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RESEARCH ARTICLE

Metacognition and the influence of polling systems: how do clickers compare with low technology systems

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Abstract Recent research suggests that clickers (electronic feedback devices) influence metacognition. This article reports qualitative findings from a quasi-experimental study comparing clickers and low technology polling. We sought to establish how clickers influence metacognition and whether differences exist in how each response system influences metacognition. The qualitative data collected includes an open-ended survey administer to all study participants ($n = 198$), informal observations, and interviews conducted using purposeful sampling. While low technology polling appears to elicit more metacognition than clickers, negative feelings and conformity affect also increase. Clickers result in positive feelings and reduction of the conformity effect. In addition to significantly higher performance outcomes, findings indicate polling systems result in different qualities of metacognition, meaning either more or less productive, and either self-reflective or group reflective. These differences contribute to the degree to which the environment is learner centered.

Keywords Metacognition · Learner centered environment · Educational technology · Clickers and researched based learning strategies · Qualitative comparative study · How clickers influence metacognition · Clickers versus low technology polling

Introduction

Education is permeated with the use of technology and is in effect "one of the most productive breeding grounds for technology," (Akilli 2010, p. 151). Use of technology to

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engage students is common among faculty (Brown 2010), and technology will continue to be part of a twenty-first century education (Collins and Halverson 2009). A consideration of consequence when selecting technology is whether there are educational benefits associated with its use. The importance of technology's effectiveness lies in the degree to which students and educators are enabled to achieve the desired learning outcomes and goals of instruction (Ross et al. 2010). Some researchers argue that increases in student learning outcomes are probably more connected to instructional design and methods rather than the technology in use (Clark and Feldon 2005). Thus, if technology is employed in rigorous, well designed academic environments, one would expect an increase in learning benefits including increased student performance outcomes.

A key goal and objective of many educators in lecture settings is to enhance learning by increasing attendance and participation. The anonymity of clickers encourages active participation from students who, for various reasons, may otherwise choose not to participate. The use of clicker questions that probe for understanding is reported to develop critical thinking and to increase comprehension of core course concepts (Mollborn and Hoekstra 2010). In addition, learning benefits, including increased performance outcomes, have been associated with clicker use primarily when used in conjunction with well-designed instructional strategies (Brady et al. 2013; Mayer et al. 2009; Meltzer and Manivannan 2002).

The use of clickers to garner feedback during instruction in order to gauge student learning aligns with the emphasis that is placed on metacognition, promoting a learner centered educational environment (Prather et al. 2006). Metacognitively aware learners tend to produce higher performance outcomes (Mayer 2008), and recent research suggests polling devices may influence metacognition when employed with specific instructional strategies. In particular, prompts that help the student reflect on his/her learning experience or that promote application of concepts may influence metacognition (Brady et al. 2013); however, questions emerge regarding the process by which this occurs in a lecture setting. Specifically, some studies report that students regard clickers positively and feel clickers may help with the learning process (Stowell and Nelson 2007; Stowell et al. 2010; Trees and Jackson 2007); however, no studies have explored the processes underlying students' perceptions and attitudes toward the effective use and contribution of clickers to the individual learner's experience. This study adds to the literature by extending previous research (Brady et al. 2013) by exploring how clickers influence student metacognition, including the social context, peer comparisons, and self-evaluations, and the extent to which differences may be experienced compared to low technology polling.

Literature review

Research on the efficacy of clickers has been rather mixed. Early research by Mazur (1991) combined the speed of electronic feedback with peer instruction resulting in significant learning gains. After this initial study, research efforts varied and ranged from claims of no learning gains/benefits from clicker use (Caldwell 2007; James and Willoughby 2011; Lasry 2008), moderate gains (Chen et al. 2010; MacGeorge et al. 2008), and significant gains (Beatty et al. 2006; Caldwell 2007; Duncan 2006; Mayer et al. 2009; Meltzer and Manivannan 2002; Van Diik et al. 2001). Despite the apparent inconsistent results in the literature, the combination of anonymous feedback with cognitive-based learning strategies (e.g., questioning, and peer instruction), seen in Mazur's initial efforts (e.g., peer instruction), emerged in later research as a combination of instructional approaches that produced increased performance outcomes (Brady et al. 2013; Mayer et al. 2009; Meltzer and Manivannan 2002), and suggested that metacognition was involved (Brady et al. 2013; Mayer et al. 2009).

Academic gains from clicker use in courses have been attributed more so to social factors, in particular, perceived utility value, than to technical factors, meaning implementation of the device and course design, according to Trees and Jackson (2007). The majority of the research that exists on the use of clickers is found in science, technology, engineering, and mathematics (STEM), there is far less in the social sciences (Kay and LeSage 2009). Several researchers conducted research in specific domains and discussed use of clickers in terms of strategies particular to subject and context, including, calculus (Bode et al. 2009), sociology (Mollborn and Hoekstra 2010), science (Moss and Crowley 2011), clinical fields/healthcare (Kazley and Annan-Coultas 2012; Miller and Hartung 2012), psychology (Dallaire 2011), and mathematics (Barragués et al. 2011). While arguably there are overlapping ideas in instructional techniques in the body of this literature there are domain specific instructional strategies. For example, psychological, social sciences, and education utilize case studies that are distinctly qualitative in nature in contrast to the quantitative needs of STEM; thus, there are differences in student learning goals, instructional strategies, and student outcomes from STEM to social sciences. The preponderance of literature has focused on the STEM fields which may bias towards domain specific pedagogy and practice. But there is a dearth of literature in social sciences thus this study fills a need by primarily focusing on the social sciences.

