Towards A Systematic Pedagogy-Oriented Model of CRS Research: Efficacy of Classroom Response System-Facilitated Peer Instruction in Psychology Lecture Classes

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ABSTRACT

Towards A Systematic Pedagogy-Oriented Model of CRS Research: Efficacy of Classroom Response System-Facilitated Peer Instruction in Psychology Lecture Classes

Ying Li

The main purpose of this mixed method study is 1) to investigate to what extent students perceive the way Classroom Response System-facilitated Peer Instruction (CRS-PI) is used as a positive influence on their learning and engagement; 2) to examine if some student characteristics, namely *age*, *academic level*, *course performance*, *preferences for learning, and assumptions about lecture courses* affect their perceived value of CRS-PI; 3) to elicit what students like best about CRS-PI and what they think is in need of improvement. Results suggest that student evaluations are highly positive on all five subscales of Learning and Engagement, namely Mastery of Subject Matter (MSM), Metacognition, Motivation, Enjoyment and Involvement (grand means being 4.08, 4.03, 3.53, 4.39 and 3.98, respectively). Multiple regression tests show *age* as a negative predictor for only one (MSM) of the five subscales, but *academic level* for all subscales but one (MSM). *Course performance* does not predict students' perceived usefulness of CRS use on any subscales. The most consistent predictor of student perceptions is their assumptions about how lecture courses should be taught. Preference for traditional lecture style is negatively associated with perceived usefulness of CRS-PI. Participants' verbal comments corroborate their quantitative evaluations, showing overwhelmingly positive attitudes. Results are discussed in light of relevant research literature and the detailed description of how CRS-PI is used in the study. It is the hope of this paper to inspire a pedagogy-oriented holistic approach to CRS research and teaching.

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Dedicated to my parents

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Introduction

With a shocking example, Duncan (2006) debunked a common myth among instructors about traditional lecturing – students will learn and retain what we teach them as long as we teach it well: 15 minutes after demonstrating with a real violin how the sound of the instrument was mainly produced by the wood in the back rather than the strings, Carl Weiman, "A Nobel Prize winner in physics and a good teacher", was surprised to find that only 10% of the students chose the correct answer to his multiple-choice question asking where the sound of a violin mostly came from.

Traditional lecture-style instruction is notoriously ineffective in engaging students and fostering deep, long-lasting learning, resulting in many graduates leaving university with their fundamental misconceptions intact (Bennett, Foreman-Peck, & Higgins, 1996; Gibbs & Jenkins, 1992; Hake, 1998; Hestenes, Wells, & Swackhammer, 1992; Specht & Sandlin, 1991; Thornton, 1999). Unfortunately, such mode of instruction remains predominant in colleges and universities due to resource constraints accompanied by ever increasing enrolment. Further compounding these old challenges in higher education is the arrival of the new, millennial generation who grow up on the internet and stay socially connected 24/7 through instant messaging, blogging, facebooking, tweeting, … With what Frand (2000) terms "the information-age mindset", they exhibit distinctively different preferences for learning than previous student generations, such as favoring teamwork, experiential and interactive learning, and learning with technology (Oblinger, 2003). These students have arguably much lower tolerance for being treated as an information dumping ground, which is exactly what traditional teaching often does.

The good news is that the problem with lectures is not so much one of a lack of good pedagogies as not being able to implement them. The ideal state of teaching and learning has been elaborated in theoretical works such as Laurillard's (2002) *Conversational Framework for Instruction*, which describes an on-going dialogue between the instructor and the student—instruction that is completely contingent on students' learning needs. This level of interaction is considered impossible in large classes, even by the author herself. However, it can be approximated with the aid of an instructional technology known as Classroom Response System (CRS), which has the potential to transform the learning environment to address long existing educational challenges as well as match new expectations of the millennial students.

Literature Review

Classroom Response System (CRS)

Technical details. Classroom Response System (CRS) is an electronic voting system used in class for collecting student responses to a given question (typically in multiple-choice format). It consists of a receiver, a software application, student input devices (handheld keypads commonly known as clickers), and an instructor remote; and it usually entails a classroom projection system. CRS questions (a.k.a. clicker questions) can be pre-inserted in lecture slides or created on the fly. At any point in time after voting is closed, the students' aggregated responses can be instantly projected as a bar chart by pressing the display button on the instructor's remote. Moreover, these clicker performance data are automatically stored by the software and can be used later for instructional (such as assigning grades) or research purposes.

