Clicker approach in Engineering Design classrooms

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Structured abstract

BACKGROUND
Depending on the method or extend of its use in the classroom, Audience Response Systems (ARS) or Clickers, can have either negative or positive effect on student learning outcomes. There are many types of clicker technologies that can provide, wireless voting/polling responses, short text type responses, and now latest web-based technology using smart-phones or iPads for various responses. In many instances and literature, clicker technology can be utilised to probe student knowledge of the lecture topic, initiate student in-class discussion, attention, instantaneous feedback and interaction with peers and lecturer. The challenges are with large Engineering Design classes where there is lack of feedback and attention in classes.

PURPOSE
The aim of this study was to evaluate two main clicker approaches, undertaken separately throughout the first and second semester, in order to improve student learning outcomes through in-class interaction, feedback, attention and response accuracy.

DESIGN/METHOD
Two approaches were applied to simultaneously implement and evaluate RMIT University's Engineering Design courses offered at year 3 undergraduate and postgraduate levels. In semester 1, clicker responses were open-ended texts with occasional multiple-choice questions (polling type responses). Students shared their clickers with their team members and any responses depend on individual or collective decisions, with student semi-anonymity being addressed. In semester 2, polling type responses with 'probing question' and the 'peer-learning' model (also known as 'peer instruction') was applied, based on full-anonymity, control and experimental study groups. Paper-based surveys were administered at 5 time-points in order to collect and analyse data.

RESULTS
The outcomes from the statistical analyses revealed an improvement in frequency and quality of clicker responses from the first to second semester. This was mainly due to peer-learning method applied in the second semester, where students were encouraged to interact more by submitting a more structured, strategic and timely multiple choice clicker responses, as compared to the first semester, where a less structured and timely open-ended response approach was applied. The survey evaluation revealed that clicker activity helped students to pay more attention in class, but it did not assist them as much for them to explain what was taught in the class nor provide them with any feedback. There was an evidence of a significant decrease in frequency of clicker responses throughout semester 1 when students were interacting with open-ended responses. However, there was a much smaller decrease in frequency of clicker responses throughout semester 2, mainly because a peer-learning method was introduced when students were interacting with multiple choice responses.

CONCLUSIONS
This study revealed that 'peer-learning' model proved to promote stronger student in-class engagement and interaction with the clicker technology and did improve the correctness of responses for the more challenging questions. On the other hand, clicker approaches did not improve feedback.

KEYWORDS
Clickers, engineering design, learning outcomes

Introduction

There has been a steady rise in the use of technology in the classroom. This has given the teaching staff the opportunity to use technology to enhance interactivity with the students in the classroom. Audience Response Systems (ARS) or Clickers allow the students to interact in the classroom and depending on the method or the extent of its use in the classroom, it can have either negative or positive effect on student learning outcomes. There are many types of clicker technologies that can provide, wireless voting/polling responses, short text type responses, and now latest web-based technology using smart-phones or iPads for various responses. In many instances and literature, clicker technology can be utilised to probe student knowledge of the lecture topic, initiate student in-class discussion, attention, instantaneous feedback and interaction with peers and lecturer. The challenges are with large Engineering Design classes where there is lack of feedback and attention in classes.

This paper presents a study conducted at School of Electrical and Computer Engineering (RMIT University, Melbourne, Australia) on the third year undergraduate Engineering Design 3A/3B (EEET2258/2259) courses. The course consists of structured and well-defined *team* project based or collaborative learning supplemented by the cross-disciplinary lectures and project teachings. One of the main objectives of this course is to improve student professional practice learning outcomes and enhance the student design skills of working on industry and research related projects, making a student more employable, entrepreneurial, productive and innovative once they graduate.

Objective of the project

The aim of this paper and the study was to evaluate two main clicker approaches, undertaken separately throughout the first and second semester, in order to improve student learning outcomes through in-class interaction, feedback, attention and response accuracy.

Methodology

The responses from ARS were anonymous to peers and this encouraged the students to interact with the lecturer (Draper and Brown 2004). The lecturer was also able to receive real time feedback from the class and give them the opportunity to create a classroom discussion (Hinde and Hunt 2006).

During most of the semester 1 and 2 2011 lectures, ARS technology was utilised to probe student knowledge of the lecture topic, initiate student in-class discussion, feedback and interaction with peers and lecturer. The aim was to make the in-class experience more interactive, improve student attention and participation. Students were able to wirelessly send SMS text messages (similar to online Twitter) with questions, comments, statements, as well as voting/polling responses to multiple-choice questions. In semester 1, typical ARS responses were open-ended texts with occasional multiple-choice questions. The class-polling results were instantaneously displayed on the projector screen on the actual lecture slides. These open-ended texts were required to be entered like SMS-type text message via the ARS keypad. Prior to start of every lecture presentation, students were required to collect one ARS keypad and share it with their team members. This way, students needed to sit next to their team members (peers) and engage in brief discussions set by the questions, strategically presented during the lecture, providing instantaneous peer feedback to each other. This feedback was also provided from the ARS data displayed on the projector screen and by the lecturer responding and elaborating on those displayed ARS responses. This method enabled a multi-way feedback.