Benefits of obtaining feedback via clickers

Research indicates that in order for feedback to benefit students it must be timely and specific to a task or concept (Chen et al. 2010), and this is precisely the type of feedback that is provided through electronic response systems. Studies support that clicker use increases student participation and attention in lecture (Duncan 2006; Gibbs and Simpson 2004; Stowell and Nelson 2007) and engenders more honest answers (Stowell and Nelson 2007).

In a discussion of the benefits and challenges of clickers based on a literature review of 67 peer-reviewed articles from 2000–2007, Kay and LeSage (2009) describe the overall benefits of clicker use as improved learning environments (e.g., increased attendance, increased attention, increased participation and student engagement), enhanced learning (e.g., increased interaction and discussion, improved quality of learning and performance), and improved assessment capabilities (e.g., in real time feedback, formative and normative assessment). Student level of preparation for lecture can be assessed and misconceptions quickly resolved so that the lecture material can be presented free from misunderstandings that may interfere with subject specific learning.

Throughout the course of the lecture, students' individual level of understanding can be evaluated (James and Willoughby 2011), and that is best done when instructors use the formative information gathered by student responses to clicker questions to guide the lecture. The information garnered allows for reforming questions and providing explanations to address student misconceptions, and tangential conversations that stem from clicker questions often unanticipated by the instructor. This responsiveness to student understanding, coupled with the immediacy of aggregated responses, permits instructors to ascertain which concepts to re-visit during lecture (Lasry 2008). Moreover, as compared to raising hands or other polling methods visible to the learners, the anonymity of clickers combined with the ability to simultaneously gather responses can eliminate the conformity effect which occurs when students wait for cues from other students who might have higher academic status in order to decide their answers (Brady et al. 2013; Stowell and Nelson 2007). These benefits are acknowledged to the degree that clickers are in the process of implementation in universities and across many subjects (Robins and Gormley-Fleming 2012).

From engagement to metacognition

Many faculty members aim to ensure that learners are engaged in the process of learning (Mollborn and Hoekstra 2010). Educators place a premium on creating learner centered contexts that increase learning outcomes and frequently use technology to this end (Brown 2010; Mollborn and Hoekstra 2010). Student engagement is a significant predictor of student learning outcomes (Mayer 2008; Schunk et al. 2008). Clickers engage students and have a unique participatory nature that transforms the learning environment (Hoekstra 2008; Meltzer and Manivannan 2002; Trees and Jackson 2007).

Mayer et al. (2009) state that questioning "…encourages students to engage in appropriate cognitive processing" (p. 56) and metacognitive skills may be developed through this generative process. This quasi-experimental study indicated that the group that utilized clickers experienced the learning process better as compared to the non-clicker group and the control group. Thus, this research indicates that student cognition is increased through the use of clickers and metacognition may be involved (Mayer et al. 2009). Furthermore, recent research concurs with this finding describing clicker benefits as nurturing the learning process and promoting critical thinking (Mollborn and Hoekstra 2010). Clickers may guide students toward a certain level of preparation for lectures based on expectation of the task; research indicates that students chose the level at which to engage in a learning related task based on expected level of difficulty (Ross et al. 2006). This type of decision is a function of metacognition stemming from self-instruction, one of the six components of self-regulation (Bandura 1977) and is an integral part in self-regulation (Schraw et al. 2006). Further research has shown a connection between use of metacognitive strategies and achievement goals (Vrugt and Oort 2008). Formation of academic goals and self-regulated learning are widely understood to be associated with higher performance outcomes and/or improved academic experiences.

Metacognition is described as a necessary skill for twenty-first century learners and is connected with improved learning outcomes (Binkley et al. 2012), and it is an essential component in the process of becoming a self-regulated learner (Pintrich et al. 2000; Zimmerman 1994). Metacognition is described as one's thought about their thoughts (Mayer 2008). Flavell (1979) was the first to identify and describe the involvement of metacognition in the learning process. Metacognition is most consistently viewed in research literature as the regulation of cognition and self-knowledge (Flavell 1979; Mayer 2008; Pintrich et al. 2000). According to Bartels and Magun-Jackson (2009) students with a high need to achieve have significantly higher performance outcomes as compared to students with fear of failure; and need to achieve students are more metacognitively aware and engage more in metacognitive self-regulation. Learner need for achievement is significantly related to metacognitive self-regulation, and fear of failure is inversely related to metacognitive self-regulation (Bartels and Magun-Jackson 2009).