History. Classroom response technology has been around in higher education since the 1960s (Judson & Sawada, 2002), evolving from hard-wired versions through wireless Infrared (IR) keypads to radio frequency (RF) handsets. However, only over the last 15 years has CRS use become widespread (Beatty & Gerace, 2009). In the United States, CRS has virtually become the most omnipresent technological aid to classroom teaching since the overhead projector

(Abrahamson, as cited in Beatty & Gerace, 2009).

Alternative terms. The various cultural and educational contexts in which CRS has been adopted as well as the many brands under which it is marketed have given rise to a large number of terms for the technology, such as Classroom Communication Systems (Boyle & Nicol, 2003), Student Response Systems (Dangel & Wang, 2008), Audience Response Systems (Collins, 2007), Group Response Systems (Carnaghan & Webb, 2007), Personal Response Systems (Gauci, Dantas, Williams, & Kemm, 2009), Electronic Voting Systems (Kennedy & Cutts, 2005), to name just a few. Kay and LeSage (2009) identified 26 labels for CRS in their review of CRS literature, but there could be more.

In this paper, *Classroom Response Systems (CRS)*, *the response (or clicker) technology* and *clickers* will be used interchangeably.

Pedagogical values.

A paradox in CRS research. Research on CRS use has been growing dramatically over the past decade. Driven by a strongly felt need for a cost-benefit analysis of the technology (Will the teaching and learning benefits outweigh the financial cost and the efforts invested in learning the technology?), a large number of empirical studies have been focusing on investigating the effects of CRS on student learning and engagement. This led to a paradox in current CRS research since it is difficult, if not impossible, to isolate the impact of a technology from that of the pedagogy it supports, especially when a particular pedagogy cannot be faithfully implemented without CRS (Beatty & Gerace, 2009). As a result, it is not uncommon to find studies confounding the effects of CRS with those produced by various pedagogical redesigns accompanying its use (e.g. Poirier & Feldman, 2007; Reay, Li, & Bao, 2008).

Although many studies controlled for instructional methods and other aspects so that the only difference is the use, or lack of use, of CRS (e.g., Fan & van Blink, 2006; Lasry, 2008; Morling, McAuliffe, Cohen, & DiLorenzo, 2008; Yourstone, Kraye, & Albaum, 2008), they often contributed to the technology-centred thinking in educational technology research by treating CRS as if it is an instructional method, not a tool, which "may be used in many possible ways for many possible ends" (Beatty & Gerace, 2009, p.147), running counter to the larger research base which shows that new educational technology does not improve learning in and by itself (Draper, 1998; Laurillard, 2002).

Some of these technology-focused investigations may mislead research consumers with their findings because of inadequate descriptions of the pedagogical variables across groups, and others could understate the enabling power of CRS because of limited pedagogical use of it. For example, Morling et al.'s (2008) study used CRS mainly for administering reading quizzes. After collecting answers from students using CRS, Mayer et al. (2009) would just display the correct answer, explain or ask a student volunteer to explain why it is correct without discussing the incorrect answers or encouraging peer discussion. As a result, students were unable to benefit from what a combination of the response technology and good pedagogies can typically afford: learning from tackling misconceptions (represented by wrong answer choices if the question is well designed), and from discussing with peers.

Addressing the dilemma. Beatty and Gerace (2009) said it all when they compared studies designed to measure learning gains caused by CRS to "asking whether a house made with a nail-gun is better than a house made with a hammer, given identical blueprints and materials" (p.147). The more valid research questions should be what pedagogies CRS can support, enable or amplify and what impact those pedagogies can have on student learning, as the authors pointed out. One way to make the distinction between technology and pedagogy, according to the authors, is to look at instructional approaches for learning impact and only evaluate technologies for their affordances.

Inspired by Beatty and Gerace's (2009) insights, the following review will focus on CRS-based pedagogies, with a preceding discussion on the characteristics of the clicker technology which enables or enhances the implementation of such pedagogies.

Pedagogy-friendly affordances of CRS. Compared with alternative tools and techniques instructors sometimes use for collating student responses, such as response cards and shows of hands, CRS is superior in several ways. For example, it allows for both anonymity and accountability (the responses are anonymous to students but can be identifiable to the instructor); it provides more privacy; and it offers more rapid and accurate counting and tabulating of the results. All these features enhance CRS' potential in providing a wide range of pedagogical support.

