. The summative exams covered questions from all dental and medical subjects taught during the second semester in the fourth year of undergraduate dental training at the College of Dentistry/ PSAU. The summative exams exam included five questions relevant to the orthodontic subjects taught in L1 and L2. The exam questions were identical for all students and delivered under controlled conditions. The summative exam scores specific to L1 and L2 questions were traced and collected using an excel sheet by an independent tutor to reduce reporting bias. The maximum achievable score for the five questions relevant to the subjects taught in L1 and L2 was 5.

Students' perception

At the end of L1 and L2, participants of the CG group filled a set of questions regarding their experience with the lecture. Similarly, participants of PB-ARS group completed another set of questions (Appendix3). The questionnaire used was a modified version from a previous study [6] with close similarity of the assessed cohorts (Dhaliwal et al., 2015). The questionnaires of CG consisted of 9 questions that assessed understanding of the topic of the lecture, possibility of participation in the lecture, interaction with the tutor and total level of satisfaction. The questionnaire of the intervention group (PB-ARS) included an additional 4 questions specific to PB-ARS that aimed to assess the perception of using PB-ARs as an adjunctive to conventional teaching. Each question was answered using the 0-10 scale. The response of the students was categorised into five categories (Table 1). The 5 categories of responses were strongly agree, agree, neutral, disagree and strongly disagree.

Analysis of the results

Students' responses and scores were exported into an excel sheet for analysis. Students who failed to attend the summative exam were excluded from this trial to reduce the effect of time as a confounding factor. An intention to treat [11] analysis was adopted to deal with dropouts and missing data of non-compliant participants. Data was analysed by a blinded statistician using IBM SPSS statistics 22, version 22. Pre- and post-lecture formative assessments' scores were analysed and compared to using cross-over analysis with Mann–Whitney U test while t-test was used to analyse summative exam's score.

Results

The entire cohort of fourth-year undergraduate dental students (34 students, aged 23.27 years ± 0.86) were enrolled in this cross-over randomised trial. During L1, three students were absent (one from PB-ARS group and two from CG). During L2, the trial's arms were crossed over, and three students were absent (all from CG). On average, the percentage of students' attendance of the lectures were similar during L1 and L2. In total, 33 students from the PB-ARS group and 29 students from the CG completed the formative exam. Figure 1 shows the CONSORT flow diagram of participant recruitment to the study.

Questionnaires

The results of both questionnaires are displayed in tables 2-3 and figure 2. In both groups, the majority of the participants agreed that the lectures were understandable (86.6% for PB-ARS group; 83% for CG) and felt that they enjoyed the presented topics (83.3% PB-ARS group; 83% for CG). Students in both groups felt they were capable of participating in the active discussion during the lectures (83.3% for PB-ARS group; 83% for CG) and agreed that they more receptive to questioning during the lectures, in particular when PB-ARS was implemented (76.7%% for PB-ARS group and 72% for the CG). Participants of the PB-ARS group reported a higher level of concentration compared to those in the CG, 80% and 66% respectively.

The majority of participants (70%) were satisfied and preferred (76.7%) the use of PB-ARS (Polleverywhere mobile app) during the lecture. Participants reported that they were more likely to prepare for future lectures if PB-ARS was to be used (83.3%). In terms of the overall rate of satisfaction levels, there was a statistically insignificant difference among the two groups (90% for PB-ARS group; 83% for CG; median and mode questionnaire score for both groups= 4, p=0.183).

Retention of knowledge

Analysis of the students' performance during the formative exam was carried out to assess short-term recall of knowledge. Twenty-nine students from the CG arm and 31 students from the intervention arm (PB-ARS group) undertook the pre-lecture and post lecture assessments. 87.5% of students in PB-ARS group showed improvement in their scores after the intervention, compared to 79.3% in the control group. The mean for the pre-lecture exam score (the maximum achievable score was 20) for the CG and the PB-ARS group were (6.4, SD 3) and (7.2, SD 2.25) respectively. While the mean of the post-lecture exam score (the maximum achievable score was 20) was (8.89, SD 3.86) for the control group and (10, SD 2.74) for PB-ARS group. However, there was no statistically significant difference between the groups (mean difference (MD) = 2.63, confidence interval [1] 1.74-3.52, p= 0.465).

