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Is Group Polling Better? An Investigation of the Effect of Individual and Group Polling Strategies on Students' Academic Performance, Anxiety, and Attention

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ABSTRACT

The purpose of this study was to investigate the effect of polling technologies (clickers or tablets) integrated with strategies (individual or group) on students' academic performance, anxiety, and attention. The participants were 34 students enrolled in an educational research methodology course. The anxiety scale, pre- and in-class quizzes, brainwaves of attention levels, open-ended questionnaires, and a 20-minute structured interview were used in this study. During the experiment period of three weeks, the instructor conducted three types of polling activities. The results showed that the instant polling strategy helped promote learning performance, and if a team was given an opportunity to discuss a topic after it was announced, this would help reduce students' feelings of anxiety and increase their attention levels. This study suggests that classroom activities can be designed to incorporate team polling for increased participation.

Keywords

Polling strategies, IRS, Anxiety, Attention

Introduction

The current Interactive Response System (IRS) has already been widely used in classroom voting systems, and many studies have confirmed its positive impact on aspects of learning, including participation, dedication, and motivation (Bachman & Bachman, 2011; Fortner-Wood, Armistead, Marchand, & Morris, 2013; Jones, Antonenko, & Greenwood, 2012; Siau, Sheng, & Nah, 2006). The portable equipment of the IRS allows instructors to design a variety of classroom feedback activities; thus, excellent teaching strategies must accompany the system to allow for its integration into the classroom and the resulting improved learning outcomes. Research by Blasco-Arcas, Buil, Hernandez-Ortega, and Sese (2013) discovered that combining the IRS with cooperative teaching strategies can significantly improve interaction among instructors and students, as well as effectively improve learning outcomes. Previous studies on learning that concerned the effects of the combination of the IRS with cooperative teaching strategies have only studied the combination of a single voting tool with a cooperative teaching strategy, such as SRS pads (Jones et al., 2012) or clickers (Zingaro & Porter, 2014). Therefore, this study examined the effect of the combination of different voting tools and teaching strategies on indicators of learning, including academic performance, anxiety, and attention.

For the classroom interactive feedback systems, there are already preliminary studies that show that students' electro-encephalogram (EEG) signal reactions vary depending on their use of different voting tools. Students using clickers have a higher EEG signal attention level when voting, while students using smartphones have an increased EEG signal attention level after voting activities (Sun, 2014). However, as for how the use of combined IRS and cooperative teaching strategies affects EEG signal attention level, in-depth research is still required. Thus, this study used a collection of EEGs throughout an entire classroom to record attention levels to data, while also comparing varying levels of attention among different IRS voting tools and cooperative teaching strategies in order to understand the effect of teaching strategies on voting activities concerning attention.

Literature review

Overview of polling strategies

The Interactive Response System (IRS) is a polling technology tool that provides instructors and students with instant feedback and allows them to make effective adjustments to their teaching and learning processes

(Roschelle, Schank, Brecht, Tatar, & Chaudhury, 2005). This technology not only increases the student levels of participation (Fortner-Wood et al., 2013; Salemi, 2009; Sun, Martinez, & Seli, 2014), concentration (Fortner-Wood et al., 2013; Siau et al., 2006), and learning motivation (Jones et al., 2012), but can also improve their learning outcomes (Bachman & Bachman, 2011; Caldwell, 2007). Smith, Annis, Kaplan, and Drummond (2012) noted that the IRS offers an educational medium in modern middle and elementary school classroom coursework that enhances interactive learning, encourages independent student thinking, and inspires them to collaborate with their peers in order to attain their learning goals.

Wireless networking and the breaking down of the space-time limitations of the traditional remote control made the rise of the mobile device possible, and this has had a vast direct impact on education. A significant number of IRS-related applications have been developed, including applications for a variety of operating systems. There are two interactive modes for IRS course integration: interactivity with peers and interactivity with the instructor (Blasco-Arcas et al., 2013). In facilitating *interactivity with peers*, the IRS allows students to discuss and then vote on an answer. Peers can collaborate to fulfill tasks assigned by their instructor, thereby improving peer relations and the overall academic environment. They are even able to complete tasks more efficiently (Beatty, Gerace, Leonard, & Dufresne, 2006; Caldwell, 2007; Trees & Jackson, 2007). The objective of *interactivity with the instructor* is for the instructor to provide feedback on the students' answers using the IRS, to evaluate the students' learning progress, explain the degree of knowledge assimilation, and deploy a teaching strategy and methodology that is adjusted to the students' learning pace which also creates a dynamic, interactive teaching environment (Bachman & Bachman, 2011; Trees & Jackson, 2007). It is clear that IRS integration into an academic program can have a positive influence on learning (Beatty, 2004; Beatty et al., 2006; Trees & Jackson, 2007).