Anonymity has contributed to the widely reported increased participation and positive attitude related to clicker use (Draper & Brown 2004; Freeman, Blayney, & Ginns, 2006; Stowell & Nelson, 2007; Wit, 2003). For instance, Stowell and Nelson's (2007) study shows the highest classroom participation by the clicker group, followed by the response card group, and then by the hand-raising group. According to Mollborn & Hoekstra's (2010) observation, CRS promotes participation in two ways: a) it allows shy students to contribute their thoughts through answering clicker questions electronically; b) it motivates students to verbalize their reasoning by exposing them to diverse views and perspectives of their peers. In addition, the anonymous affordance of CRS also makes it an ideal tool for eliciting wider and more honest student opinions on sensitive, controversial topics, especially in courses such as sexuality education (Fisher, 2006). CRS is also found to be responsible for boosting the participation of female students who were far outnumbered by their male counterparts and less likely to engage with course content in a general chemistry course for engineering majors (King & Joshi, 2008). King and Joshi (2008) also find a positive correlation between CRS participation and examination (containing similar content) performance, suggesting that CRS use could promote academic performance by increasing rate of participation.

The increased privacy in submitting responses makes CRS a better choice than a show of hands (even flashcards) for obtaining honest student responses. Stowell and Nelson (2007) note in their study that only 66% of the clicker group in contrast to 88% of the hand-raising group provided the correct answer to the most difficult common review question; moreover, the clicker group's performance scores on the review questions were most consistent with their post-lecture quiz scores among all four groups under study, suggesting that CRS is less susceptible to peer influence than low tech alternatives, which may generate a false impression about student understanding for the instructor, hence misleading the subsequent instruction.

The fast, accurate and tallied feedback afforded by CRS has been shown to be valuable in various ways. Mollborn and Hoekstra (2010) observed in their sociology courses that the display of tabulated student responses helped to set up "the crucial stage for critical thinking and discussion"; Dufresne, Wenk, Mestre, Gerace, and Leonard (1996) found that showing the histogram before class-wide discussion encourages greater participation not only for students choosing the most popular answer, but also for those who voted for minority answers as they took comfort in the fact that they were not alone in their selection even when they were wrong. In addition, the instantaneous feedback afforded by CRS has been shown to lead to higher exam performance than delayed paper feedback for the same set of questions (Yourstone, Kraye, & Albaum, 2008). Moreover, such feedback obtained at different points during a lecture can facilitate agile teaching (Beatty, Leonard, Gerace, & Dufresne, 2006a), also known as contingent teaching (Draper & Brown, 2004), a teaching method in which the instructor adjusts the lecture to meet students' real-time needs instead of delivering strictly according to a lesson plan.

The histogram also helps raise learner morale and motivation by allowing students to see that they are not the only one in their misunderstanding (Beatty, 2004). Furthermore, the contrasts among different ideas as reflected in the different categories of responses could promote learning and self-regulation, as argued by Roschelle, Penuel, and Abrahamson (2004), based on research on contrasting cases and cognitive conflict.

Albeit not an inherent feature of CRS, another interesting point about CRS is that, the technology seems to have a push effect on the exploration and employment of new pedagogies. For example, a lot of instructors have started using Peer Instruction (an interactive teaching method to be discussed below) as a result of using clickers (Lasry, 2008). Lasry (2008) observed that the popularization of CRS prompted instructors to recontemplate teaching and reshape instruction in favor of building robust understanding as opposed to covering content.

CRS-based Pedagogies

A number of pedagogical innovations can help bring forth the above-mentioned potentials of CRS to synergistically create an improved learning experience for students. Examples are Peer Instruction popularized by Eric Mazur and colleagues at Harvard University, Question-driven Instruction developed by University of Massachusetts Physics Education Research Group (UMPREG), and the Question Sequence Method created by The Ohio State University's Physics Education Research Group. Although conceived independently, these pedagogies share a lot of similarities, beyond their common disciplinary context. Theoretically, they are all grounded in social constructivism and represent a radical shift from earlier behaviorist use of CRS that focused on the "stimulus and response" affordance of the technology. In practice, they all use structured questioning and feedback, peer discussion, and agile teaching as strategies to help students build conceptual understanding.

Peer Instruction (PI). Peer Instruction (PI) is an interactive teaching technique developed by Eric Mazur in 1991 for introductory physics courses at Harvard University (Crouch & Mazur, 2001).