Analysis of the students' performance during the summative exam was carried out to assess long-term retention of knowledge. The mean for the summative exam score (the maximum achievable score was 5) was (2.87, SD1.51) for the CG and (3.06, SD 1.49) for the PB-ARS group; the mean difference was statistically insignificant (MD 0.194, 95% CI (-0.467)-0.854, p=0.560).

Discussion

Recently, several reports have explored the effectiveness of ARS in medical teaching and education. Nathaniel et al., 2016 in their meta-analysis found small but significant effects following the use of ARS technologies on both cognitive and non-cognitive learning outcomes [12]. However, few of the conducted trials studied ARS application for the undergraduate dental teaching programs, in particular in the field of orthodontics [13, 14]. The materials of the subject of orthodontics are considered to have a relatively high level of speciality and consequently are considered out of the scope of practice for a general dentist. Therefore, it has always been a dilemma for dental faculties and tutors to effectively measure their students’ essential understanding of orthodontic knowledge and principles [15].

In this cross-over study, it was not possible to include female undergraduate students since the trial was undertaken at gender-specific dental school. However, this might have helped in sample standardisation since studies have found a gender variation in the attitude toward learning via ARS [16]. Orthodontics as a taught subject at PSAU starts in the fourth year of Bachelor of Dental Science (B.D.S.) degree; thus the choice was made to select this cohort of students who had no previous exposure to orthodontic taught materials. The entire class was included in the study; this ensured no selection bias since all the assessed participants had the same level of dental knowledge.

One tutor (F.A.) delivered both taught lectures (L1, L2), one week apart, and the groups were crossed-over, this reduced further bias and enhanced the blinded cross-over protocol. Both groups had a formative exam following each lecture, to assess the short term retention of information, and a final summative exam ten weeks later, to evaluate the long-term recall of the knowledge.

The results showed that the majority of the participants in both groups rated the lectures as enjoyable, interesting and found it easy to understand the taught topic. This finding was in line with that reported in the literature [11, 17].

Besides these findings, the participants in the intervention group reported higher levels of concentration probably due to the need for active participation during the lecture. Students responded positively towards upcoming lectures in which PB-ARS was planned to be used; this might represent the effectiveness of PB-ARS in building interest in the subject materials, though the difference in the overall rating was statistically non-significant; this was in agreement with previous studies [10]. However, it is crucial to notice that the use of smartphones as PB-ARS tool might have some disadvantages which could limit its feasibility within the classroom. For instance, smartphones might create a source of student distraction and demand internet access. In addition to that, faculty members might need further training on use of this fast-developing modern technology. To lower the probability for biased results, participation in this study was not mandatory; no students were asked to complete the questionnaire and participants were allowed to leave the lecture hall at their will.

In this trial, the formative and summative exam scores of the participants from the PB-ARS group improved marginally compared to those from the control group; this is different from previously reported findings [18, 19]. Stowell and Nelson reported a noticeable, but statistically not significant, improvement in students learning curves [20]. Moreover, students' attendance in this trial was almost identical in both arms of the study, unlike the previous study [21]; this could be because students involved in this study had been informed that they were participating in a research project which might have increased the level of interest and alertness during both lectures (Hawthorne effect).

Limitations of the study

Although the sample included all undergraduate students in their fourth year of dental training, retrospective sample size calculation showed the study was underpowered. Robson and colleagues have suggested conducting a parallel multi-centre research, including several dental schools to increase the sample size with a minimum of 74 students per group [10]. Nonetheless, undesirable effects such as lack of standardisation of lecture delivery, would then need to be accounted for.

Another point to consider when interpreting the results is the carry-over effect as a result of cross-over design of this study. This might have affected students' experience, although the taught topics were different in the presented lectures. A further long-term parallel-arm randomised controlled trial with larger sample size is required to evaluate the effectiveness of using PB-ARS in teaching orthodontics to dental undergraduate students.

