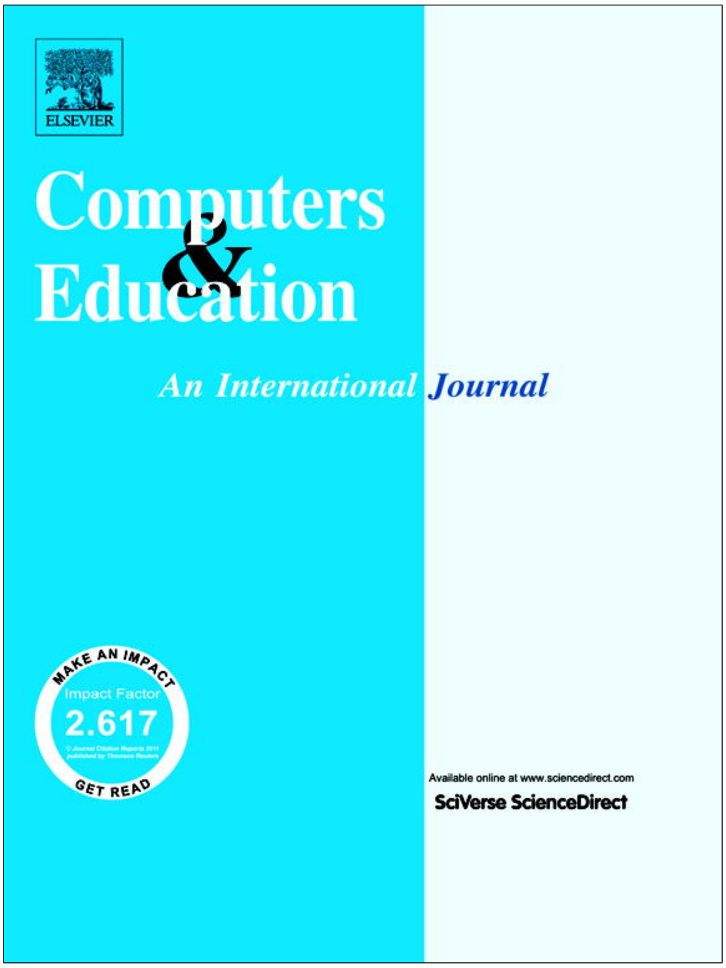
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"Clickers" and metacognition: A quasi-experimental comparative study about metacognitive self-regulation and use of electronic feedback devices

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ABSTRACT

The purpose of this study was to establish whether electronic response systems (clickers) influence student metacognition in large lecture settings more than low-technology polling devices. In this first part of a two part mixed methods study inquiry was made into whether student metacognition was influenced and how metacognition was influenced. This quasi-experimental study was performed with students from three sections of the same undergraduate educational psychology course taught by the same instructor. Participants totaled 198: 33 in the summer section, 87 in the fall experimental (clickers) group, and 78 in the fall (paddles) comparison group. Because metacognition is associated with higher academic outcomes, we hypothesized that the response device which elicited higher levels of metacognition would also demonstrate higher performance outcomes. While results from the study indicate that metacognitive processes are influenced more so by paddles than by clickers, clicker use produced significantly higher performance outcomes. Results of this study support recent research findings indicating that higher performance outcomes result when clicker use is combined with instructional strategies; furthermore, findings suggest metacognition from clicker use was a more productive influence on the learning process.

1. Introduction

Creating a student-centered learning environment in which student learning outcomes increase is a priority of educators (Brown, 2010; Mollborn & Hoekstra, 2010). Higher outcomes tend to occur for students who are more metacognitively aware (Mayer, 2008), that have the self-knowledge that allows self-monitoring and self-regulation (Dinsmore, Alexander, & Loughlin, 2008). Metacognitively engaged and self-regulated learners use cognitive learning strategies (Wolters, 2010), and have the ability to form learning goals that lead to desired academic outcomes (Zimmerman, 2000). The use of strategies that influence meaningful learning and the conditions that lead to meaningful learning are often the foci of research (Chen, Whittinghill, & Kadlowic, 2010).