During Semester 1, the lecture activities were designed so that the student anonymity and semi-anonymity was addressed. Only student's own team members were able to identify each other's responses. Students from other teams and lecturers were not able to identify it. The experimental design involved two SETs of teams ('SET 1' – team numbers 1-19, and 'SET 2' – team numbers 20-38). The study design in semester 1 consisted of combined SET

1 and SET 2 teams, labelled as Experimental (2) group. This semester 1 design did not include the Control group. Refer to Table 2. The ARS activity was conducted only during week 4, 5, 7, 8, 9 and 11 lectures.

In Semester 2, a 'peer-blind' method was applied. During the class the team members (peers) and others in the class were blind to any individual student responses. However, only the study investigator was able to identify the respondents once the data was being analysed – not during the semester and within the student assessment period. This semester 2 study consisted of Control (1) and Experimental (1) conditions (refer to Table 1 and 2). The Control (1) condition included individual student responses. These students were not required to sit together with their team members, nor be involved in any peer (own team) discussions, nor interact with the rest of the class. The Control (1) group students were required to collect one of the ARS keypads and keep it with them for the entire lecture session without sharing it with anyone. The Experimental (1) group were required to sit together with their own team members, collecting one of the ARS keypads and keep the keypad with one student for the entire lecture session. This Experimental (1) group students needed to be involved in any peer (own team) discussions and interact with the rest of the class using ARS at a particular point during the lecture, when instructed. Considering that this study adopted peer-blind design, only the investigator could identify the ARS respondent. The identification was done when a student signed the Ethics application's 'Participant's Consent' form, by being asked to provide a password code. This code needed to remain the same throughout semester 2. Prior to sending any ARS responses at the start of any lecture, students were instructed to initially send an ARS text of their password code which would enable for their further ARS responses to be time stamped and tagged. Students who participated in the study needed to use this same password code for all other study activities. During semester 2 week 2-3, SET 1 teams were assigned to Control (1) group and SET 2 teams to Experimental (1) group. During week 4-6, these SET teams needed to swap their groups - SET 1 was Experimental (1) and SET 2 Control group. Refer to Table 1 and 2.

The Semester 2 in-class ARS activity was based on 'probing question' and the 'peer-learning' model (also known as 'peer instruction'). The implemented 'probing question' was actioned 5 minutes into the lecture, used to 'probe' student's pre-existing level of understanding of the lecture topic in order to prepare them to learn. The class polling which consisted of all submitted responses plotted as bar graph and showing distribution of all responses, was displayed on the projector screen, instantaneously. The lecture shortly announced the correct response to this probing question (Q1). The second and third questions (Q2 and Q3) evaluated student learning. Q2 would typically be presented to students 45 minutes into the 1-hour lecture or 90 minutes. The Control (1) and Experimental (1) groups requires students to think and respond to Q2 independently. Then they would not receive the correct answer or see the class polling (bar graph) until they respond to Q3 which is quickly followed after Q2 responses. Prior to Q3, Control (1) group remains with another chance to respond independently. Whereas, Experimental (1) group students needed to quickly sit with their team members and then spend time challenging one another to reach a consensus answer. The 3 questions were all multiple-choice questions with 4-5 choices and 1 correct answer.

Table 1. Feedback activity study design for Semester 2.

Semester 2, 2011	Control (1)	Experimental (1)	Method
Week 3	SET 1 teams	SET 2 teams	Peer-Blind Responses
Week 4-6	SET 2 teams	SET 1 teams	

Note: **Control (1)** - (individual – self responses, no peer feedback and partial class-interaction); and **Experimental (1)** - (team – self and team responses, peer feedback and team/class interaction).

Table 2. Feedback activity study design for Semester 1 and 2.

Semester 1 & 2, 2011		ARS Feedback	Team SET No. & Method
Semester 1	Week 1-12	ARS – 'Experimental (2)'	Combined SETs Semi-Anonymous Responses
Semester 2	Week 3	ARS – 'Control (1)' & 'Experimental (1)'	SET 1 & 2 Peer-Blind Responses
	Week 4-6	ARS – 'Control (1)' & 'Experimental (1)'	SET 2 & 1 Peer-Blind Responses

Study Protocol and participants

The paper-based surveys have been administered at 5 time-points and data has been collected and analysed for both semester 1 and 2. Each survey had 60+ Likert-type and open-ended questions which were statistically analysed using various quantitative techniques (with hypotheses testing). RMIT University Ethics committee approved the study and 32 participants signed the consent letters, administered throughout 5 time points during the data collection. The student enrolment number was 210.