Individual and group polling strategies

Zhu (2007) proposed that when integrating IRS into an academic program, collaborative learning should be combined with other teaching strategies, such as peer instruction, peer-sharing, or class discussion. Collaborative learning allows for the mutual sharing of opinions, mutual guidance and criticism, and the collaborative resolution of problems among the students in order to efficiently complete related activities (Roschelle et al., 2005). Blasco-Arcas et al.'s (2013) empirical research integrated IRS and a collaborative learning strategy with 198 tertiary business students during a 2-year marketing course. The students provided responses by means of IRS, and the groups interpreted, shared, and discussed the topics in order to complete the question and answer assignments. They found that the IRS-integrated collaborative learning strategy significantly enhanced interaction between teachers and students and between peers, and it also effectively improved the learning outcomes. Another study found that IRS integrated into mobile devices provided more functions than traditional IRS (Roschelle et al., 2005). Specifically, context simulation, by which these systems were integrated into a collaborative learning strategy for the duration of a course, enhanced the mechanisms for posing questions or reading and commenting on articles. Significant improvements were found in the students' conceptual cognitions and interactions.

The use of peer instruction as a collaborative learning-based teaching strategy can enable students to learn course content and may encourage them to conduct mutual criticism, characterized by discussion and response production, with their peers (Zhu, 2007). The peer instruction method consists primarily of individual students first producing a response to the topic and then discussing and conveying the final answer with their peers. The teacher then displays the students' answer and finally conducts an explanation and discussion session (Smith et al., 2012; Zingaro & Porter, 2014). The integration of the peer instruction method into the course, together with IRS, can provide students with important learning opportunities and enhance peer discussion and interaction, thus improving the students' learning outcomes (Smith et al., 2012). McDonough and Foote (2015) explored the effects of collaborative learning (in pairs vs. small groups) and clicker use (shared vs. individual clickers) on learning among undergraduate students who were taking an English grammar course. Their results showed that students had a higher percentage of correct answers in the shared clicker polling activity and a stronger tendency to collaborate, regardless of the format of the groups.

In summary, an integrated course combining IRS with collaborative learning does lead to a better outcome than individual IRS student feedback alone. Furthermore, IRS acts as a tool for formative feedback and can effectively improve student cognitive knowledge acquisition (Jones et al., 2012). Previous investigations into how an IRS teaching strategy combined with peer instruction affects learning have only studied peer instruction strategies combined with single polling tools, such as SRS pads (Smith et al., 2012) or clickers (Zingaro & Porter, 2014). In his study, Sun (2014) compared the differences between two types of polling instruments, clickers and mobile devices. He found that among the students in a sociology of education course, those using mobile polling had significantly better academic performance compared to those using clicker-based polling. However, the two groups did not differ significantly in terms of their cognitive engagement or anxiety. To date, little research has investigated the combination of different polling tools with teaching strategies in relation to their effects on such indicators as learning outcomes, test anxiety, and ability to concentrate. Therefore, as an exploratory study, we combined two types of IRS polling tools (clickers and tablets) and strategies (individual and group) and divided them into three stages. We hoped to gain a full understanding of the differences in the effects of the traditional IRS clickers, group polling on tablets, and group polling with competition on tablets on student learning performance, anxiety, and attention levels.

Anxiety and polling

Anxiety is a form of pressure that affects students' mood and cognitive performance, and interferes with their attention levels and cognitive processing (Matthews et al., 2006). Test anxiety is frequently found among university students. This hinders the students' learning, and it has a significant negative impact on their physical and mental health. When a student develops test anxiety, it is generally due to a lack of confidence in his/her own ability and a belief that he/she will not perform well (Damer & Melendres, 2011). Many studies have shown that the level of test anxiety will affect students' motivation and their academic performance (Damer & Melendres, 2011; Yousefi, Talib, Mansor, & Juhari, 2010). Most studies have found that the classroom performance of students with a comparatively low level of test anxiety is better than that of students with high levels of test anxiety, but when the students are willing to devote great effort to their studies, their levels of test anxiety will be relatively low (Bembenutty, 2009). Although many studies have investigated how test anxiety influences learning, few have focused on how different polling tools integrated with strategies affect their test anxiety. Therefore, this study sought to explore the differences in test anxiety among different polling activities.

Attention and polling

Attention levels can be evaluated based on brain activity, which is thought to be able to represent human consciousness, emotions, and health states. When an individual carries out some specific task that requires the investment of attention, such as attending a lecture, reading, or driving, it is possible to use various types of monitoring equipment to measure the degree of attention being used. Most studies have used brainwaves to monitor attention. A widely used brain activity monitoring device is the electroencephalogram (EEG), which is a non-invasive brain imaging technology that can immediately capture the state of activity in the human cerebral cortex (Li et al., 2011 ; Li et al., 2012). A relatively inexpensive, user-friendly portable wireless brainwave device has now appeared on the market that can be fully exploited in a variety of research settings (Patsis, Sahli, Verhelst, & De Troyer, 2013). A study by Patsis et al. (2013) used it to capture brainwave data from players of the computer game Tetris. At the end of the game, the players were asked to conduct a self-evaluation with the objective of being able to dynamically adjust the degree of difficulty according to the player's state of attention, while the researchers observed the relation between the degree of difficulty, individual levels of attention, and mental state. Their study found that the degree of game difficulty did indeed affect the individuals' levels of attention and mental states.