Technology is frequently employed in an effort to increase engagement and thought to improve student outcomes, but often research does not demonstrate these commonly held beliefs; in order to gain insight into what is actually accomplished with the use of technology rigorous research designs are necessary (Clark & Feldon, 2005). Because clickers have been shown to increase student cognition it has been suggested that metacognition may be influenced (Mayer et al., 2009), which may, in turn, contribute to learning outcomes. In this study a quasi-experimental research paradigm was employed so that levels of metacognition and performance outcomes resulting from clicker use could be compared to a low technology response device. This study explored the possible relationships between technology, metacognitive self-regulation, faculty use of technology, and student response.

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2. Literature review

2.1. Interaction and student engagement

The use of technology in higher education as a means to engage students, and to impact achievement and course completion is evidenced by the growing number of colleges that provide e-based learning opportunities and programs (Nora & Snyder, 2008–2009). According to Nora and Snyder (2008–2009) there is a positive link between engagement of students with information technology and reenrollment. The use of clickers is a popular means by which to develop an interactive environment and engage students (Chen et al., 2010). Clicker use is common to the degree that recommendations exist for their use connecting the quality of the instructional design of a lecture based on research and practice (Beatty, Grace, Leonard & Dufrense, 2006). The use of clickers is increasingly popular among faculty and students, and these devices are widely employed (Mollborn & Hoekstra, 2010; Moss & Crowley, 2011), so much so that clickers are described as "all the buzz in higher education" (Bode, Drane, Kolikant, & Schuller, 2009, p. 253).

Student satisfaction with clickers has been linked to interest (Morin, Thomas, Barrington, Dyer, & Boutchkova, 2009), and the use of clickers has consistently demonstrated a positive influence on attendance (James & Willoughby, 2011; MacGeorge et al., 2008). Previous research has revealed that students feel clickers enhance the learning experience (Prather & Brissender, 2009). Several studies indicate that students believe clickers aid in identifying misunderstandings of course concepts (Bode et al., 2009). Clickers transform the learning environment because of the increase in interaction between students and instructor; there is a natural participatory quality to clicker use that requires student participation, inhibiting passive learning (Hoekstra, 2008).

2.2. Technology and outcomes

Previous research has revealed mixed findings on the extent to which clickers increase performance outcomes. Mazur (1991) reported large learning gains and there have been several replications confirming such gains (Beatty et al., 2006; Caldwell, 2007; Duncan, 2006; Mayer et al., 2009; Meltzer & Manivannan, 2002; Van Dijk, Van Der Berg, & Van Keulen, 2001). Some researchers have reported moderate gains (Chen et al., 2010; MacGeorge et al., 2008) while other studies state that learning gains were not affected (Caldwell, 2007; Lasry, 2008). James and Willoughby (2011) state that while increased attendance is consistently found when clickers are in use, this occurs without improvements in learning benefits.

A distinct characteristic of electronic polling devices consistently reported in research literature is the provision of anonymity (Caldwell, 2007; Lantz, 2010; Mollborn & Hoekstra, 2010; Stowell & Nelson, 2007; Stowell, Oldham, & Bennett, 2010). The relationship between anonymity and student learning outcomes is uncertain (Stowell & Nelson, 2007). When large learning gains were reported by Mazur (1991), clickers were used in conjunction with Peer Instruction. Clickers have demonstrated greater learning gains than traditional lecturing, but there are few studies with quasi-experimental designs confirming when and how learning gains are created through clicker use. Mayer et al. (2009) utilized such a design and demonstrated increased learning gains with clicker use over control (straight lecturing) and comparison (questioning) groups. Mayer and colleagues suggest that learning gains are enhanced with clicker use when student cognitions are engaged by using instructional strategies such as questioning. Moreover, they describe their research as "fledgling literature," and further research with a rigorous design is necessary to validate findings (p. 56).

Overall evidence suggests that clickers engage learners and some research demonstrates learning gains; the social context, the influence that clickers have on the learning experience, and the conditions under which performance outcomes increase are important elements to explore and confirm. The intent of this study was to examine clickers' influence upon student metacognitive self-regulation and the resulting self-evaluation and peer comparisons in a large lecture context with undergraduate students in an introductory educational psychology course about learning and motivation. Clickers may increase student self-evaluation more than a traditional lecture context. In addition, the social context may be altered as a result of an increase in opportunities for peer comparisons. This study examined whether there was a relationship between peer comparisons and clickers use, whether clickers influenced metacognition, and whether performance outcomes increased.