Lectures using PI are punctuated with ConcepTests (multiple-choice conceptual questions). Typically, a ConcepTest is conducted in the following manner:

1. Question posed 1 minute
2. Students given time to think 1-2 minutes
3. Students record/report individual answers
4. Neighboring students discuss their answers 2-4 minutes
5. Students record/report revised answers
6. Feedback to teacher: Tally of answers
7. Explanation of correct answer 2+ minutes

(Crouch, Watkins, Fagen, & Mazur, 2007, pp.6-7)

An inherently adaptable method. The above description should not be considered as a formula for PI use, for PI is "an inherently flexible and adaptable method" (Crouch et al., 2007, p. 36). Diverse practice has been observed among PI users, even within the physics faculty community (Turpen & Finkelstein, 2007). Some published studies comparing the so-called 'Mazur method' to some other peer discussion method (e.g., Nicol & Boyle, 2003) based on the general steps provided by the developers could be misleading. They failed to capture the essence of the method and practically send the message that PI is a fixed set of steps to be rigidly implemented without considering the instructional context. In fact, PI is better understood as a strategy. Some steps can be skipped over or telescoped while others can take a different order depending on the difficulty level of the question and other contextual factors. For example, in Lasry's (2008) study, when 30% of students gave the correct response, the instructor would revisit the concept instead of going directly to peer discussion; when more than 80% of students answered correctly, the instructor would skip peer discussion, explain and move on to the next topic.

For another example, the PI used in Freeman and Blayney's (2005) study started with peer discussion followed by students' voting and then another round of peer discussion. There are some advantages to having students vote independently before jumping into discussion – after committing to a particular answer, they may be more emotionally involved and therefore more attentive in the subsequent discussion (Beatty, 2004). However, the 'discussion first' method is not without merits. In case of very difficult questions, Hoekstra (2008) found that her female students favored and learned more from an initial discussion because they could hardly benefit from the first independent vote.

The flexibility of the PI method also has its downside as the variations in implementation may produce different instructional impact, and it is difficult to unpack the various practices of PI to determine what works and what does not in a particular context. Awareness of this challenge could be a step in the right direction, for people might assume that they are using the same powerful method called PI when they are doing something very different that will not result in much success.

Pedagogy before technology. PI had enjoyed some success and popularity before CRS became technically less cumbersome to use and financially more affordable for wide adoption. In the initial year of implementing PI, the PI pioneers at Harvard University used scanning forms combined with a show of hands for polling students (Crouch & Mazur, 2001). Crouch and Mazur (2001) stated that the response technology they adopted later did not add significantly to student learning, although they benefited from anonymity of student responses and efficiency in data collection. They concluded that the impact of PI was independent of feedback tools. In the same vein, T. Stelzer (Personal communication, April 30, 2009), co-founder of i>clicker and a Physics professor at the University of Illinois-Urbana Champaign, mentioned that it was the logistical challenge of implementing PI with flashcards that led to their invention of i>clicker. Since i>clicker initially came to the scene to respond to a technical deficiency in materializing an established pedagogy, it (or CRS with other brands) should be adopted elsewhere for the same reason. That is to say, identifying the instructional goals and how CRS can help achieve those goals should precede the actual adoption of the technology.

Research measuring the effects of PI. The learning benefits of PI have been widely documented. For example, comparing the performance of groups of students taught with and without PI, Miller, Santana-Vega and Terrell (2006) conclude that the benefits of "Good Questions" (their adapted version of ConcepTests for teaching mathematics) mainly came from peer discussion, and discussing questions that required higher-order thinking were even more beneficial.

So far the most compelling evidence of PI's impact on learning, unsurprisingly, has been provided by the developers of this method (Crouch & Mazur, 2001). Crouch and Mazur (2001) studied the implementation of PI in introductory physics courses at Harvard University for ten years and consistently found solid evidence of improvement in conceptual knowledge as well as quantitative problem solving. In addition to PI's extensive success at Harvard University, a survey on 384 instructors around the world (Crouch et al., 2007) indicates that with the majority of the instructors, PI helped elevate students' understanding of concepts to the level typical of courses taught with interactive methods.