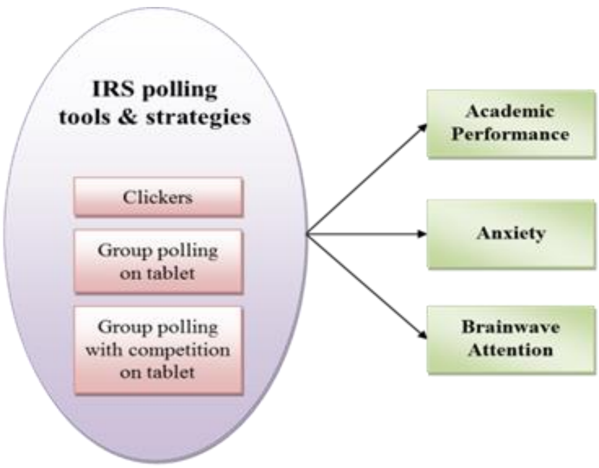

Figure 1. Research model

In Sun's (2014) study, this type of portable wireless EEG was also used to record students' brainwave data. The students were asked to use different types of educational technology products to conduct classroom polls, while changes were observed in their attention levels and sense of relaxation to see if they affected their learning outcomes. The results of the study showed that the students did indeed experience different mental and physical reactions when using different classroom activity tools. We hoped that the present study's use of an EEG to conduct a comparison of different classroom activities would lead to an understanding of different classroom polling activities in terms of their effects on students' attention levels. The research model of the study is shown in Figure 1.

Research methods

Participants

There were 34 students registered in the educational research methodology course in a national university in Taiwan (27 female; ages 22 to 33). We compared their performance over the final 3 weeks of the course with their pre-class quiz grades, in-class quiz grades, anxiety scale values, and brainwave measurement. We excluded incomplete data from any student who did not participate fully. A total of three students across 3 weeks (voluntarily) chose to wear the brainwave headphones for researchers to obtain brainwave data.

Methods and instructional design

This study utilized a quasi-experimental research design. We collected data from a class at a large research university in Taiwan. This study was conducted over a period of 3 weeks. Each week's course time consisted of two 100-minute classes, and a pre-class quiz grade was required to be completed by 5 p.m. on the afternoon before the class. The response time was limited to 30 minutes. Subsequently, a classroom lecture was conducted together with *group polling*, and three students were selected to monitor brainwave changes throughout the process. When the week's coursework was complete, in the 30 minutes before finishing the class, a closed-book in-class quiz grade was obtained. Meanwhile, an anxiety scale survey and open-ended questionnaire were administered, and nine students were invited to undergo a 20-minute structured interview following each class in Week 3.

Over a period of 3 weeks, the instructor conducted three types of group polling activities (treatments). There was no fixed time for any week's polling. Individual clickers (Week 1) were issued to each person before class. During class, the instructor projected prepared questions on a screen at the front of the classroom, the students used the handheld clickers to vote, and the selected correct answers were delivered to the instructor. The students were not permitted to discuss their answers with others during this process.

For the group polling on tablets (Week 2), the students were divided before class into groups of three to four people, and each group was issued with a tablet on which the researchers had previously installed an Interactive, Feedback-based In-class Teaching (iFIT) application (Sun, Chang, Chen, & Lin, 2016; Sun & Lee, 2016). After the instructor projected a question, each group of students could discuss it together. Following that, each group member would select an answer on the tablet using individual members as the unit, and the answers were delivered to the instructor. Group polling with competition on tablets (Week 3) was similar to the activity in Week 2, but with the distinction that each group's members had to reach a consensus following their discussion, and an answer was jointly selected by the entire group as a unit before it was delivered to the instructor. In addition, the instructor would convert each group's polling results into a publicly displayed group score, thus turning the groups' polling into a team competition. The purpose of the shared tablet for each group was to facilitate small group discussions and avoid distractions which may occur when students use their own mobile devices to vote (Sun, 2014).

The instructor conducted a review and discussion after each poll in order to clarify concepts that were not understood by the students. To avoid any carryover effect during the three treatments, the degree of difficulty of both the pre-class and in-class quiz was equivalent, the course unit concepts were similar, the conceptual themes of the 3 weeks' teaching were each stand-alone units, and there was no sequential relation between the units (the Week 1 course unit was "threats to internal validity," Week 2 was "experimental design methods," and Week 3 covered "investigation and study methods"). The experimental sequence is shown in Figure 2, and the classroom setup is shown in Figure 3.