Research indicates that when clickers are utilized appropriately, metacognition may be involved in the process when performance outcomes increase (Brady et al. 2013; Duncan 2006; Mayer et al. 2009). Research suggests that emotions in academic contexts are positive when clickers are in use (Stowell and Nelson 2007); positive emotions in academics are linked to possible increase of flexibility of strategy use and utilization of metacognitive strategies that is more sophisticated (Pekrun et al. 2002). Stowell et al. (2010) suggest clicker answers are more honest, shyness is reduced, and response systems may reduce shame and social conformity. Anonymity seems to provide for the involvement shy students without peer pressure (Stowell et al. 2010), and this process may be linked to metacognition and coupled with the concept that students choose the cognitive level at which to engage in a task based on perceived difficulty of the task (Ross et al. 2006). As clicker items are presented learners may have the opportunity to self-monitor their learning, a metacognitive function of self-regulation (Bandura 1977), so that greater clarity may occur in determining task difficulty, which in turn may relate to how a student prepares for lecture and studies for a course.

This study builds on prior research by Brady et al. (2013). We found that clicker groups consistently outperformed low technology polling groups (Brady et al. 2013); these findings support current research that suggests when higher performance outcomes occur, clicker use is combined with research-based learning strategies that encourage deeper cognition (Mayer et al. 2009). We hypothesized that the polling device that influenced metacognition more so would result in higher performance outcomes; however, our quantitative survey findings were somewhat inconsistent (Brady et al. 2013), which was the impetus for this study.

Previous research overview

Previous research by Brady et al. (2013) laid the foundation for this current qualitative investigation. Quantitative results from the study reported employed a pre-post-test design and mean quiz scores were utilized as the determinant of performance outcomes. The pretest was administered the first day of class and included 15 items pertaining to metacognitive self-regulation from the Motivated Strategies for Learning Questionnaire, MSLQ (Pintrich et al. 1993). The post-test consisted of two instruments to measure metacognition experienced by students in the lecture context in addition to the post-test (MSLQ); these two instruments utilized a 5-point Likert scale and were administered after the 5th lecture following lab sections. The first of these two measures, (Electronic) Feedback Devices and Metacognitive Self-Regulation (CQ-for clickers/PQ- for paddles), was designed to gauge the level of metacognition that occurs in lecture as experience by students when utilizing response devices. This instrument, adapted from Mokhtari and Reichard (2002) as described in Mayer (2008) which provides examples of reading strategies awareness items, was designed to measure lecture strategy use as related to response device use. Moreover, the reading strategies awareness items were designed to measure awareness of student metacognition surrounding the reading process based on research that indicated students can be influenced to monitor their reading comprehension.

For our purposes the primary researcher developed the response system and metacognition instrument as a self-report survey with items using a 5-point Likert scale. Instructions for this survey read, “Please read the follow and think about whether clickers/paddles influenced your learning.” Examples of items from this survey are, “Clickers/paddles help me know if the reading I did to prepare for lecture was on track” and “Clickers/paddles help me focus on questions to write down when a topic is difficult, so I can look for an opportunity to ask questions.” The second instrument developed by the primary researcher, Metacognitive Self-Regulation in Lectures (MCC-for clickers/MCP-for paddles), measured the degree to which participants attributed increases in metacognition to the use of the response device (Brady et al. 2013). The survey items for this measure were designed to examine the perceived degree of learning benefits participants attributed to the response device in lecture context. These questions were used as the framework for developing the pencil and paper qualitative survey to have a direct pathway of comparing the quantitative results to the qualitative survey and interviews in order to increase the potential understanding of how response devices influence learners.

The first instrument in this qualitative effort was a pencil and paper survey administered to all participants ($n = 198$). When filling out the pencil and paper qualitative surveys and during the interviews, participants were given the instructions, “Please tell us how clickers/paddles may have influenced you.” The following are examples of survey/interview items that align with the preceding quantitative survey items and were also used as the interview protocol, “How have clicker/paddle results cause you to change the way you take notes?” and, “How have clickers/paddles helped you understand course concepts?” The survey/interview instructional prompt was phrased with an acknowledgement of the possibility that response devices may or may not influence. The survey items focused participant attention on how the changes occurred so that their responses focused on how these devices may have impacted the learning context. Finally, quizzes were administered at each lecture; mean quiz scores were utilized as the means to compare performance outcomes between and among cohorts.

Based on the quantitative analysis alone, students attributed some influence to clickers, and a higher degree of influence to paddles, but this was inconsistently reported. In order to clarify how students experience clickers and low technology polling the next step in our examination required inductive research strategies. The pivotal concern involved the process underlying the influence of clickers on metacognition when that influence results in increased self-regulatory behavior. This is another function of metacognition, self-evaluation, which may be increased by use of clickers. Because the social context of large lecture settings may facilitate peer comparisons when clicker item results are displayed (e.g., histogram, bar charts, pie charts), an auxiliary purpose of this study examined student self-evaluation that occurs surrounding the use of clickers including that which results from peer comparisons. In order to have a basis of comparison, a low technology polling system was included in the study.