Results

For Semester 1, a comparison of the ARS frequency (count) of responses for each participant for each question and week was conducted because some participants may respond more or less for each question than others (refer to Table 3). This descriptive analysis was conducted to find the rate of four-question (Q1-4) responses per participant in each of the weeks. There were participants who made multiple responses per question. These were the open-ended (text) responses. However, for this analysis it was ignored whether the responses were correct or incorrect.

Table 3. This data provides the frequency (counts) and % (total responses for each question across weeks) of responses for ARS Semester 1.

	Week 4		Week 5		Week 7		Week 8		Week 9		Week 11	
	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate
Q1	27	35.06%	18	23.38%	12	15.58%	8	10.39%	7	9.09%	5	6.49%
Q2	29	43.94%	19	28.79%			7	10.61%	8	12.12%	3	4.55%
Q3	30	50.00%	15	25.00%			4	6.67%	8	13.33%	3	5.00%
Q4	30	44.12%	18	26.47%	7	10.29%			9	13.24%	4	5.88%

Observing this frequency and % of responses for ARS semester 1, it was evident that it decreased substantially from week 4 to 11 (refer to Table 3). There was a novelty of students being introduced to interact with ARS in the first lecture (week 4), which explains the frequency of responses being around 30. But because this was also a new experience for investigator, visiting lecturer and assistant, it may have been a delay in re-engaging students with it or even altering its design. By week 5, there was a substantial decrease in interest, engagement or interaction with ARS technology during the lectures. The lecturer engagement (industry guest lecturer) with this ARS technology and students may be the reason, but most probably it was due to ineffectiveness of just relying on open-ended responses without combining it with multiple-choice questions and type of topic questions. Nevertheless, this issue was noticed throughout semester 1 and an alternative design applied in Semester 2.

Hypothesis #1: *The timely ARS response from week 4, 5, 7, 8, 9 and 11 (semester 1) show a gradual increase in the **frequency** of provided responses (open-ended type). For example, there is a gradual increase in the number in responses from the start to the end of semester 1. The increase in number of responses should correspond to the increased student 'interaction' with the ARS technology in lectures.*

The literature suggests the use of ARS and Clickers helped engaging the students in the lecture and the anonymity in the responses allowed the students to interact freely and be active members in the classroom discussion (Bank 2006, Durbin and Durbin 2006, Hu et.al. 2006 and Preszler et al., 2007). The use of the ARS increased the student participation and allowed them to interact with their peers and promoted active learning in the classroom (Beatty 2004, Kennedy et al. 2006 and Stuart et al. 2004).

This ***hypothesis #1 was not supported***, as the frequency of responses decreased over the semester. A Chi-Square goodness of fit test was conducted to see if there was a difference across weeks. Results confirmed that there was a significant ($p < 0.05$) decrease in the number of responses using the ARS. For semester 2, throughout week 3-6 lectures, the descriptive statistical analysis was performed in Table 4 shown below.

Table 4. This data provides the number (N) and % (valid responses) of students who answered questions correctly for ARS Semester 2.

	Week 3		Week 4		Week 5 (1)		Week 5 (2)		Week 6	
	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate
Q1	7	41.2%	6	40%	5	55.6%			6	54.5%
Q2	6	42.9%			2	25.0%	2	15.4%	3	30.0%
Q3	4	36.4%	12	85.7%	3	25.0%	3	25.0%	6	54.5%
Q4									9	81.8%

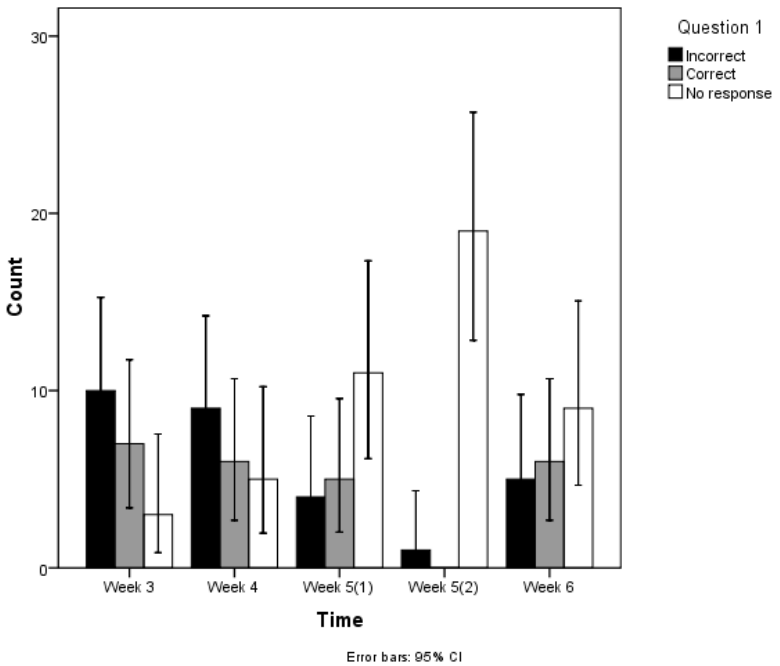
For semester 2, a comparison of the ARS frequency (count) of responses for each participant for each question and week was conducted because some participants may respond more or less for each question than others (refer to Table 5).