Some smaller scale studies focusing on the immediate and short-term learning gains caused by PI are also revealing. Counting and comparing the voting results before and after peer discussion, these studies have generally indicated substantial improvement from the first vote to the second (e.g., Cutts, Carbone, & van Haaster, 2004). More stringent studies (Smith et al., 2009) have also been conducted to address the concern that the improvement in student responses after peer discussion might result from peer influence -- less competent students conforming to more knowledgeable students in their revote. Smith et al. (2009) used sixteen pairs of clicker questions with each pair testing the same concept but disguised by different “cover stories” to measure learning gains generated by PI. Students were instructed to vote on “Q1” (the first question) on their own, discuss with peers, and then vote again on the same question. Without seeing the response distribution chart, without being told the correct answer, and without discussion, students were asked to vote on “Q2” (the second question) independently. Averaging clicker scores for each participant for all 16 pairs of questions, the authors found significantly better performance on Q2 as well as Q1ad (the post-discussion vote for Q1) in comparison with Q1 (before discussion) across all three difficulty levels. For the most difficult questions, learning gains were even more impressive: on average, 16% of the students answered Q1 correctly on their own, 32% answered Q1 correctly after peer discussion (Q1ad), and 54% answered Q2 correctly on their own. As the data suggest further learning gain for Q2 compared with Q1ad, the authors recommended using series of questions to bring out the *delayed benefits* of PI. More interestingly, both clicker performance and survey data showed that PI helped shape correct reasoning even no one in the discussion group initially chose the right answer.

Apart from performance gains, there are also studies that measure more advanced outcomes of PI, such as metacognition. For instance, Lucas (2009) found, with his "Learning Index" method, that his PI class values peers as a source of learning significantly more than the non-PI class.

Question Driven Instruction (QDI). Question Driven Instruction (QDI) was developed by the University of Massachusetts Physics Education Research Group (UMPREG). QDI provides not only some instructional techniques but a theoretically solid and empirically well-grounded framework for designing active teaching and learning experiences.

As an instructional method, QDI is similar to PI but goes a step further towards student-centered teaching. Whereas PI inserts questions (ConcepTests) into an otherwise full-sized lecture, QDI *begins* with and *centers* around questioning, only using "microlectures" occasionally when such need arises (Beatty & Gerace, 2009).

QDI is based on the concept of active learning, emphasizing the building of "robust, durable, transferable knowledge" through engaging the mind of students by questioning, feedback and peer interaction (Beatty et al., 2006a, p.98). It also draws on the four characteristic of an effective learning environment (learner-centered, knowledge-centered, assessment-centered and community-centered) depicted in *How People Learn* (Bransford, as cited in Beatty et al., 2006a), which are summarized as follows: Learner-centeredness means treating students as individuals with varied prior knowledge and beliefs who move towards their goals along their unique learning paths; knowledge-centeredness means viewing knowledge as fluid and interconnected, and information "as the raw material of useful knowledge rather than as something to be acquired for its own merits" (Beatty et al., 2006a, p.3); assessment-centeredness emphasizes formative assessment as an integral and crucial part of instruction; and community-centeredness promotes collaboration among students as they approach learning.

Below is a summary of a "question cycle" used in QDI (Beatty & Gerace, 2009).

1. Pose a challenging question. (*without* any preceding lecture)

2. Have students tackle the question either on their own or in small groups or both in succession, and then vote for an answer.

3. Collect and display student responses using CRS.

4. Draw out student reasoning, expose them to one another's ideas without revealing the correct answer (there might *not* be a single best answer in some cases).

5. Gauge and scaffold student understanding; help them develop scientific reasoning and practice talking science through students-led discussion.

6. Wrap up with any of the following instructional actions, depending on the situation: summarize the key points, pose a related question, give a micro-lecture or provide meta-level comments…

Similar to PI, QDI is not designed to be mechanically followed. However, flexibility does not mean loose application but a deep understanding of the founding principles and central tenets of the pedagogy, which usually entails some training and a great deal of practice.

The Question Sequence Method. The design rationale behind the question sequence method is that since learning is context dependent, a series of questions set in different contexts may help students build solid understanding of complex concepts and form transferrable knowledge structures. The researchers of The Ohio State University's Physics Education Research Group created and tested two specific question patterns called "easy-difficult-difficult" and "rapid-fire" (Reay, Li, & Bao, 2008).

"Easy-difficult-difficult" starts with a quick "warm-up" and then follows up with a second, more difficult question. For the second question, the instructor asks students to cast an individual vote, then discuss the question in small groups and then vote again. Without revealing the correct answer to the second question, the instructor presents a third question which provides a different context for the same concept, to check if the students are able to transfer what they have learned to the new context. "Rapid-fire" comprises a series of moderately difficult questions so students can practice the same concept in slightly different contexts.