Research methodology

Participants and design

Participants included 198 first-year undergraduate students who elected to participate in this comparative study from a large, urban university in the Southwestern United States enrolled in three sections of the same undergraduate educational psychology course. The three sections included a summer cohort and two fall cohorts ($n = 198$). Because the summer cohort had a smaller number of students ($n_1 = 33$) than the fall cohorts ($n_2 = 165$), this group experienced both response systems during the time of the study. The fall experimental group (clickers) included 87 participants and the comparison group included 78. The mean age of the students from cohorts differed by less than 2 % for the summer (mean = 18.03), fall clicker/experimental group (mean = 18.31), and fall paddle/comparison group (mean = 18.37); the ratios of females to males differed by less than 9 % for the summer (45 % female), fall clicker group (47 % female), and fall paddle group (43 % female). Each section was taught by the same instructor and utilized the same instructional design. The setting included clicker use, a strategy of choice for several years, so that clicker use and learning strategies were not newly introduced items into the teaching context; hence, there was no learning curve for instructor implementation and use. The course format included use of clickers for formative assessment, questioning, Peer Instruction opportunities, and was easily adapted for the comparison of high verse low technology polling devices.

Theoretical lens

In rough terms, Flavell (1992) defines metacognition "as knowledge and cognition about cognitive phenomena" (p. 113), and more specifically,

> "the part of [a learners'] acquired world knowledge that has to do with cognitive matters…the knowledge and beliefs…accumulated through experience and stored in long-term memory that concern the human mind and its doings. Some of this stored knowledge seems more declarative ('knowing that') than procedural 'knowledge how'" (p.115).

According to Flavell, there are three areas of sub-area of metacognitive knowledge: person, tasks, and strategies. The first, person, concerns one's beliefs and knowledge regarding how human beings process information, including universal differences and similarities. Second, task knowledge is about the strategies one chooses to handle a certain task and knowledge about the difficulty or ease of the task. Last, strategy knowledge pertains to one's understanding about which strategies are best suited for a particular task. All in all, metacognitive knowledge is the interaction of two or all three of these categories. For the purposes of this study, we are concerned with how response systems influence the interaction of these categories.

The role of metacognition in academics is widely recognized (Schraw and Moshamn 1995). Often definitions and use of this term overlap with that of self-regulation and self-regulated learning (Dinsmore et al. 2008). In an examination of use of these terms, Dinsmore et al. (2008) argue the importance of clearly defining and accurately measuring these constructs, otherwise findings may have confounding factors leading to weak results. Metacognition is traditionally thought about in two ways: (a) what an individual knows about his or her thought process, and (b) how he or she uses such knowledge to self-regulate (Schraw and Moshamn 1995). For the purposes of this study, metacognition is defined in terms of the conditions that enable self-regulation, and is, therefore, operationalized as the cognitive self-knowledge that enables self-regulatory action which adapts according to the perceived needs of the environment (Artino 2005; Pintrich et al. 1993).

Materials and apparatus

Materials for this study included clickers (electronic response devices) and paddles (low technology polling). The clicker and paddles were provided for the summer cohort and the fall cohort was provided with paddles, but all fall students were required to purchase clickers as a part of the course requirements. Clickers use radio-frequency signals to register to survey/question items, TurningPoint 2008 software with ResponseCard IR. Paddles were fabricated from tongue depressor-like sticks and colored paper; multiple choice answers were colored coded with a large, black letter 'A' on pink paper, green for 'B,' orange for 'C,' and green for 'D.' Letter 'A' was glued to the back of the letter 'B' and letter 'C' was glued to the back of letter 'D' and each student was provided with two paddles for responding to survey items/questions. When polled students raised the paddle with the letter corresponding to the desired letter/answer choice. Polling items included surveying opinions, true/false questions, and multiple choice questions checking for understand of key concepts or for application or analysis of content. When discussing learning environments and group size a potential question would be, "True/False: The bigger the group, the more and better the ideas!" When using clickers participants selected the button for 1/A to respond "True" and 2/B to record an answer of "False." When paddles were in use, participants indicated a response of "True" by holding up the side of the paddle marked "A" and "False" by holding up the side marked "B."

Procedure

For this study, IRB approval was obtained and current ethical research guidelines with human subjects were satisfied. The fall groups were quasi-experimental in nature and random group assignment determined which would experience clickers and which would experience paddles. A toss of a coin assigned the fall cohorts to either clicker or paddle use for the first five lectures, after which both cohorts continued with clickers. The summer cohort experienced paddles for the first five lectures, and then switched to clicker use for the remaining lectures.

The format of the lectures was consistent for all cohorts so that the two systems could be compared. The lectures occurred mid-morning for all cohorts and were conducted by the same instructor and using the same materials (e.g., instructional design, instructional strategies, course materials). The groups experienced variation in two ways. First, the summer 2011 cohort experienced use of paddles for the first five lectures and clickers for the remainder of the semester and in delivery of the correct response indicator. Second, during clicker use the correct response was indicated on the slide when the instructor chose to display the slide/indicator, while during paddle use, the correct response was given after polling and after learning strategies were used (e.g., questioning, Peer Instruction). The learning strategy was dependent on instructor choice according to perceived need of the learners.

Information gained from feedback systems (e.g., clickers or paddles) through questions and surveys during lecture served as a platform for instructor/student interaction, Peer Instruction opportunities, formative assessment to guide the lecturer, and re-polling as needed to re-assess understanding. The determinant for interviewee groups were the result of the metacognition instruments and mean quiz scores.