3. Method

3.1. Participants and design

This study included 198 participants from a large urban university in the Southwestern United States. Three sections of the same undergraduate educational psychology course were the context for the comparative study. The first section was eight weeks in length and was in session from June 20, 2011 to August 12, 2011 ($n = 33$). The fall sections of the course were offered from the last week in August 29, 2011 to December 16, 2011 ($n = 165$). Each section was taught by the same instructor, using the same instructional design which included clickers, so the course was ready to format for the study's context which included questioning, formative assessment, Peer Instruction opportunities, and the use of high verses low technology polling devices.

3.2. Materials and apparatus

Materials for this study included clickers (purchased by students during fall and provided by instructor in summer) or paddles (a type of low technology flashcard system provided by the primary researcher). Lecture format was the same for the comparison and experimental segments except for the manner in which responses were gathered and displayed. Use of clickers and learning strategies were embedded in the instructional design of the course. Turning Point 2008 software was used with Response Card IR, which uses radio-frequency signals to register survey/question items. After clicker responses were registered, a histogram was displayed, followed by the correct indicator slide when the instructor chooses. When students were polled, for formative assessment (e.g., conceptual understanding) and responses varied, Peer Instruction was employed. Students engaged in peer-to-peer discussions followed by further instruction or re-polling as needed. When paddles were in use, a visual survey of student responses was used to gage opinion/understanding. The instructor took a visual tally of responses when participants held up the paddles displaying selected responses; participants could see peers' responses more or less depending on seat position in the lecture hall. If enough disparity existed in participant responses, students were instructed to discuss peer-to-peer, after which the instructor choose one of the following strategies: a) re-polling, b) a lecture wide group discussion to explore the concept further, or c) the instructor would re-visit the concepts.

Quizzes were administered, and the mean of the combined quizzes over a five week period in which either clickers or paddles were used with each cohort were the measure of performance outcomes. These quizzes occurred bi-weekly for the summer cohort on Mondays and Wednesday, from June 20 to July 6, 2011 when paddles were in use and July 11 to July 25, 2011 when clickers were in use, due to the shorter summer session format. For the fall cohorts quizzes occurred weekly on Mondays for the experimental group (clickers) and on Wednesday for the comparison group (paddles) from August 29 through October 3, 2011. The quiz questions covered lecture preparation and conceptual understanding. Clicker/paddle items were in some instances similar to quiz questions; however, most quizzes had questions requiring short answers and application of concepts; very few questions were multiple choice. An example of a quiz question that required a short answer and application of lecture preparation and lecture materials is as follows: "Think about the lecture material presented in this course to date. Write one lower level and one higher level question that could be part of your notes. Be sure to label each question identifying the question as lower or higher level." These questions were intended to address more cognitively complex levels of learning (Bloom & Krathwohl, 1956). The following conditions were the same or similar: a) instructor, b) instructional design, c) lecture hall, d) time of day (Monday or Wednesday mid-morning, respectively), e) power point presentation, f) quizzes were administered promptly during the first 10 min of class, g) the questions asked of students, and e) instructional strategies (e.g., questioning, Peer Instruction, re-polling, and group-wide discussions).

3.3. Procedure

The study employed a quasi-experimental design. Because there was only one section during the summer and a smaller number of students ($n = 33$) than during the fall ($n = 165$), the summer group experienced both response systems during the time of the study. During the fall one section was designated as the experimental group and the other as the comparison group. Group assignment to response device (e.g., clickers or paddles) was randomly determined through the toss of a coin a week prior to the fall semester's start, August 22, 2011. The experimental group included 87 students and 78 were in the comparison group.

The most notable difference between the cohorts' experiences was the summer group experienced both response devices due to its small size and because there was only one section. A high degree of continuity was experienced by the cohorts, because lectures, location, time of the lecture (mid-morning), instructional design, and instructional strategies were the same for each. Similarities also existed in the group characteristics including the mean age of the cohorts and the proportion of male/female participants. The summer group's mean age was 18.03 years, the fall experimental group (clickers) was 18.31, and the fall comparison group (paddles) was 18.37. The proportion of male/female participants was similar; the summer cohort had 45% female participants, the fall experimental (clicker) cohort had 47%, and the fall comparison (paddles) cohort had 43%.