Table 5. This data provides the frequency (counts) and % (total responses for each question across weeks) or responses for ARS Semester 2.

	Week 3		Week 4		Week 5 (1)		Week 5 (2)		Week 6	
	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate
Q1	17	32.08%	15	28.30%	9	16.98%	1	1.89%	11	20.75%
Q2	14	28.57%			12	24.49%	13	26.53%	10	20.41%
Q3	11	18.33%	14	23.33%	12	20.00%	12	20.00%	11	18.33%
									11	100.00%

While there was an evidence of slight decrease in frequency of responses in semester 2, there was a strong student in-class engagement and interaction with the ARS (refer to Table 4 and 5).

In Week 3, 41.2% of students got Q1 correct, 42.9% got Q2 correct and 36.4% got Q3 correct (refer to Fig. 1). This indicated that the ‘peer-learning’ model-type questions proved to be more challenging with Q3 when students had to re-submit their responses independently or after brief peer discussion. In week 4, 85.7% got Q3 correct which may have indicated effectiveness of peer-learning but once again, it needed clarification which experimental group showed the majority of those correct responses. In week 5, the probing question was best answered, but the peer-learning questions (Q2 and Q3) remained lower in correctness and with no difference between them. Overall, these descriptive statistics suggested that the questions in week 5 (lecture 2) were the most difficult and questions in week 6, the least difficult, with Q4 a bonus peer-learning question.



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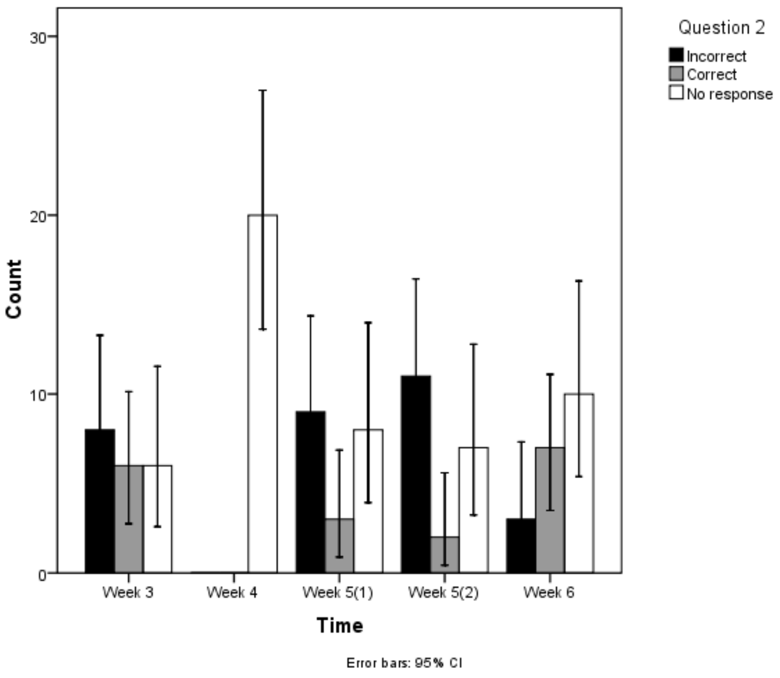

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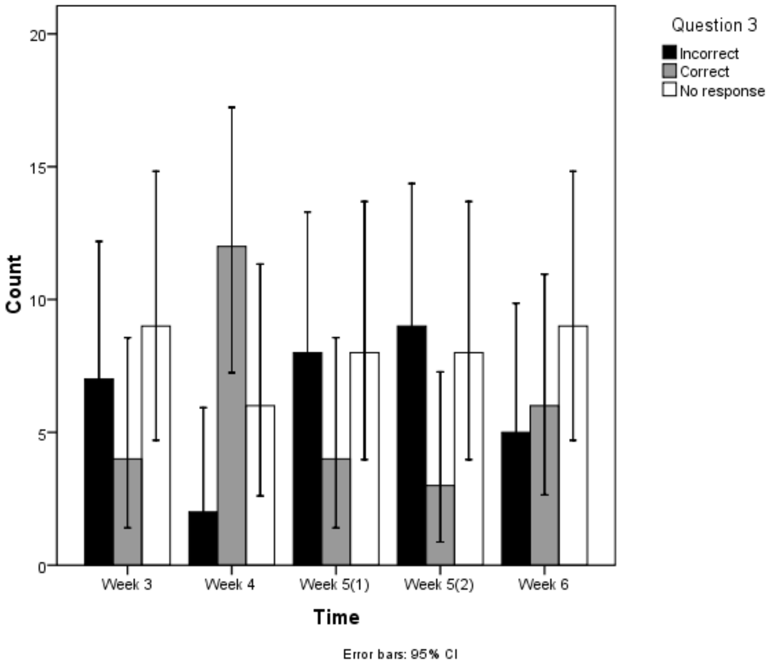

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Fig 1. The correct and incorrect ARS responses in Semester 2 for Q1-3 (a-c).