Instrumentation

Results from Brady et al. (2013) were used to form criteria for a qualitative comparative examination of the influence of polling systems on learner metacognition. Interviews were selected as a second source of qualitative data to clarify and enhance data collected from all study participants in survey form. In addition, interviews were necessary to determine the process by which metacognition was influenced by polling devices. This is a function of that which is "on someone else's mind" (Patton 2002, p. 341), and as such cannot be directly observed to determine how an individual interprets the function of this educational tool in the context of a large lecture (Merrian 2009).

A determination was made that meaningful interview data would result from interviews with participants who represented the mean or average participant response. Purposeful sampling was used to select interview participants and they were categorized into three groups: (1) those who had low means indicating little metacognitive influence attributed to clicker/paddle use; (2) those who had means in the median range indicating a moderate/

neutral influence of clicker/paddle use; and (3) those who had high means indicating a strong influence to clicker/paddle use. These means were determined using the data from the instruments measuring metacognition and response devices with a Likert scale from 1 to 5. A score closer to 5 indicated higher metacognition. The mean of the clicker cohort (experimental group) for both metacognition surveys was 3.12 and for the paddle cohort (comparison group) 3.39. Participants whose survey means were 4.3 or above for clickers and 4.0 for paddles were considered to attribute a high degree of influence of metacognition to clickers/paddles, and participants with means that were low were considered as attributing little to no influence of the polling device to means that were under 1.24 for the clicker cohort and 2.2 for the paddle cohort.

The primary researcher conducted brief interviews between the 10th and 15th weeks of classes following the lecture session. A total of 45 interviews were conducted: 14 for participants who mean scores were in the lowest range, 15 who were in the median range, and 15 whose means were high as defined above. The qualitative survey was administered to all study participants at the time of the posttest. The same four questions asked of participants on the survey were utilized for the interview. The first question, "How did clicker/paddle results cause you to evaluate your thoughts?" Second, "How have clickers/paddles caused you to change the way you take notes?" Third, "How have clickers/paddles caused you to compare your answers to other students?" Fourth, "How have clickers/paddles helped you understand course concepts? The interviewees were asked an additional question, "Is there anything else you would like to tell me that wasn't asked?" The structured interview was selected, because the information we sought was specific to the polling devices and the resulting lecture behaviors and thought process. The additional question was to allow for a more open-ended, less structured question in case the respondent had a unique perspective on the process or function of the polling devices' influence (Maxwell 2013). The questions were selected to elicit the interviewee's attitudes about the paddles and clickers, as well as gain deeper understanding of the extent to which the clickers/paddles shaped their strategies for learning.

The interviews were $\sim$5 min in length and were conducted one-on-one with the principal researcher in a corner of the large lecture hall where the lecture occurred and out of the range of other students' hearing, or in a private office when available and convenient for respondents. Interview transcriptions were analyzed several times by the primary researcher for themes related to metacognition, social comparisons, changes in lecture/note-taking behaviors, and conceptual understanding. Responses were coded according to these themes and ascribed a general tone (e.g., positive, negative, or neutral). Information collected in the form of open-ended surveys and interviews can illuminate the process by which tools of instructional technology influence learning in the lecture context. Qualitative data was vital to this study due to the potential to demonstrate causation (Maxwell 2013). It is important to understand how the concept of causation is interpreted; therefore, for the purposes of this study, causation is viewed as a valid concept, grounded in the idea that each participant/interviewee's understanding about how response devices may have influenced metacognition is accurate according to the his or her understanding and experience of the environment.

Data analysis process

The primary investigator conducted interviews and two weeks following began the qualitative analysis. The qualitative interview questions were as follows: (a) "How did clicker/paddle results cause you to evaluate your thoughts?" (b) "How have clickers/paddles caused you to change the way you take notes?" (c) "How have clickers/paddles caused you to compare your answers to other students?" and (d) "How have clickers/paddles helped you to understand course concepts?" Data analysis included transcribed interviews, notes taken by interviewer following interviews, and informal observations. Categories that emerged from data included: (a) social comparisons, (b) academic benefits, (c) effectiveness, (d) engagement, and (e) response device preference. The primary researcher employed the following criteria to determine appropriate categories: Social comparisons result from social conformity; social conformity is the inclination of a student to change answers or opinions based on perceived pressure from peers (Aronson 2008). Academic benefits were viewed in terms of self-monitoring, improved learning environment/experience, confidence, and motivation. Effectiveness included indications that use of response devise influenced learning benefits, increased ability to self-monitor, understand course material, and learn key concepts. Engagement included references to on-task behavior, refocusing, and guiding the learning process. Preference for one response system over the other occurred with enough consistency in comments that this category was added. Impartial reviewers reviewed data analysis.

Positive and negative tones emerged from data as well, but this served to inform categories and was not viewed as separate category or categories in the coding process. Three subgroups corresponding to the purposeful sampling method employed were formed to compare responses from each sub-group: (a) low (e.g., mean of metacognition surveys from Brady et al. 2013), (b) mid, or (c) high. Data was examined to determine overall student perception and for between group differences. After data was coded, responses were tallied for total responses for each sub-group and themes were identified for further analysis and discussion as listed above.