Conclusions

The PB-ARS with text- and multimedia-based questions has no significant effect on the short- and long-term retention of taught information to the undergraduate dental students. However, PB-ARS is perceived positively by undergraduate dental students, and it might be a useful adjunctive interactive educational tool. A further long-term parallel-arm randomised controlled trial with larger sample size is required.

Declarations

Acknowledgements

Not Applicable

Ethics approval and consent to participate

The trial was registered with ClinicalTrials.gov Protocol Registration and Results System (NCT04336813) on 7th April 2020, retrospectively registered (https://clinicaltrials.gov/ct2/show/NCT04336813?term=NCT04336813&draw=2&rank=1) and the protocol was not published before.

Consent was obtained from all participants.

Consent for publication

Written consent for publication was obtained from each participant.

Availability of data and material

Data and material are available at the orthodontic department in the College of Dentistry, Prince Sattam Bin Abdulaziz University/Alkharj/ Saudi Arabia.

Competing interests

The authors declare that there is no financial interest or conflict of interest in this trial.

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This study was self-funded.

Authors' contributions

FA and MA designed the study. FA collected the subject data. KA, BE, AA, LA, MW and MA analysed, interpreted and contributed to the writing of the manuscript. All authors read and approved the final manuscript.

Abbreviations

Audience response system (ARS)

Short message service (SMS)

Randomised controlled trial (RCT)

Phone-based ARS (PB-ARS)

Multiple-choice questions (MCQs)

Lecture 1 (L1)

Lecture 2 (L2)

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Tables

Table 1 Combination of questionnaire scores

Combination of scale	Assigned score
0-1	Strongly disagree
2-4	Disagree
5	Neither agree nor disagree
6-8	Agree
9-10	Strongly agree

Table 2 Students responses in the PB-ARS

Question		Response				
		Strongly agree	Agree	Indifferent	Disagree	Strongly disagree
1	Do you feel that you understood the topic that was being delivered today?	9 (30%)	17 (56.6%)	2 (6.7%)	2 (6.7%)	0 (0%)
2	How interesting did you find the seminar?	10 (33.3%)	14 (46.7%)	2 (6.7%)	4 (13.3%)	0 (0%)
3	Did you enjoy the seminar today?	13 (43.3%)	12 (40%)	0 (0%)	4 (13.3%)	1 (3.3%)
4	Do you find it easy to concentrate?	9 (30%)	15 (50%)	4 (13.3%)	2 (6.7%)	0 (0%)
5	Did you find it easy to participate in the session?	9 (30%)	16 (53.3%)	1 (3.3%)	4 (13.3%)	0 (0%)
6	Was there an opportunity to ask questions?	9 (30%)	14 (46.7%)	3 (10%)	2 (6.7%)	2 (6.7%)
7	Do you feel you were able to give feedback to your tutor?	7 (23.3%)	18 (60%)	3 (10%)	2 (6.7%)	0 (0%)
8	Did you prepare for this seminar?	1 (3.3%)	7 (23.3%)	3 (10%)	13 (43.3%)	6 (20%)
9	Were you more likely to answer questions using the Polleverywhere ?	9 (30%)	15 (50%)	3 (10%)	3 (10%)	1 (3.3%)
10	Do you prefer the conventional method of seminar teaching?	11 (36.7%)	10 (33.3%)	1 (3.3%)	4 (13.3%)	4 (13.3%)
11	Do you prefer the Polleverywhere?	9 (30%)	14 (46.7%)	1 (3.3%)	4 (13.3%)	2 (6.7%)
12	Will you be more likely to prepare for the next seminar if you know that Polleverywhere will be used?	9 (30%)	16 (53.3%)	1 (3.3%)	2 (6.7%)	2 (6.7%)
13	Overall, rate your level of satisfaction with the seminar?	8 (26.7%)	19 (63.3%)	1 (3.3%)	2 (6.7%)	0 (0%)