During the summer the instructor provided students with clickers during the lectures, because of the group size ($n = 33$). During the fall students were required to purchase clickers. During the summer and for the comparison group, students were provided with paddles for the first five lectures then clickers were used for the remainder of the semester. Although both of these groups experienced paddles for five lectures followed by clickers for the subsequent lectures, the parameters of the study provided for administration of the post-test instruments for clickers for the summer cohort only. Lectures were designed with clicker questions as a key instructional strategy, because questioning is a strategy that engages student cognitively (Dembo & Seli, 2007; Mayer et al., 2009). Information garnered during lectures from polling was utilized for Peer Instruction opportunities, questioning for formative assessment to guide the course of the lecture, a platform for student/instructor interaction, and re-polling of the same question was used to check progress when appropriate or necessary. These strategies were used when there was a split in the poll responses, and the instructor determined the most appropriate strategy. Peer Instruction was used in the form of asking participants to convince peers of the correct response or to discuss the question in small groups (e.g., two to three participants). To check for participant understanding of lecture or textbook concepts participants were polled and the instructor could determine the concepts that required further explanation at the start of the lecture or after key concepts were presented. These strategies provided a platform for student/instructor interaction resulting in increased active participation in a large lecture setting. Polling students during lecture (e.g., questions and survey items) was performed similarly regardless of polling device in use.

3.4. Instrumentation

All students who elected to participate in the study were administered a pre-survey which provided demographic and biographic data, and the pre-test (see Appendix A), which was the MSLQ (Pintrich, Smith, Garcia, & McKeachie, 1993). The survey and pre-test were administered the first day of class for those students who elected to participate in the study. These were administered June 20, 2011 for the summer section, August 24 for the experimental group (clickers) and August 26, 2011 for the comparison group (paddles). Three self-report surveys were employed to measure student metacognition, and quiz scores were the measure of student performance outcomes (see Appendices B And C). These were administered during the lecture following the 5th quiz. For summer this means that these measures were administered for paddles in Labs on July 7, 2011 and for clickers in Labs on July 26, 2011; during the fall these surveys were administered to the experimental group (clickers) in Labs on October 4, and administered to the comparison group (paddles) October 6, 2011.

The MSLQ (Pintrich et al., 1993), a well-validated instrument, served as an indicator to verify the legitimacy of the metacognition measures designed for this study. This instrument was developed for the express purpose of examination of college students' motivation and self-regulation specific to a course (Artino, 2005). The 15 items pertaining to metacognitive self-regulation were employed as the pre-post-test. Two measures were designed because there were no notable records of surveys designed to measure student metacognition that occurs in lecture as a result of using a particular response device or that measured the self-regulatory changes that may be a function of student metacognition stemming from use of response device during lecture. These measures were self-report surveys with questions/items using a 5-pt Likert scale. The first measure had 15 items modeled after Mayer's (2008) metacognition items related to reading. This measure was titled the "(Electronic) Feedback Devices and Metacognition in Lecture" (see Appendix B). The next measure included items directly related to self-regulation tendencies that students attribute to use of the response devices and was called "Metacognitive Attribution Feedback Device Scale" (see Appendix C).

3.5. Data analysis

Quantitative data was analyzed using the Statistical Package for the Social Sciences (SPSS) 18.0 program. Due to the assumption of the statistical analyses employed in this study that distribution of data was along a normal curve, all data was examined for equality of variance, skewedness, and kurtosis. To prevent careless or invariant responses reverse coded items were included in the surveys. Seven surveys were eliminated due to invariant responses; these were excluded from survey data analyses, but included in establishing mean performance outcomes, because we reasoned that the apparently incorrect manner in which the surveys were completed was a separate issue from performance outcomes for the group using clickers (experimental) as compared to the group using paddles (comparison). Instrument validity was computed using Cronbach's alpha as seen on Table 1. Cronbach's alpha for each of the measures was strong with one exception as noted in the limitations section. Differences in metacognitive processes and performance outcomes were examined with paired sample and independent sample *t*-tests, and ANOVAs were computed to examine whether extent of use and performance outcomes were related. In order to perform this analysis, participants were asked on the "(Electronic) Feedback Devices and Metacognition in Lecture" what percentage of the time, were clickers/paddle used; the following options were given: a) 0%, b) 25%, c) 50%, d) 75%, and e) 100%. In essence, participants self-assigned to groups.