The use of ARS allowed the lecturer to provide for interactivity within the classroom and also to use it as a tool for formative assessment and feedback. The regular method used during classrooms was on volunteers sharing their answers to questions asked or a ‘show of hand’. However, these methods had disadvantages and proved difficult in determining an accurate sense of class understanding and may have been particularly limited in a large classroom (Abrahamson 2006). The use of ARS allowed the lecturer to gather real-time feedback and allowed them to gauge the understanding in the class and modify the mode of instruction or modify the explanation based on real time data (Beatty 2004, Hatch et al. 2005). The anonymity in the responses again allowed the students to interact freely with the class and they were required to think of the question or problem at hand (Beatty 2004 and Pradhan et al. 2005). The following hypothesis presented below tested this theory.

Hypothesis #2: *The timely ARS response from week 3 to 6 (semester 2) did improve the correctness of responses. For example, there was a gradual improvement in correctness of ARS responses from week 3 to 6.*

Chi-Square tests were conducted to examine the association between correct responses and weeks using the ARS systems. There was a significant difference between the number of correct and incorrect responses for Q1 and Q2, $p < 0.05$. For Q3, there was no significant difference. Chi-Square test of association was conducted to determine the association between intervention week and question response on the ARS - in other words, to compare the correct and incorrect responses and its progression throughout weeks 3-6. The assumption of expectancy was violated, so Fisher’s Exact was used as an alternative. Results indicated a significant association (p<0.05) for ‘probing questions’ (Q1) across all weeks 3-6. The Time Cross-tabulation description, revealed that for Q1 week 3, there were 7 correct responses (std. residual 1.0), 6 (week 4), 5 (week 5a) and 6 (week 6), compared to expected 4.8 responses. This suggested that the number of correct responses were better than expected and fairly consistent throughout all weeks. However, week 3 and 4 showed the highest number of incorrect responses with 10 (std. residual 1.7) and 9 (1.3) compared to expected 5.8 responses. The incorrect responses decreased by the end of week 6, as shown in Fig 1a. For Q2, the Fisher’s Exact was also used, indicating a significant association (p<0.05) across all weeks 3-6. For both week 5 exercises, the actual number of correct responses was 3 and 2, compared to expected 3.6 responses, but substantially improved by week 6 with 7 correct responses. For the same Q2, the number of incorrect responses was substantially higher, with 8, 9 and 11 incorrect responses compared to 6.2 expected responses, in week 3 and both week 5, respectively (refer to Fig. 1b). For Q3, as the second part of part of peer-learning method, the assumption was not violated and Chi-Square test of association was conducted and showed non-significant association. While the expectancy of 5.8 correct responses was used (higher than 3.6 for Q2), there were 4 recorded correct responses (6 for Q2), 12 (compared to 2 incorrect for Q3 and missing responses for Q2), 4 (3 for Q2), 3 (2 for Q2) and 6 (7 for Q2), for week 3, 4, 5a, 5b and 6, respectively (refer to Fig. 1c). There was a substantial increase in correct response in week 4 and slight improvement for week 6 and slight decrease in week 5 (being the hardest week for ARS exercise). The expected incorrect responses for Q3 was the same as Q2, 6.2, there was one less response, 2 (missing), 8 (9 for Q2), 9 (11 for Q2), and 5 (3 for Q2), in week 3, 4, both exercises in week 5 and 6, respectively. Overall, there were less incorrect responses for Q3 than Q2 for weeks 3 and 5 (being the most difficult week for ARS exercises) and substantially more correct responses for week 4. Week 6 was as indicated the easiest of all week lectures and was not improved for Q3 compared to Q2. It seemed that for the more challenging questions, the peer learning model was effective. It was discovered that students did improve (more correct responses) from weeks 3 to 6 and with this mind, ***this hypothesis #2 was supported***.

The aim of using ARS in the classroom was to improve on the student engagement during the class and to also to improve their interactivity and understanding of the material presented in the class. The question presented in the audience polling and the use of SMS type responses allowed the students to interact with the lecturers, their peers and compare their responses and their understanding with their peers (Burton 2006 and Caldwell 2007). Hypothesis #3 explored if this peer interaction and cooperative learning has an impact on the correctness of the responses.