Table 3 Students responses in the CG

Question	Response				
	Strongly agree	Agree	Indifferent	Disagree	Strongly disagree
o you feel that you understood the topic that was being delivered today?	6 (21%)	18 (62%)	1 (3%)	4 (14%)	0 (0%)
How interesting did you find the seminar?	7 (24%)	17 (59%)	2 (7%)	3 (10%)	0 (0%)
Did you enjoy the seminar today?	9 (31%)	14 (48%)	2 (7%)	4 (14%)	0 (0%)
o you find it easy to concentrate?	6 (21%)	13 (45%)	3 (10%)	6 (21%)	1 (3%)
d you find it easy to participate in the session?	7 (24%)	17 (59%)	4 (14%)	0 (0%)	1 (3%)
Was there an opportunity to ask questions?	7 (24%)	14 (48%)	3 (10%)	5 (17%)	0 (0%)
Do you feel you were able to give feedback to your tutor?	3 (10%)	19 (66%)	4 (14%)	3 (10%)	0 (0%)
Did you prepare for this seminar?	3 (10%)	12 (41%)	1 (3%)	7 (24%)	6 (21%)	
Overall, rate your level of satisfaction with the seminar?	4 (14%)	20 (69%)	3 (10%)	2 (7%)	0 (0%)

Figures

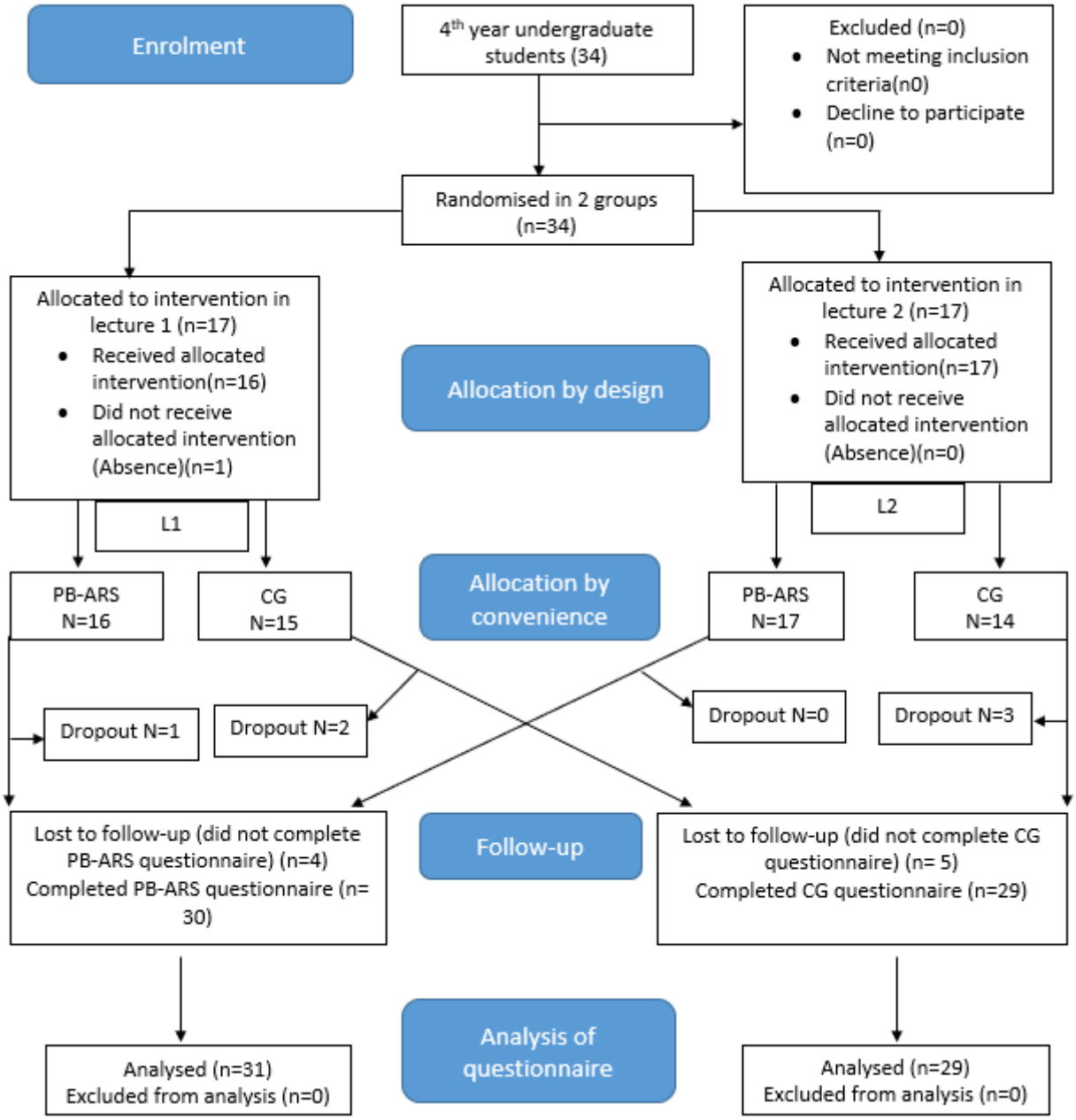

Figure 1

CONSORT Flow Diagram of the trial

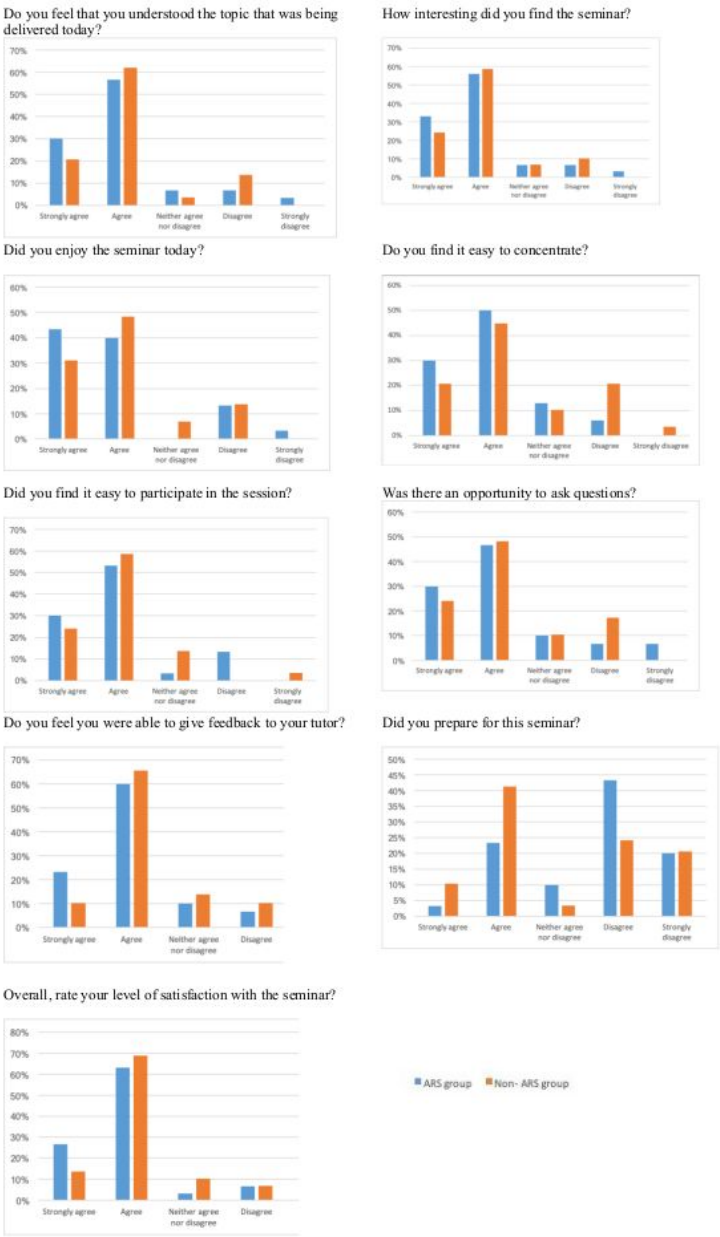

Figure 2 Comparison between students' perception about the taught lecture in both groups