Results and discussion

Metacognition

We anticipated the response device that resulted in the highest metacognition, as reported by participants, would correlate with the performance outcomes. This hypothesis was derived from findings in research connecting improved student outcomes with students who are more metacognitively aware (Bembenutty 2007; Mayer 2008; Pintrich et al. 1993). While quantitative findings inconsistently indicated paddles elicit more metacognition (Brady et al. 2013), qualitative findings consistently supported increased metacognition with clicker use. According to the interview and qualitative survey data, clicker use resulted in a learning experience that allowed individual reflection on concepts and level of preparation while allowing a safe degree of social comparison in the form of histograms and similar reports generated following clicker items. There was little difference reported in metacognitive self-regulation between clickers and paddles in the form of changing the note-taking experience. The interviewees reported significant differences in self-reflective thoughts and social comparisons resulting from clicker use, and, as a result, conceptual understanding increased. The use of paddles was associated with worry about other students' answers, whether one should conform to the majority, and uncomfortable feelings when answers differed significantly from that of peers. The inconsistent findings from the quantitative effort may be explained through the interference in the self-reflection capabilities with the more overt nature of paddles. Clicker use was associated with higher performance outcomes in each instance; as a result of these findings we are inclined to assume that the metacognitive influence of clickers has a more direct, less muddled path to individual reflections on preparation and understanding course concepts. So that the distinct difference in the metacognitive experience between response devices occurred in student metacognition resulting from social comparisons.

Metacognition versus social conformity

Contrary to expectations, in the initial quantitative study (Brady et al. 2013) paddles seemed to elicit more metacognition from students according to quantitative data. We surmised that, because metacognitively aware students tend to have higher performance outcomes, the device that produced more metacognition would also be the device for which student performance outcomes were higher. However, this was the case only after factoring in the current effort's qualitative findings. Examination of the qualitative and quantitative data seems to indicate that there may be more productive and less productive types of metacognition. In each group (clicker and paddle) 50 % of participants indicated note-taking changes as a result of the response device while the other half indicated no change in the note-taking process or uncertainty about how response devices may influence this process. Each method of garnering feedback was reported to clarify concepts through answering questions, increased effort and interest in one's own learning, clarifying the concepts, discussion resulting from items, explanations from professor, increasing the relevancy of course material, self-evaluation of learning, and wrong responses cause attending to understand the correct response.

Key differences emerged in terms of self-reflective thoughts and social comparisons. Both devices contributed to self-reflective thoughts and, in turn, social comparisons; however, when clickers were in use, comparisons occurred privately before correct responses were indicated, but when paddles were in use the visibility of this system contributed to negative feelings and a sense of vulnerability. A point of interest having to do with the visible nature of paddles, were reports from a small margin of participants, less than 10 %, who reported debating with themselves about whether to conform to the majority or to answer according to their own determination of the correct answer.

With the use of clickers, participants engaged in academic-related social comparisons as a result of the visual representation of answers to clicker items and in terms of interest in peer responses. There was perceived social pressure with paddle use that resulted in the conformity effect. When paddles were in use students frequently reported determining correct responses based on peer group and changing answers to match peers. In addition, the undesirable distractions that occurred with paddles seemed to impede learning goals by interrupting self-instruction, one of the six components of self-regulation (Bandura 1977). It may be that the self-instruction engaged in was inhibited by distractions from the social comparisons with paddles, while with clickers self-instruction was not interrupted by uncomfortable social comparisons.

When clickers were in use, instead of perceiving pressure to conform, participants were able to answer "honestly." In the case that incorrect answers were submitted, misconceptions were addressed without feelings of shame. One respondent summed up the general feeling of the vulnerability by stating, "It's embarrassing; you shouldn't do that stuff." Other respondents reported, "clickers allow honesty and with paddles you see and change," "Paddles are similar to clickers, except with paddles I would change to others' answers to put my answer out there with the majority," and "Using paddles cause me to judge myself against the class. I wasn't exactly using my own answer at the time." Specifically addressing clicker use and the learning process one respondent stated, "Once it's visible it's cool. It opens up discussion. When I see, I have to think about why it's the right answer and ask questions and look at the material." Others reported similarly about clicker use, "I felt pride if I was right, and I guess if I was wrong I need to pay more attention and find out why I was wrong," and, "Clickers are more honest. I like them better. No one can see." According to respondents seeing the results of the clicker items was interesting while looking about to see peer responses with paddles was, in general, uncomfortable. Clickers afforded learning and self-reflection opportunities free from interruptions due to uncomfortable social comparisons. This finding may reflect current research suggesting that when students have a sense of power, the use of information for social comparisons may be reduced (Johnson and Lammers 2012).

Student feelings and preference

Social comparisons resulting from paddle use resulted in negative feelings. Over 95 % of students indicated a preference for clickers over paddles. Students' attitudes toward clickers were overwhelmingly positive and toward paddles predominantly negative. These feelings stem from the social influence of the polling systems and are reflective of the distinct visual nature of each system. The nature of the social comparisons when paddles were in use was reportedly uncomfortable. In contrast, clickers were described as "safe." This distinction, clearly related to students' thought processes as a reaction to the response systems, emerged with consistency in interviews in spite of the quantitative significance found for paddles over clickers. Participants who fit into the category of low to middle level performance outcomes, as in Fig. 1, expressed a clear preference for clickers over paddles. This may aligns with recent findings about metacognitive self-regulation and at-risk students' tendency to experience fear of failure; improving metacognitive skills may reduce the behavior of avoiding academics (Bartels and Magun-Jackson 2009).