4. Results and discussion

In this article results are presented for the quantitative portion of this study. For the purpose of clarity in presentation, results for the three surveys utilized in this study are reported below and discussed in the sections that follow. In addition, because the summer cohort experienced both response devices and completed the "(Electronic) Feedback Devices and Metacognition in Lecture" and "Metacognitive Attribution Feedback Device Scale" twice, results uniquely pertaining to this group are identified apart from the overall study results. For Cronbach's alphas see Table 2. For Pearson product correlations see Tables 3 and 4.

4.1. Measures of metacognition

Because two measures were developed for the express purposes of this study, establishing a connection to a well validated instrument was deemed necessary, in this case the MSLQ. The MSLQ is known to measure metacognitive self-regulation specific to a course. The summer cohort's MSLQ demonstrated significance with many of the measures (See Table 2). This measure was significant at the .05 level with the Metacognitive Attribution Feedback Device Scale which indicates that participants connected the use of clickers to an increase in metacognition. Significance was found with the MSLQ at the .05 level with performance outcomes (quiz means for quizzes 6–10) during use of clickers which means student may have been more aware of learning strategies when clickers were in use. Greater significance was found with the MSLQ and Metacognitive Attribution to Feedback Device Scale when clickers were in use and when paddles were in use. This may indicate that participants noted significant changes in taking notes, understanding course concepts, knowing what questions to ask in lecture, and in preparation for lecture. This may imply that for the summer cohort both devices stimulated metacognitive self-regulatory activities that improved lecture engagement and participation.

The pre-post-MSLQ demonstrated significance at the .05 level for the fall experimental group, clickers. The fall comparisons group's pre-post-MSLQ demonstrated a high degree of significance at the .001 level; significance was not found with the other measures for either the fall experimental (clickers) or comparison (paddles) groups. MSLQ contributed in part to performance outcomes for the fall groups, although significance was not found for the pre-MSLQ ($\beta = .747$, $p = .037$). With the dependent variable as the post-MSLQ and the independent variables group belonging (e.g., paddles v. clickers), significance was found for the group that utilized paddles over those that used clickers when controlling for pre-MSLQ. The mean for the experimental group (clickers) was 4.40 ($SD = .95$) and for the comparison group (paddles) 4.58 ($SD = .10$). With the dependent variable as the quiz mean, and the independent variables as the pre and post MSLQ, the post-MSLQ was predictive of quiz outcomes ($\beta = .365$, $p = .045$), but the pre-MSLQ was not related to outcomes ($\beta = -.070$, $p = .725$).

The "(Electronic) Feedback Devices and Metacognition in Lecture" instrument sought to determine whether response devices influenced metacognition in lecture (e.g., participation in lecture, knowing level of preparation, gauging level of understanding, understanding how lecture fits with text, helping refocused), those features of self-regulation that may affect metacognition through response device usage. Paired sample ANOVAs were employed to determine whether the summer cohort experienced differences in metacognition when clickers

Table 1
Cronbach's alphas for metacognition and feedback device scales.

Instruments	α summer cohort-paddles	α summer cohort-clickers	α fall-clickers experimental group	α fall-paddles comparison group
MSLQ	.82	–	–	–
Pre-MSLQ	–	–	.73	.74
Post-MSLQ			.83	.89
(Electronic) feedback devices and metacognition in lecture	.49	.37	.96	.92
Metacognitive attribution to feedback device scale	.74	.75	.78	.75

Table 2
Pearson product correlations for measured variables: summer group.