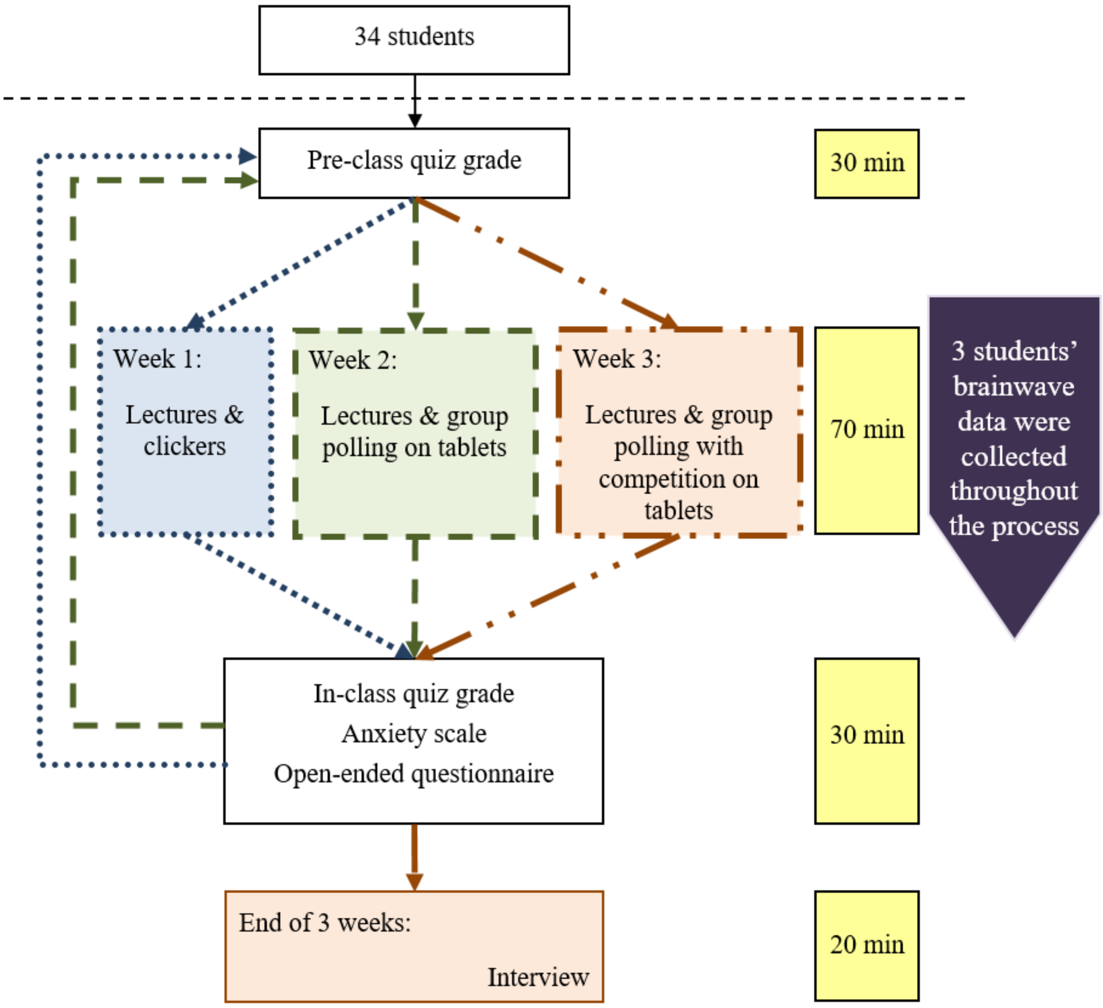

Figure 2. Experimental design

Figure 3. Classroom setting (group polling with the iFIT application on tablets)

Instruments

We used Pintrich, Smith, Garcia, and McKeachie's (1991) anxiety scale from their Motivated Strategies for Learning Questionnaire (MSLQ). After the topics were adapted to ensure that they were applicable to the circumstances of this study, this tool was used to measure the degree of anxiety faced by the students during the quiz. This scale has a total of five topics and uses a Likert-type 6-point scale. A representative statement might be, "When I take the quiz on educational research methods, I can feel my pulse speed up." The scale's Cronbach's α values in Weeks 1-3 were sequentially .86, .86, and .84.

The pre-class and in-class quiz grade questions were set by the instructor, and the students were informed in advance as to the scope of the tests. The pre-class quiz consisted of multiple-choice questions, and the in-class quiz included options, padding, and brief questions and answers. For collection of brainwave data, three students were invited to wear an EEG during class time to gather indicators of their attention levels. All of them used the brainwave sensor chips provided by NeuroSky, a company which partners with business and academics to make biosensors. The electrical signal across the electrode is measured to determine levels of attention (based on Alpha waveforms) and is then translated into binary data. NeuroSky has been validated to have good validity and reliability. In a study conducted by Rebolledo-Mendez et al. (2009), the results of this evaluation suggested that the headset provides accurate readings regarding attention, since there is a positive correlation between measured and self-reported attention levels.

The brainwave data were analyzed based on the methods used in previous studies in the field (Crowley, Sliney, Pitt, & Murphy, 2010; Rothkrantz, Wiggers, Wees, & Vark, 2004). We used the first three minutes of the EEG data as the baseline regarding attention levels, since students were in a serene state of mind at this point. We then divided the EEG raw data into two parts: class lecture and in-class activities (in the first and second weeks, the topics and answers were announced; in the third week, the accumulated group points were also displayed). For the class lecture and in-class activities, we calculated the percentage of data that was observed to be in excess of the baseline attention level data. Then, we generalized participants' brainwave patterns between the lectures and in-class activities based on the observed data, and we plotted the EEG diagram from selected participants. We combined the EEG observations with the results of the pre-class quiz, in-class quiz, post-class surveys, and open-ended questionnaires in order to analyze the students' in-class learning efficacy. In this way, we could meaningfully explain the variations in brainwave data.