A noteworthy finding occurred with participants who were interviewed due to very low mean survey scores on metacognition and feedback devices measurements. If data interpretation was based solely on quantitative data, a potentially misleading conclusion could have easily been drawn; interview data provided clarification and meaning, and increased the integrity of the results. That is, the interpretation would have been that these students do not attribute any influence on the metacognitive processes to clicker use. Moreover, the assumption would have been that these participants preferred the low technology response system. Based on interview data, respondents from this category generally preferred clickers and attributed some influence on metacognition to the use of clickers. One respondent in this category preferred paddles and was not favorable toward clickers. This represented less than 2 % of the cohorts; in some cases these were students with higher than average grades.

Performance outcomes

In the context of the current study, the use of response devices with strategies that encourage deeper cognitions resulted in higher performance outcomes for the experimental (clickers) group ($p = .015$; $p = .001$). There are students who seem to have higher performance outcomes regardless of response system type. These students seem to experience confidence displaying answers before peers prior to indications of the correct response. When these students selected the incorrect answer, they viewed the situation as a learning opportunity rather than a threat. However, this was untrue for the majority of undergraduates who had middle or lower performance outcomes and experienced enhanced

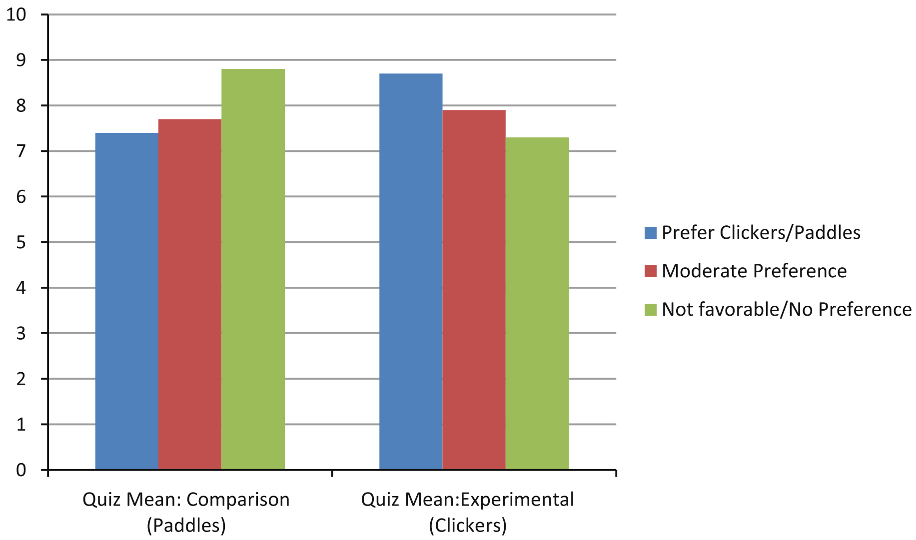

Fig. A Mean quiz performance outcomes and response device preference ($N = 45$). Quiz performance outcomes based on the mean of five quizzes with 10 points possible on each for the experimental group (clickers): Prefer clickers $n = 8$ ($m = 7.4$), Moderate preference, $n = 6$ ($m = 7.71$), and Not favorable/No preference $n = 5$ ($m = 8.8$). Quiz performance outcomes for the control group (paddles): Prefer paddles $n = 4$ ($m = 8.7$), Moderate preference, $n = 3$($m = 7.9$), and Not favorable/No preference $n = 6$ ($m = 7.3$). Quiz mean for high performer in experimental group (clickers) student who did not prefer clickers. Outliers included in statistical analysis

learning outcomes because of clicker use. Figure 1 displays data, which indicated preference for response device compared to mean performance outcome. Results demonstrate lower level performers preferred clickers while higher level performers seemed to prefer paddles; results of this study indicate that lower and mid-level performance outcomes were higher when clickers were in use.

Conclusions

Implications to practice

The educational significance of this study added to recent research by suggesting conditions under which clickers contribute to improving performance outcomes. Moreover, this study contributes to research literature the initial qualitative findings regarding how response devices influence the learning process that was previously unavailable. This quasi-experimental study contributes to the research efforts indicating that clickers can be employed so that academic benefits are experienced by students in large undergraduate lecture contexts. Results of this study have possible implications for the process surrounding how learners experience metacognition related to clicker use. The quality of clickers, specifically that the anonymity results in more honest and authentic feedback (Brady et al. 2013: Stowell and Nelson 2007), seemed to reduce the conformity effect to which students are prone. Paddles, in contrast, and according to our analysis of interview data, seemed to interrupt the learning process with uncomfortable peer comparisons. This indicates that use of clickers with learning strategies resulted in learners engaging with the learning process in such a fashion that self-reflections and self-monitoring occurred and as a natural consequence improved metacognitive processes. In effect, learners who normally would not engage in questioning in lecture due to shyness and/or other factors (Stowell and Nelson 2007), have specific learning concerns addressed, helping, as it were, low and middle level performers in their learning process more effectively, guiding such learners in a metacognitive discovery of self-knowledge pertaining to the lecture at hand. This finding may be related to Bartels and Magun-Jackson's (2009) findings that use of metacognitive strategies by fear of failure learners has an inverse relationship. The fear of failure learners may have been lead through use of metacognitive strategies that they would not normally engage in. In terms of this current study, this means that need for achievement learners engage in metacognitive self-regulation without the use of such instructional technology, while fear of failure learners, who would avoid or be less likely to engage in such strategies, are guided through a metacognitive process thus supporting self-regulated learning behaviors.