Variables	*M*	SD	1	2	3	4	5	6	7
1. MSLQ	4.51	.82	–	.333	.587**	.537**	.482*	.425	.260
2. (Electronic) feedback devices and metacognition in lecture-paddles	3.50	.77		–	.333	.418*	.517**	.260	.226
3. (Electronic) feedback devices and metacognition in lecture-clickers	3.87	.73			–	.388*	.456**	.363*	.289
4. Metacognitive attribution to feedback device scale-paddles	3.59	.59				–	.449**	.490**	.401*
5. Metacognitive attribution to feedback device scale-clickers	4.10	.55					–	.325	.118
6. Performance outcomes-paddles	9.3	.80						–	.511**
7. Performance outcomes-clickers	8.3	1.13							–

*$p < .05$; **$p < .01$; ***$p < .001$.

Table 3
Pearson product correlations for measured variables: fall experimental group – clickers.

Variables	*M*	SD	1	2	3	4	5
1. Pre-MSLQ	4.63	.09	–	.440*	−.87	.176	.057
2. Post-MSLQ	4.41	.11		–	.256	.303	.204
3. (Electronic) feedback devices and metacognition in lecture	2.94	.09			–	.867***	−2.06
4. Metacognitive attribution to feedback device scale	3.39	.11				–	.189
5. Performance outcomes	7.81	.156					

*$p < .05$; **$p < .01$; ***$p < .001$.

or paddles were in use. Significance was not found with either clickers ($F = .662$, $df = 2$, $p = .394$) or for paddles ($F = .198$, $df = 3$, $p = .897$). An ANOVA was also performed to examine for differences between the fall experimental (clickers) and comparison (paddles) groups. Significance was found for paddles ($F = 4.845$, $df = 1, 147$, $p = .000$), but not for clickers. The group that utilized paddles had a higher mean ($M = 3.26$, SD = .69) while the group that utilized clickers had a lower mean (2.94) and spread of the data was much smaller (SD = .09).

An ANOVA was performed for the summer cohort to measure possible differences in the level of metacognition participants attribute directly to the response device from data collected with the "Metacognitive Attribution to Feedback Device Scale." Significance was found at the .05 level when use of clicker ($F = 2.458$, $df = 14(18)$, $p = .039$), but significance was not found when paddles were in use ($F = .703$, $df = 14(18)$, $p = .745$). This indicates the summer cohort attributed improved understanding of course concepts, self-monitoring, and peer comparisons to use of clickers, but not to use of paddles. An ANOVA was also performed for the fall experimental (clickers) and comparison (paddles) groups; significance was not found for either clickers or paddles ($F = .418$, $df = 8, 147$, $p = .909$) (Tables 5 and 6).

4.2. Metacognition

Results indicate that metacognition seems to be more influenced by paddles, the low technology response device, than by clickers. These quantitative findings were inconsistent. There were three hypotheses for this study. First, we hypothesized that as extent of use of response device increased so would student performance outcomes. Significance was not found for extent of use for either paddles or clickers as shown in Table 6; however, Fig. 1 clearly shows that extent of use is potentially a factor in performance outcomes, but not as defined in this study. Second, we hypothesized that clickers would result in higher metacognition than the low technology polling system. This was not the case, because paddles inconsistently demonstrated higher significance shown in Table 5. However, other factors may be involved in these results because of the visibility of responses when paddles were in use. While the summer cohort data indicated that clickers are very influential, the fall comparison group indicated otherwise. As noted above the fall comparison group (paddles) experienced increased

Table 4
Pearson product correlations for measured variables: fall experimental group – paddles.

Variables	*M*	SD	1	2	3	4	5
1. Pre-MSLQ	4.80	.08	–	.775***	.191	-.010	.205
2. Post-MSLQ	4.58	.10		–	−1.09	.055	.277
3. (Electronic) feedback devices and metacognition in lecture	2.94	.09			–	.611**	.036
4. Metacognitive attribution to feedback device scale	3.62	.07				–	.115
5. Performance outcomes	7.53	.17					

*$p < .05$; **$p < .01$; ***$p < .001$.

Table 5
ANOVA results for "(Electronic) feedback devices and metacognition in lecture".

Group assignment	*n*	*M*	SD	*F*	*df*	*p*
Paddles – summer group	33			.198	3	.622
Clickers – summer group				.662	2	.394
Clickers – fall (experimental group)	87	2.94	.09			
Paddles – fall (comparison group)	78	3.26	.69	4.845	1, 147	.000***

*$p < .05$; **$p < .01$; ***$p < .001$.

Table 6
ANOVA results for "metacognitive attribution to feedback device scale".