The open-ended questionnaires included the following questions: (1) When you used the polling system in today's class, did you encounter any problems? Please explain what the problems were and how many times they occurred; (2) What do you think are the advantages of the polling system and polling method (group discussion and competition) used by the instructor to conduct today's class? and (3) How do you think the instructor might use the polling system to conduct the class? Can you suggest any other innovative approaches? Separately discuss any problems the students had in relation to the advantages and disadvantages of the polling system, the effects of anxiety and attention levels, any recommendations for improvement, and the degree of course difficulty.

Statistical analyses

All quantitative data were coded and prepared for computer analysis using Predictive Analytics Software (PASW) 18.0. Cronbach's α was computed in order to validate the reliability of each of the measurement scales. The brainwave data were analyzed based on the methods described in previous studies (Crowley et al., 2010; Rothkrantz et al., 2004). For the descriptive statistics, frequencies were computed for nominal variables, and means and standard deviations were obtained for both interval and nominal variables. Finally, paired *t* tests and a one-way ANOVA with repeated measures (RM-ANOVA) were conducted to examine the differences in means between the treatments.

Research results

Trajectory analysis of academic performance

Descriptive data and paired *t*-test results for the 3 weeks' pre- and in-class quiz performance are shown in Table 1. Although the sample size in this study was relatively small, skewness and kurtosis were in an acceptable range and the data approximated to normal distribution. Comparing the significant statistical differences for the pre-class and in-class quizzes from the paired-samples *t* tests conducted using different treatments, we found that the pre-class and in-class quiz student performance in Week 1 showed significant differences (t = 7.13, p < .001), with the in-class quiz performance being clearly better than that of the pre-class performance (M = 81.43 > M = 50). There were no significant differences between the Week 2 and Week 3 pre-class and in-class quizzes (t = 1.95, p = .07; t = 0.62, p = .54, respectively). From the table below, it can be seen that after implementing the clicker polling strategy, the extent of quiz performance progress in Week 1 was clearly greater than that of Weeks 2 and 3.

Table 1. Descriptive statistics and paired *t* test for pre-class and in-class quizzes

Weeks	Quizzes	Mean	*SD*	Skewness	Kurtosis	*t*	*p*
1st	Pre-class	50.00	14.49	-0.76	-1.58	7.13	< .001
	In-class	81.43	11.08	-0.36	-0.47		
2nd	Pre-class	61.90	28.91	-0.18	-0.61	1.95	.07
	In-class	76.91	17.96	-0.52	-0.59		
3rd	Pre-class	80.95	17.29	-0.61	-0.11	0.62	.54
	In-class	84.52	16.80	-0.63	-0.52		

Using the RM-ANOVA to test whether there were significant differences between different treatments of students' pre-class and in-class quizzes, the results of the Mauchly Spherical Test show that neither performance violated the spherical test hypothesis, and RM-ANOVA verification analysis could be conducted. The results are shown in Table 2. Prior to implementing the teaching method, there were significant differences between the students' pre-class quiz performances during the 3 weeks (F = 13.63, p < .001). When post hoc pairwise comparison was conducted post hoc, it was found that in the pre-class quiz, Week 3 > Week 2 > Week 1 (M_3 = 80.95 > M_2 = 61.90 > M_1 = 50). On the other hand, after implementing the teaching methods, there were no significant differences between the students' quiz performances during those 3 weeks (F = 1.52, p = .23).

Table 2. RM-ANOVA with pre-class and in-class quiz grades

Source	*SS*	*df*	*MS*	*F*	*p*	Partial η^2
Pre-class quiz	10238.10	2	5119.05	13.63	<.001	.41
Error	15028.57	40	375.71			
In-class quiz	616.67	2	308.33	1.52	.23	.07
Error	8116.67	40	202.92			

Anxiety

When measuring student anxiety levels after conducting the polling strategy teaching method, we obtained the following measurements: Week 1: M = 3.77, SD = 1.58; Week 2: M = 3.43, SD = 1.23; and Week 3: M = 3.63, SD = 1.39. We used an RM-ANOVA to conduct a comparison of differences between anxiety levels during the 3 weeks. The result shows that the application of the different teaching strategies did significantly influence students' test anxiety levels (F = 3.89, p = .03, partial η^2 = .12). When we conducted an equivalent post hoc pairwise comparison, we found that the Week 2 anxiety level was significantly lower than that of Week 1 (M_1 = 3.77 > M_2 = 3.43).

Attention levels based on brainwave data

Initial comparison was made between changes in participants' degrees of attention under the teaching methods using the different polling strategies. Table 3 shows that the attention level was greater than the baseline frequency, and the frequencies for Participants A and B were ordered Week 2 > Week 3 > Week 1. Participant C's frequencies, on the other hand, were ordered Week 1 > Week 3 > Week 2. We found that the sequence was completely inverted, while the frequencies of their attention levels that were greater than the baseline in the highest week were greater than 50% in each case. In the second highest week, the percentage was around 40%, and in the lowest week, the percentage was between 20% and 40%. Dividing the class periods into different activities showed that over the entire course, Participants A and B both showed the optimum degree of attention during Week 2, while Participant C showed optimum attention during Week 1.