Hypothesis #3*: The initial self-discussion followed by peer-discussion for peer-learning method, which included Q2 and Q3, in providing the ARS responses in Experimental (1) group, improves the correctness of responses to questions (due to cooperative learning) than Control (1) group in semester 2.* Refer to details in Table 6-8, and Fig. 2, on all ARS responses from students who did and did not participate in the study. However, this hypothesis #3 was related for students who participated in the study. It was required to compare the statistical difference between SET 1 and SET 2 in week 1-3 & week 4-6. In week 1-3, SET 2 was Experimental (1) and SET 1 was Control (1) group. In week 4-6 it was the vice versa. From Table 6, it can be seen that in Weeks 1-3, there were more correct responses from SET 1 than SET 2. This trend was reversed for weeks 4 – 6, where there were more correct answers for SET 2, than SET 1. This indicated that the Experimental (1) group which utilised the peer-learning method (initial self responding followed by peer-discussion) revealed substantially less correct responses than for Control (1) group for all three questions (Q1-3). There were evident differences in N of responses from both SETs in those weeks (4-6) – SET 1 had a greater N for Q1 (by 4 responses) and lesser N for Q3 (by 7 responses). Weeks 1-3 needed to be ignored due to low N of responses, mainly because it was 1 lecture as compared to 4 lectures (weeks 4-6). Note that a lot of students did not provide response using the ARS and not all participated in the study. The total number of responses can be seen from Table 3 and 4. With these results, ***this hypothesis #3 was not supported***.

Table 6. The comparison between SET 1 and 2 correct and incorrect ARS responses.

		SET 1			SET 2		
		N of responses	*N* of correct	% of correct	*N* of responses	*N* of correct	% of correct
Weeks	Q1.	8	1	13%	1	0	0%

1-3	Q2.	2	2	100%	1	0	0%
	Q3.	1	1	100%	0	0	0%
Weeks 4-6	Q1.	16	4	25%	12	4	34%
	Q2.	11	4	37%	11	6	55%
	Q3.	12	5	34%	19	10	53%

Hypothesis #4: *The timely ARS response in semester 2 (both Control (1) & Experimental (1) or Control (1) or Experimental (1) groups) were more frequent (i.e. show a gradual increase or consistency in the frequency) responses compared to semester 1 Experimental (2) (open-ended type) group. For example, semester 2 ARS 'peer-blind' method is more interactive than semester 1 ARS 'semi-anonymous' method. Refer to Table 2 and 7.*

This ***hypothesis #4 was not supported***, as the frequency of responses decreased in semester 2 compared to semester 1. Additionally, Chi-Square tests revealed that the difference between the two semesters was significant, $\chi^2 = 21.63$, $p < 0.01$ – semester 1 total frequency of responses (271) was significantly higher than for semester 2 (173). A comparison between semester 1 and 2 of the frequency of responses for each participant and each question was conducted. Even though semester 1 and 2 were mainly different type of questions, Q1 was similar probing students' knowledge prior to topic being presented. Q4 for semester 2 should not be considered because it was only a bonus question (refer to Table 4). The majority of semester 1 frequency of responses was due to week 4 lecture when ARS was introduced to students. If only week 4 data was to be excluded from Table 8 we would have N=50 (Q1), 37 (Q2), 30 (Q3) and 38 (Q4). Note also that semester 1 had 6 weeks (6 ARS exercises) whereas semester 2 had 4 weeks (5 ARS exercises).When week 4 from semester 1 and Q4 from both semesters was excluded, we again obtained the results which showed a significant difference between the two semesters, $\chi^2 = 7.25$, $p < 0.01$. But semester 1 total frequency of responses (117) was significantly lower than for semester 2 (162).

Table 7. The rate of ARS responses in Semester 1 and 2.

	Semester 1		Semester 2	
	N	Rate	N	Rate
Q1	77	59.23%	53	40.77%
Q2	66	57.39%	49	42.61%
Q3	60	50.00%	60	50.00%
Q4	68	86.00%	11	13.92%

The key reason to use the audience response system or clickers was to improve the classroom environment with increased attention and engagement during the class. Also, improve the learning in the class through interaction between the peers and teachers and help students discuss the learning material and clear the misunderstanding or misconception to help build knowledge (Beatty 2004, Caldwell, 2007, Draper and Brown 2004, Pradhan et al. 2005, Stuart et al. 2004 and Siau et al. 2006).

Hypothesis #5*: From the Survey conducted at five time points, from 'prior semester 1' to 'semester 2 week 7-13', students (individually and as a team) exhibited improvement in each of the learning items listed under Q21-33.* Chi-Square tests were conducted for each item to see if there was a significant association between responses and time point.