Group assignment-polling method	*F*	*df*	*p*
Paddles – summer group	.703	14(18)	.703
Clickers – summer group	2.458	14(18)	.039*
Fall – clickers (experimental group) v. paddles (comparison group)	.418	8,147	.909

* $p < .05$; ** $p < .01$; *** $p < .001$.

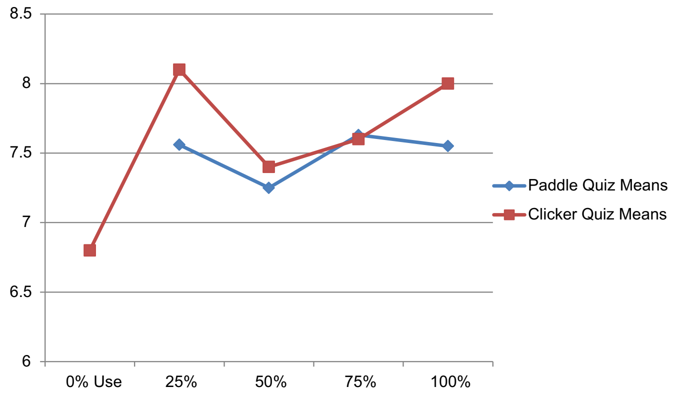

Fig. 1. Extent of paddle/clicker use and performance outcomes percentage of response device use reported by participants.

metacognition in lecture as a result of paddles, but the summer group, the group that experience paddles and then switched to clickers, credited clickers with enhancing metacognition. The ability of these participants from the summer cohort to compare response device use from experiencing paddles and then switching to clickers may have implications.

Third, we hypothesized that the polling method which elicited more metacognition would be the response device that also had higher performance outcomes. Results were mixed; the summer cohort attributed more metacognition to clickers and the performance outcomes of this group were highly significantly improved during clicker use as demonstrated in Table 7 ($p = .001$). Contrary to expectations, during the fall experimental portion of this study, paddles demonstrated significance in metacognition over clickers; however, the fall group that utilized clickers demonstrated significance in performance outcomes over the paddle group at the .05 level ($p = .015$), almost the .01 level. For the summer cohort it is likely that growing accustomed to the professor and the course expectations influenced performance outcomes, but because of the high degree of significance when clickers were in use, clearly clickers influenced performance outcomes.

For the quasi-experimental section of this study the MSLQ demonstrated predictive power for the fall group, but only on the post MSLQ ($\beta = .365$, $p = .045$); the pre-test did not have predictive power for quiz outcomes ($\beta = -.070$, $p = .725$). These results were slightly contrary to expectations. Because the MSLQ is a well-established measure, to show that there were not any significant issues with the MSLQ, and to establish that there is strength to the results of this study, statistical analyses were run to validate the scale. Significance was found at the .05 level for the *t*-test (the pre-MSLQ was $t_{(142)} = 66.541$, $p = .000$, and post-MSLQ was $t_{(140)} = 59.118$, $p < .000$). The *t*-test revealed that the pre-MSLQ is significantly higher than the post-MSLQ. Hence, the illusion is given by the previously presented tests of significance that the pre-MSLQ was not a predictor of quiz outcome.

4.3. *Performance outcomes*

Performance outcomes were examined for differences between groups. Results demonstrate that response devices may influence metacognition. This may be due to an increased ability to self-monitor which has been highly correlated with learning benefits (Mayer, 2008). Further research is needed to explore this possibility. Clickers consistently demonstrated a high degree of significance for performance outcomes when compared to an alternate low technology response device (paddles) during the summer at the .001 level ($p = .000$) and during the fall at the .05 level ($p = .015$).

Table 7
Performance outcome descriptive statistics.

Group assignment	*N*	*M*	SD	*t*
Summer group				5.400***
Paddles	32	8.304	1.134	
Clickers	32	9.259	.801	
Fall groups				2.416*
Clickers experimental	83	8.028	1.031	
Paddles comparison	74	7.545	1.42	

*$p < .05$; **$p < .01$; ***$p < .001$.