Figure 2

Comparison between students' perception of the taught lecture in both groups

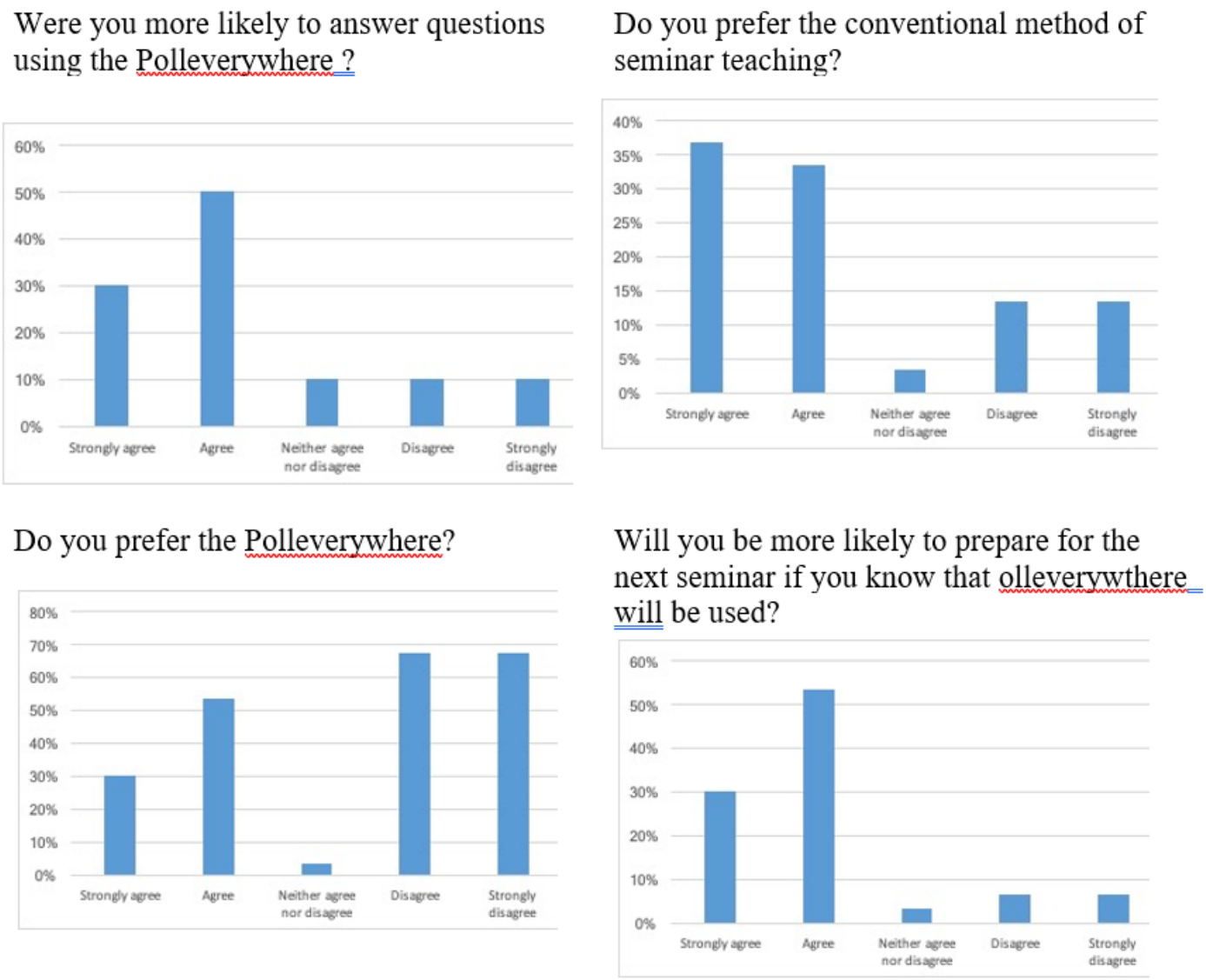

Figure 3

Students perception using PB-ARS

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- CONSORT2010Checklist.doc
- Appendix1WrittenMCQsforL1.docx
- Appendix2WrittenMCQsforL2.docx
- Appendix3Questionnaireforstudents.docx