This ***hypothesis #5 was not fully supported.*** The results revealed no significant association for both SETs. Cross-tabulations were provided for Q21–Q29. The data when the standardised residual (s.r.) was greater or lower than +2.0/-2.0, this represented a group that was over-represented/under-represented to what was expected of the data. However, the question related to ‘attention’ (paying attention to the lecture being presented helped me learn) revealed the most positive response ‘strongly agree’ at the end of semester 2 in SET 2 group (‘2-2’ under SEM column in Table 8). This was the only learning item that has exhibited improvement. It wasn’t the case with other items. The questions with the negative responses were ‘explanation’ (seeing and hearing my peers explanations helped me learn) as ‘disagree’ at the end of semester 2 in SET 1 group and as ‘strongly disagree’ at the middle of semester 2 in SET 2 group; and ‘misunderstanding’ (discussing questions with my peers addressed my misunderstanding about the lecture’s initial questions asked) as ‘disagree’ at the middle of semester 2 in SET 1 group. Refer to Table 8 Q22 ‘interaction with peers’ was evident at ‘prior’ stage as ‘neither agree nor disagree’ response in SET 2. Interestingly, *Q23 ‘interaction with technology’ and Q24 ‘instantaneous feedback’ responses were not over-represented, which were initially assumed.* Both SET 1 and 2 found ARS the least (rating ‘disagree’ and ‘strongly disagree’) related with Q25 ‘explanation’ at the middle and end of semester 2. Q31 ‘At what moment did you feel most *engaged* during lecture?’ was evident as ‘none of above’ response and ‘while working on my own’ at ‘prior’ stage – possibly relating to not working in a team and not using ARS. Both Q31 responses were revealed in SET 1 group where there were mainly negative responses.

For Q32 (On average, how many ARS entries have you submitted per lecture (as a team or individual)?), a one-way ANOVA was conducted to examine if there was a difference between time points for the number of ARS responses students had submitted. No significant difference was discovered between the two SETs 1 and 2, $F = 0.018$, $p = 0.99$ and $F = 0.832$, $p = 0.48$ respectively. Whilst we did get more responses in SEM 1 than SEM 2 using the ARS, there were also more responses for the survey regarding ARS in SEM 1 compared to SEM 2. At all time points, SET 1 claimed to have more ARS responses than SET 2 (refer to Fig. 2). This finding coincides with Table 6 data which showed higher frequency of responses in SET 1 group during semester 2. Q33 was a qualitative response converted to quantitative response ‘Briefly explain how did the ARS technology help you learn and understand the lecture topic?’ – but this data was ignored in this study and used mainly as a student feedback to investigator. Thus hypothesis 5 was supported in part with students stating it helped in attention during the lecture but was not supported in the areas of peer interaction, explaining concepts, clearing misunderstandings and engagement.

Table 8. Summary of cross-tabulations provided for Q21–Q29 (feedback activity).

		SET 1			**SET 2**		
Q #	**question**	**s.r.**	**rating**	**SEM**	**s.r.**	**rating**	**SEM**
21*	***attention*** *				2.1	Strongly Agree	2-2
22	interaction with peers				2.4	Neither Agree nor Disagree	prior
25	explanation	2.4	Disagree	2-2	2.3	Strongly Disagree	2-1
					2.5	Disagree	2-1
27	misunderstanding	2.4	Disagree	2-1			
31	At what moment did you feel most *engaged* during lecture?	1.9	While working on my own	prior			
		1.9	None of above	2-1			

Note: **Q21-27 rating scale:** (1) Strongly Disagree; (2) Disagree; (3) Neither Agree nor Disagree; (4) Agree; (5) Strongly Agree.

Q31 rating scale: (1) While working on my own; (2) While working on my own and considering oral/ARS responses from other students (not only my team) during the class; (3) While working in my team; (4) None of above.

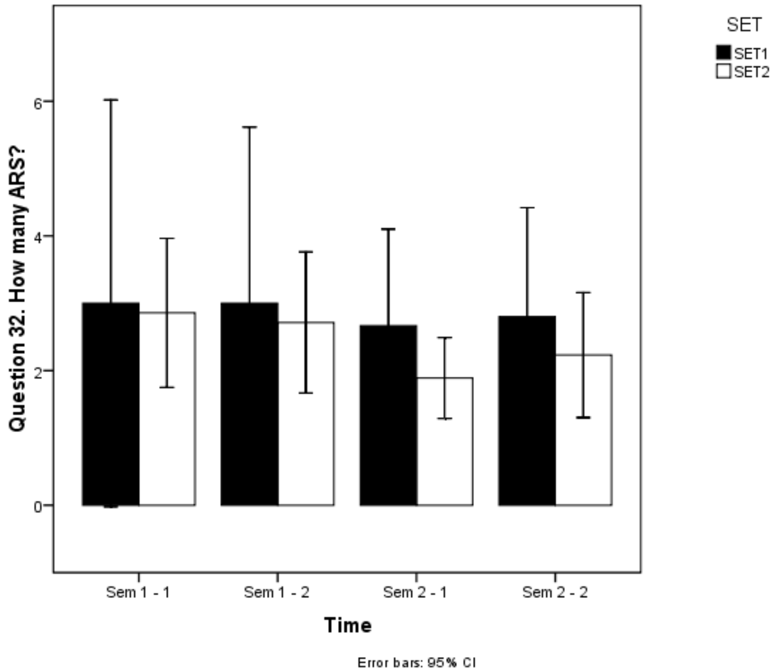

Fig. 2. Survey indication on the frequency of ARS responses.