5. Conclusion

5.1. Practical implications

Clickers were anticipated to produce increased metacognition when compared to paddles, but paddles seemed to produce more metacognition. Clickers consistently produced higher performance outcomes. Regarding educational significance this study lends evidence to recent research about the circumstances under which clickers contribute to improved academic outcomes. In this study, through a quasi-experimental design, we confirmed that clickers can be employed so that academic benefits are experienced by students in large under-graduate lecture contexts. Clicker items were juxtaposed with research based learning strategies (e.g., questioning and Peer Instruction). Our findings support recent research that suggests when clickers are used these devices should be implemented in conjunction with strategies that engage students in deeper cognitive processing (Mayer et al., 2009).

5.2. Methodological implications

Regarding methodology of this study, educational technology and research based instructional strategies were strategically combined within the instructional design of the course. Ecological validity and methodological soundness were included in the design of the study, because an existing undergraduate educational psychology course was the setting for the study. Each section of the course was taught by the same instructor using the same instructional design. This improves the confidence with which comparisons can be made between clickers and the low technology response device; in addition this consistency reduced confounding factors. This study contributes to the existing research investigating the pedagogical value of clicker use with research based instructional strategies in large lecture contexts. The attempts this study made to achieve well designed constructs, multiple measures and points of data collection, use of multiple groups, and data triangulation (e.g., pre-post-MSLQ, two response device surveys, qualitative survey, and interviews), bolster the rigor in the design of this study. These efforts increase this study's potential contribution to evidence based practice.

5.3. Limitations

This study had several limitations. First, this study established the influence response devices have on students with only a low to moderate level of confidence. Second, the quasi-experimental design of this study included experimental and comparison groups, but not a control group, and groups were randomly assigned to response devices, but individuals were not randomly assigned to groups. This means that the results of this study are correlational and not causal, because in order for a study's results to have causal implications a more rigorous experimental design, seldom possible in educational research, is needed. A control group was not possible because of a bias that clickers and instructional strategies contribute to learning and using a control group without polling and instructional design may be an unfair practice. Third, due to human error, the summer group results did not have the intended pre-post-test design. Fourth, the (Electronic) Feedback Devices and Metacognitive Survey had very low alphas when administered to the summer group (e.g., $\alpha = .39$ for paddles, and $\alpha = .47$ for clickers) while this same measure during fall demonstrated very high alphas (e.g., $\alpha = .92$ for paddles and $\alpha = .96$ for clickers). Normally high alphas suggest repetition of items, while the lower alphas for the summer group suggest that we can only have a moderate level of confidence that the test is measuring what it is intended to measure. Group differences may be a possible explanation for this inconsistency, although repeated use of this measure would be necessary to explore this and other possible explanations. Sixth, and finally, this study relied on self-report surveys for the construct metacognition which may cause desirability effects, a type of bias that can occur when participants report only those answers that are believed to be socially acceptable. Moreover, psychological constructs are difficult to measure, and in an effort to strengthen the results of this study data was triangulated and the pre-post-test measure was a well-regarded and validated scale (e.g., MSLQ).

5.4. Future direction

Future research could take several directions. This study brings up more questions than it answers in particular regarding metacognition. First, future research may include replication of this study to confirm results. In future replications we recommend changing the scales "(Electronic) Feedback Devices and Metacognitive Survey" and "Metacognition Attribution to Feedback Device Scale" to a 7 point Likert scale. This would permit data that is more readily comparable to that collected on the MSLQ, and, more importantly, this would provide another option for students to express the degree to which metacognition may be influenced by the response devices. The suggested additional options are to add 'agree somewhat' and 'disagree somewhat' to the existing scale. Second, according to the manner in which extent of use was measured for the purposes of this study, significance was not found with extent of use and academic performance outcomes (e.g., quiz means). See Fig. 1 to view the results of extent of use. While with increased use of response devices academic outcomes do not consistently increase, there may be significance if the comparison is between extent of use groups (e.g., 0%, 25%, 50%, 75%, and 100%). For both the clicker and paddle groups performance drops for those who reported using response devices 50% of the time. Understanding the extent of use factor for response devices that are anonymous has value for lecture contexts. Other than tutors or one-on-one instruction, such a device utilized with instructional strategies that engage cognitions are the closest instructors can come to achieving a learner centered environment that is attuned to the academic needs of the individual.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.compedu.2013.02.001.

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