Because of these metacognitively oriented distinctions stemming from the differences in response device type, it may be useful to view the resulting metacognition as productive or unproductive, and as having a self-reflective or group reflective quality. By productive metacognition we mean the ability of the individual to engage in the learning process so that self-reflections and self-monitoring of learning occur with the least possible interference from competing stimuli (e.g., uncomfortable social comparisons). Unproductive metacognition would result from a learning context in which the learner experiences distractions that interfere with self-monitoring and self-reflections. This competing stimuli concept in the context of these definitions pertains to that which is in the power of the instructor to influence through instructional design, in this case type of response device. If the learning goal is to induce social comparisons, to expose to peer influence resulting in social conformity, then paddles or raising hands will suffice. If learning goals require self-reflection, individual measures of learning, or honest comparisons of social issues/polling questions that are free from overt judgments of intelligence, preparation, character or preferences, then reducing the conformity effect is desirable, and clickers would be the response method of choice.

When efforts are made by instructors to improve learning situations, it is the lower and middle level learners who stand to gain the most. The higher performing students seem to adjust and perform regardless of how difficult a subject, how great the demands of the course, or even how boring the lecture is perceived to be. In high stakes situations in which performance outcomes are a driving factor for middle to lower performing students, performance outcomes can be increased when clickers are implemented in conjunction with strategies that engage students in deeper cognitive processing. Clickers allow for increased internal reflections because of the anonymity, and contribute to a learner centered environment as a result of producing more beneficial or productive metacognitions. Instructors for undergraduate courses should ensure metacognition influenced (or produced) during lecture leads to productive learning, uninhibited by distractions caused by social processing. Additionally, in building learner centered environments instructors should employ anonymous polling systems in conjunction with learning strategies (e.g., questioning, chunking, and peer instruction) to increase performance outcomes, accurately assess conceptual understanding, and to create the highest degree of specificity possible during lecture. Time is necessary in order to reformat lectures for use with clickers and cognitive based learning strategies (e.g., questioning, Peer Instruction, re-polling, and formative assessment opportunities); this change to instructional design is well worth the efforts to the end that the needs of individuals and groups are met in higher education. Short of personalized tutoring for each student, considerations to instructional design such as these made when combining clickers and learning strategies may target student learning at the most individualized level possible, and the combination seems to be a highly effective means to provide support for each student. In particular, at the level of freshman introductory courses, the use of clickers with learning strategies may have the potential to contribute to an increased retention rates as an incidental by-product. This conjecture stems from the reports lower to middle level performing participants gave expressing a clear preference for clickers due to the anonymity afforded which did not compromise a student's self-worth through obvious peer comparisons and in this study consistently resulted in higher performance outcomes.

Methodological implications

The methodology of this study included combining educational technology and research based instructional strategies strategically placed in the instructional design of each lecture in the course. In addition, the study maintained ecological validity and methodological soundness by conducting research in an existing undergraduate general education educational psychology course as the setting for the study. Each section of the course was taught by the same instructor using the same instructional design. This allowed for a solid basis for comparison of clickers with the low technology response device. This study contributes to the existing research investigating the pedagogical value of clicker use with research based instructional strategies in large lecture contexts. The rigorous design of the research may contribute to evidence-based practice.

Limitations

There are limitations to this effort to consider. First, the primary researcher was an instructor of record for a lab in the fall comparison group. To control for possible influence, none of the students in this lab section were included in the interview process. There were multiple measures and points of data collection; however, the three surveys used as measures of metacognition were self-report instruments and as such may have influenced the study by social desirability effects. We recommend changing the scales on metacognition and response devices to 7-point Likert scales instead of 5-point (Brady et al. 2013), because the additional response categories may provide more clarity about the influence of feedback devices on metacognition. Finally, this study did not have a control group, because of a bias that polling and learning strategies increase learning and not providing this combination of learning strategies would place a group of students at a disadvantage.

Future directions

Metacognitively aware students are able to discern and select productive thoughts while disregarding unproductive thoughts, a type of thinking that is strategic in nature (Anderson and Krathwohl 2001). According to this research these thoughts can be enhanced or impeded in spite of the use of research based learning strategies, based on response device type choice. If there is, as this study indicates, more or less productive metacognition elicited from the polling strategies used by instructors, confirming these results and clarifying the conditions that lead to more and less productive metacognition is important. A possible direction for future research is to examine the conditions under which metacognition is productive/unproductive in the learning context, and possibly to devise a scale that more aptly measures such conditions. Furthermore, replicating and extending this study would serve to confirm and strengthen results and validate the surveys designed for this study to measure metacognition and response devices.

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