Next, comparison was made under each teaching method of changes to participants' attention levels following periods of course activity. Participants' attentional indicators were at an optimal level during the 3 weeks of classroom lectures or announced topic with responses. The greatest number of participants displayed optimal attention during the classroom lectures, while their responses to the announced activities presented during the announced topic with responses came second. Careful examination of the 3 weeks found that both classroom lectures and announced topic with responses showed the highest percentage increase over the baseline in Week 2, and it is clear that attention performance was best in Week 2 out of all 3 weeks.

Table 3. Frequency of participant attention greater than the baseline

Participant	Week 1	Week 2	Week 3
		Classroom lectures	
A	46.5%	87.8%	19.2%
B	30.5%	56%	47.9%
C	62.9%	30 %	44.6%
		Announced topic with responses	
A	18.5%	75.7%	27.2%
B	8.5%	48.4%	41.9%
C	79.4%	33.8%	23%
		Announced answers	
A	32%	75.8%	5.8%
B	10%	50.6%	30%
C	78%	25.4%	40.3%

In addition, it can be observed from Figure 4 that when Participant C in Week 2 completed Activity 2 (announced topic with responses) and Activity 3 (announced answers), there was less change in his attentional performance relative to Activity 1 (classroom lecture), indicating that his attention was in a comparatively stable state. When conducting Activity 1 (classroom lectures), the extent of change in attention level was greater, and although the attention level index was very high, especially low states of attention were also not uncommon. From this, it can be seen that Participant C's attentional stability was better than during the classroom lectures when conducting activities related to an announced topic with responses and announced answers.

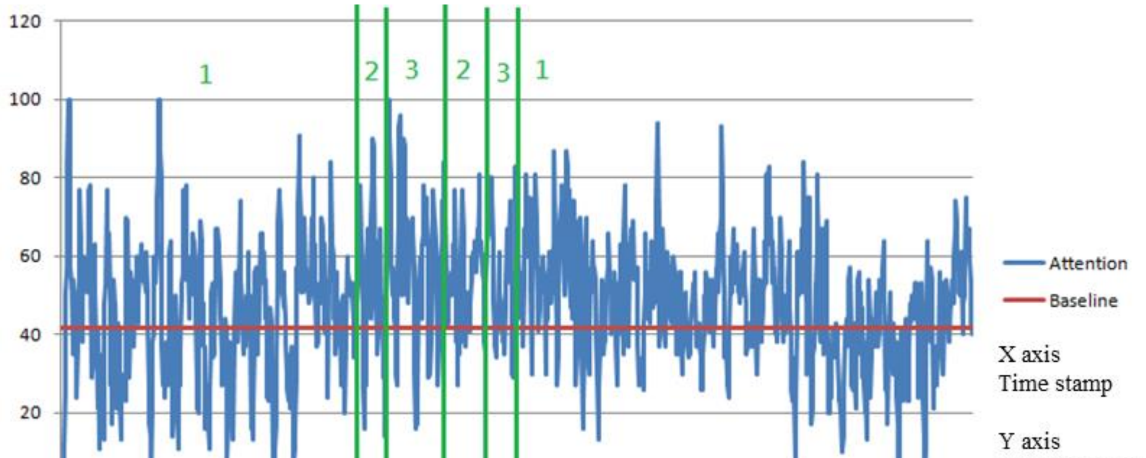

Figure 4. Participant C's changes in attention levels during various Week 2 classroom activities
Note. 1: Classroom lecture; 2: Announced topic with responses; and 3: Announced answers.

Table 4. Participants' attention reaching their highest levels of frequency

	Classroom lecture		Announced topics with responses		Announced answers		Entire class		Weekly total
	Week	Activity	Week	Activity	Week	Activity	Week	Activity	
Week 1	1	2	1	1	1	0	1	-	3
Week 2	2	2	2	1	2	0	2	-	6
Week 3	0	2	0	1	0	0	0	-	0
Total Activity		6		3		0			9

Table 4 shows that, in terms of attention, participants most often attained the highest frequency of attention in Week 2, followed by Week 1. In terms of classroom activities, *classroom lecture* was the most focused on activity after highest attention, followed by *announced topic with responses*. From this, we learned that, in terms of *group polling on tablets* in the second week, the students were more capable of paying attention in the classroom and were more able to urge themselves to concentrate on listening to a lecture in class. They paid more attention, especially, to the classroom lectures. In addition, during the *announced topic with responses* stage of the activity, *group polling on tablets* enabled the students to focus their attention more steadily in order to deal with the topics raised by the instructor (as shown in Figure 4).

Open-ended questionnaire and interviews

Individual vote clickers are viewed as a polling tool, which although simple to operate, lacks a feedback mechanism to indicate whether a response has been successfully transmitted. A few students thought they would see whether their peers had submitted a response, which made them feel somewhat nervous (S4). Another classmate said a student could boldly select his/her own answer without worrying about giving the wrong answer or suffering under the gaze of his/her peers (S34). The instructor could also make adjustments to course content in light of a student's response, but some people considered this kind of technical matching of a single individual's answers lacking in terms of liveliness and interactivity. They suggested that competition should be added in order to obtain the quickest answer instead.