Conclusions

A study was designed and conducted to evaluate the learning outcomes through the use of ARS in-class interaction, feedback, attention and response accuracy from teaching methods employed within the Engineering Design 3 courses. There was an evidence of a significant decrease in frequency of ARS responses throughout semester 1 when students were interacting with open-ended ARS responses. However, there was a much smaller decrease in frequency of ARS responses throughout semester 2, mainly because a peer-learning method was introduced when students were interacting with multiple choice ARS responses. This semester 2 method proved effective in promoting stronger student in-class engagement and interaction with the ARS technology and did improve the correctness of responses for the more challenging questions. Survey evaluation revealed that ARS activity helped students to pay more ‘attention’ in class and did not assist them to ‘explain’ what was taught. The expected outcome, where students would ‘interact with ARS technology’ and provide them ‘instantaneous feedback’, was least common response revealed from the survey evaluation. The study showed the students appreciated the interactivity in the class but more needs to be done in terms of the designing of the questions and the use of clickers to improve the in class understanding.

References

Abrahamson, L. (2006). A brief history of networked classrooms: Effects, cases, pedagogy, and implications. In D. A. Banks (Ed.), Audience response systems in higher education (pp. 1–25). Hershey, PA: Information Science Publishing.

Banks, D. A. (2006). Reflections on the use of ARS with small groups. In D. A. Banks (Ed.), Audience response systems in higher education (pp. 373–386). Hershey, PA: Information Science Publishing.

Beatty, I. (2004). Transforming student learning with classroom communication systems. *EDUCAUSE Research Bulletin*, 2004(3), 1–13.

Burton, K. (2006). The trial of an audience response system to facilitate problem-based learning in legal education. In D. A. Banks (Ed.), Audience response systems in higher education (pp. 265–276). Hershey, PA: Information Science Publishing.

Caldwell, J. E. (2007). Clickers in the large classroom: Current research and best-practice tips. *Life Sciences Education*, 6(1), 9–20.

Draper, S. W., & Brown, M. I. (2004). Increasing interactivity in lectures using an electronic voting system. *Journal of Computer Assisted Learning*, 20(2), 81–94.

Durbin, S. M., & Durbin, K. A. (2006). Anonymous polling in a engineering tutorial environment: A case study. In D. A. Banks (Ed.), Audience response systems in higher education (pp. 116–126). Hershey, PA: Information Science Publishing.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics text data for introductory physics courses. *American Journal of Physics*, 66(1), 64–74.

Hatch, J., Jensen, M., & Moore, R. (2005). Manna from heaven or clickers from hell. *Journal of College Science Teaching*, 34(7), 36–39.

Hinde, K., & Hunt, A. (2006). Using the personal response system to enhance student learning: Some evidence from teaching economics. In D. A. Banks (Ed.), Audience response systems in higher education (pp. 140–154). Hershey, PA: Information Science Publishing.

Hu, J., Bertol, P., Hamilton, M., White, G., Duff, A., & Cutts, Q. (2006). Wireless interactive teaching by using keypad-based ARS. In D. A. Banks (Ed.), Audience response systems in higher education (pp. 209–221). Hershey, PA: Information Science Publishing.

Kennedy, G. E., Cutts, Q., & Draper, S. W. (2006). Evaluating electronic voting systems in lectures: Two innovative methods. In D. A. Banks (Ed.), Audience response systems in higher education (pp. 155–174). Hershey, PA: Information Science Publishing.

Pradhan, A., Sparano, D., & Ananth, C. V. (2005). The influence of an audience response system on knowledge retention: An application to resident education. *American Journal of Obstetrics and Gynecology*, 193(5), 1827–1830.

Preszler, R. W., Dawe, A., Shuster, C. B., & Shuster, M. (2007). Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses. *CBE-Life Sciences Education*, 6(1), 29–41.

Kay, R. H., & LeSage, A. (2009). Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education*, 53(3), 819-827.

Siau, K., Sheng, H., & Nah, F. (2006). Use of classroom response system to enhance classroom interactivity. *IEEE Transactions on Education*, 49(3), 398–403.

Slain, D., Abate, M., Hidges, B. M., Stamatakis, M. K., & Wolak, S. (2004). An interactive response system to promote active learning in the doctor of pharmacy curriculum. *American Journal of Pharmaceutical Education*, 68(5), 1–9.

Stuart, S. A. J., Brown, M. I., & Draper, S. W. (2004). Using an electronic voting system in logic lectures: One practitioner's application. *Journal of Computer Assisted Learning*, 20(2), 95–102.

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