S4: When I come across confusing options, I don't have too much time to think because other people have already finished answering. The instructor also wants to announce the answer, but I'm still of two minds about it, and this makes me nervous.

S34: You could increase your understanding of the students' situation. Most of the students are not used to responding directly to the instructor's questions in colloquial speech, but this problem can be solved by using the polling system.

In connection with group polling on tablets, the students responded that joint use of a tablet would lead to apprehension about the convenience of seating. Students said that group discussion could increase interaction by first conducting group discussions and then polling people individually to allow those who were lacking in confidence to build it before answering on their own (S5). Conducting activities in this way could offer more variety to question and answer sessions (S6), while designing more controversial questions and answers and allowing students to conduct debates would give fullest play to the effectiveness of group discussion.

S5: First discussing, then voting, could increase confidence in the responses.

S6: The answers to some topics might not be unanimous. Let students divide into subgroups to discuss them.

In the group polling with competition on tablets, the students thought competition could increase their sense of achievement (S15) and their focus on the discussion, but during the question and answer segment, the students would have preferred a greater level of topic difficulty and more room for discussion.

S15: One subgroup showed its score to encourage and motivate others.

To summarize the results of the open-ended questionnaire, in terms of technology use, Week 1 was easiest, while there was no difference between Weeks 2 and 3. In terms of situations that occurred while using technology, Week 1 gave rise to psychological tension, while Weeks 2 and 3 saw a lack of familiarity with the technology. In terms of interactivity, Week 1 was relatively lacking in interactivity, while Week 2 had a greater level of interactivity than Week 1. Week 3 was even more interactive than Week 2.

Regarding the interview results, all of the interviewees thought there was no difference in the degree of difficulty of the topics. Most of the participants preferred the clicker polling method, mainly because it was simple to operate and made it easier to concentrate. However, two participants thought that when they pressed on the clicker, it was not possible for them to know whether they had successfully chosen an answer. There was no way to get feedback, while the interactivity of the tablet computer was more diverse. As regards *feelings of anxiety*, some participants thought the questions that were too hard or that giving wrong answers would give rise to anxiety, but there were also those who thought that the polling system was fun and could lower feelings of anxiety. Others pointed out that since no names were recorded when voting, it would not directly affect their feelings of anxiety. Concerning *attention*, the participants universally thought that polling and in-class quizzes would increase concentration levels and cause them to think harder in order to avoid wrong answers, but because tablet computers were more versatile in terms of capabilities and information handling, they could easily reduce their concentration. Although group competition had the advantage of letting everyone have an opportunity to learn cooperatively, it had the drawback of not being able to allow individual answers, and participants' ideas were easily influenced by their peers. Furthermore, it was easy to spend a lot of time using it.

I think the strong point of the tablet is that its operating interface and its weak point are the same thing; that is, it tends to limit a group to selecting a group answer. If your answer is different from those of other people, you can still only choose one answer, and you certainly cannot truly reflect the thoughts of each individual in the group. (Interviewee 4)

Discussion and implications

In terms of *academic performance*, this study found that only the Week 1 pre-class and in-class quiz measurements showed significant progress. In the pre-class quiz, we found that Week 3 > Week 2 > Week 1, while there was no significant difference between the in-class quiz measurements. It is possible that having taken the Week 1 course, the clicker polling aroused the students' sense of novelty and interest in learning, inducing them to take the initiative after Week 1 to prepare for classes, so that their pre-class quiz performance gradually improved and also led to a reduction in the difference between pre-class and in-class quiz performance. There was no significant difference between the in-class quiz performances, probably because of the experiment's ceiling effect. Average in-class quiz scores had already reached an overall steady high score level ($M_1 = 81.43$, $M_2 = 76.91$, $M_3 = 84.52$), and the three types of polling strategies were all capable of effectively improving in-class learning outcomes. Although this study did not match previous studies of cooperative learning and peer instruction in terms of the results of improving pre-class and post-class performance (Blasco-Arcas et al., 2013; Smith et al., 2012), given the continued application of teacher-student and peer interactive activities, the students showed distinct progress over the 3 weeks of pre-class quizzes. In-class performance was also fairly good, and both types of polling strategies had their own specific results.

In the investigation of the effect of polling strategies on *feelings of anxiety*, this study found that the Week 2 anxiety levels were significantly lower than those of Week 1. Possibly, after undergoing group discussion, the students experienced a reduction in their feelings of nervousness and had more confidence in their chosen answers, so their anxiety levels in Week 2 were clearly lower than Week 1's. Previous studies have found that test anxiety levels significantly affect student performance (Damer & Melendres, 2011; Yousefi et al., 2010). During Week 1, we observed that students had a comparatively high degree of test anxiety, and there was a significant difference between the pre-class and in-class quiz results. This study used a self-report inventory following the in-class quiz to measure the state of anxiety, so it was not possible to measure anxiety levels using objective physiological indicators, yet it remains evident that there existed a partial relationship between anxiety and performance. Sun (2014) found that although they did not attain statistical significance, the anxiety scores of students using mobile devices were lower than when they used clickers, and polling tools will still give rise to a partial difference in anxiety. However, not all students can operate even an easy-to-use tablet without difficulty. During the open-ended questionnaire, segment situations did occur where students were not sufficiently familiar with the technology and were unable to operate the devices.

In relation to *attention*, investigation of the effect of polling strategies on brainwave attention indicators found that, in terms of the class as a whole, peak attention frequency was the highest in Week 2. If the class as a whole was subdivided into different periods of activity, it was found that attention was most concentrated in Week 3's classroom lectures, followed by the announced topic with responses, while the level of attention during the announced topic with responses of Week 2 was more stable than during the lecture program. Sun (2014) found that clickers brought about a higher attention level during the polling period, but attention plummeted after polling. Although mobiles could not significantly increase attention during polling, they could increase students' concentration during the post-polling program. This study has further extended Sun's (2014) results. In addition to the polling tools' strong effects (clicker or mobile), polling strategies (individual or group) also clearly affected attention levels. Attention during group polling on tablets in Week 2 was certainly higher than during individual polling using clickers in Week 1, and it was more stable in terms of making students pay attention during the announced topic with response. However, this differs from previous views suggesting that collaboration is beneficial to learning outcomes (Blasco-Arcas et al., 2013; Smith et al., 2012; Zingaro & Porter, 2014).

The present study found that group polling with competition on tablets did not meet the expectations of increasing attention levels, and we speculate that this may be an effect produced by the polling strategy. Group polling with competition on tablets requires groups to select answers based on consensus. The individual's voting responsibilities were replaced by the group. Students *expected* to be able to discuss answers with their group members during the response activity, or they were influenced by their peers and relied on their group members to make decisions for them. As suggested by participant S4, an answer that is jointly discussed and decided on cannot reflect an individual's true ideas. Group polling offers limited opportunities for individual thinking and decision making. On the other hand, for the individual perhaps there was the pressure of not being able to express one's own opinion. This, therefore, gave rise to low levels of attention to lectures and response polling in the Week 3 teaching because in both the "individual clicker votes" and "group polling on tablets" strategies, the answer must be decided by the students themselves. When the power is in the individual students' hands, they tend to listen carefully to the lecture, but the added team discussion may be more helpful in terms of increasing students' attention levels. When implementing a group discussion teaching strategy during polling, compared to the polling approach that takes the group as a unit, the reply method that takes the individual as a unit is better able to promote the student's level of attention when listening to lectures and providing answers.

Conclusion, limitations, and recommendations for future study

This study investigated a variety of instant polling systems and application strategies and their effects on students' quiz performance, anxiety, and brainwave-measured attention levels. It was found that: (1) All polling activities clearly increase in-class learning outcomes, while using clickers can help individuals clearly raise their pre-class and in-class quiz performance; (2) Individual voting following group discussion results in lower anxiety levels than individual voting, in which discussion is prohibited; (3) Use of a teaching strategy in which group discussion is followed by individual voting results in optimum attention levels; (4) Under a teaching strategy of individual voting following group discussion, an announced topic with responses results in a more stable attention level than a lecture. Put briefly, instant polling systems help to promote learning outcomes, and if a team is given an opportunity to discuss a topic after it is announced, this would help to reduce students' feelings of anxiety and increase their attention levels.

One of the limitations of this study was the small sample size and relatively short duration of the experiment (3 weeks), which restricted the generalizability of the study results. Razali and Wah (2011) noted that when the sample size is less than 30 participants and normal distribution testing has a significance level of .05, the statistical power of the experiment will be less than 40%. Therefore, statistically, it is suggested that the sample size should include 30 or more participants, which will generally satisfy the normal distribution assumption of ANOVA. This study included 34 participants and, therefore, this criterion of sample size is fulfilled. However, future research can increase the number of participants and the scope of the research. In addition, there was a lack of wearable brainwave headphones used in this study; further, when wearable brainwave equipment was utilized to collect EEG data in the classrooms, the equipment had to be connected to computers throughout the entire experiment. Moreover, the computer screens had to be monitored by someone who would pay close attention to the connection status of each brainwave apparatus in order to prevent any loss of data due to instabilities in the connection. Therefore, the sample EEGs collected in this study were limited as well. In terms of the duration of the experiment, since it lasted only 3 weeks, the measured effects of the experiment may not be sufficiently robust. It is suggested that in future studies, the time of exposure for the experiment should be extended. Concerning the content of the experiments, the subject explored in this study was educational research methodology. We suggest that future studies could try including content from other disciplines, which will allow us to explore how other course content affects students' levels of anxiety and brainwave responses. Finally, future studies are needed in order to more thoroughly understand the effect on anxiety and attention when polling. It is suggested that classroom activities can be designed in such a way as to adopt a strategy of team polling in which students can take turns acting as group leader for increased accountability in order to help build a team consensus and to avoid passive group member participation. This would also prevent a scenario in which group members do not dare to express divergent views.

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