Other pedagogical models for CRS use. As one can infer from the above description, a lion's share of existing research on CRS-based pedagogy is conducted in natural sciences, especially in physics. However, there have been growing efforts in other fields to create their own discipline-specific instructional models for clicker use. For example, Mollborn & Hoekstra (2010) developed and tested a pedagogical model for CRS use in teaching sociology. Building on established CRS-based pedagogies, the model stresses the use of different types of clicker questions (such as reading quiz questions, opinion questions, demographic questions, past experience questions, instant feedback questions, student self-created questions) for meeting different learning goals. What is particularly interesting is that it explicitly includes instructor metanarrative (explaining the rationale behind instructional actions) and student self-created clicker questions within the model, with an aim to foster advanced skills such as critical thinking. Both their quantitative and qualitative data suggested very positive student perceptions of this CRS-based instructional model.

Three Active Ingredients of Effective CRS-based Instruction

As CRS-based pedagogies are highly flexible in implementation, it is important to know what is at the core of these pedagogies that is indispensable to their effectiveness. Based on extensive review of the CRS literature, the researcher identified the following three active ingredients of CRS-based instruction: a) questioning with good questions; b) formative assessment, cybernetic feedback and agile teaching; c) peer dialogue.

Questioning with good questions. Questioning is a time-honored teaching technique, a central pillar in the widely-recognized Socratic method of teaching. At the very least, posing questions can help direct students' attention to what is important about the course material, an essential first step to understanding (Beatty, Gerace, Leonard, & Dufresne, 2006b). In addition, questioning helps create situations where students have to use active mental processes in order to come up with a response, and thereby they learn to think (Bligh, 1998). Campbell and Mayer (2009) used the following three terms in their attempt to offer some theoretical explanations for the power of questioning: 1)

Generation. knowing a question will be asked will induce students to process the material at a deeper level and organize it in their brain in a way that is easily retrievable when needed; 2) *Engagement.* In order to answer a question, students will need to be more attentive and actively engaged in effortful cognitive activities. 3) *Metacognition*. Answering questions and especially receiving feedback will cause students to gauge their own state of understanding and think about where they should focus their cognitive energy.

Although questioning itself has inherent value, deep understanding and higher-order reasoning is advanced by good questions that can stimulate some intended cognitive processes and discipline-specific habits of mind towards meeting certain learning objectives (Beatty et al., 2006b). The characteristics of a good clicker question will be discussed later in the *Important Pedagogical Considerations for Using CRS* section.

Formative assessment, cybernetic feedback and agile teaching. In the assessment literature, a distinction has been made between *summative evaluation* and *formative evaluation (*Scriven, 1967*).* These two types of assessment have widely been conceptualized as *assessment of learning* and *assessment for learning* (Elwood & Klenowski, 2002), respectively. Generally speaking, summative evaluation is usually conducted at the end of a learning episode to determine if students’ performance levels have met required standards towards certification or selection or some other purposes that involve judgment of the students’ work. Formative assessment, on the other hand, forms an integral part of the ongoing teaching and learning process and is performed at regular intervals to provide feedback to be used for attuning instruction to meet students’ learning needs (Black & Wiliam, 1998).

Whereas both assessments are necessary, large learning gains have been empirically linked to formative assessment (Black & Wiliam, 1998), leading to Elwood and Klenowski‘s (2002) assertion that “to improve learning and indeed teaching, assessment must be formative in both function and purpose and must put the student at the centre of the assessment process” (p. 244).

Formative assessment had its origin from cognitive and constructivist learning theories. It is closely associated with the conception of feedback and development, which is achieved through monitoring and mediation. Constructivist feedback is cybernetic and iterative, taking place between the instructor and students, between students and within the student (Roos & Hamilton, 2005). CRS has the potential to help create such feedback in even a large lecture room. The tallied student responses generated by CRS inform students about their own state of understanding (even better, also that of their peers). They are at the same time feedback for the instructor about how the entire class is following. The benefits of CRS in terms of feedback will stop here if it is not combined with further pedagogical actions. However, when used to stimulate peer and class-wide discussion, the computer-generated feedback will lead to further and more informative feedback for both the instructor and the students (between and within themselves) as students are exposed to one another's ideas and erroneous reasoning is being surfaced.

Agile teaching, as discussed earlier, is instruction contingent on students' real-time learning needs as revealed by the feedback from formative assessment. Formative assessment, feedback and agile teaching, therefore, form an iterative cycle, turning the class into a dynamic, student-centered learning environment.

Peer dialogue. A large body of literature suggests that successful clicker-based pedagogies usually have a peer discussion component. The social aspect of CRS use not only makes a large lecture class less impersonal, but directly contributes to better learning.

Peer dialogue is a crucial element that shifts CRS use from a behaviorist approach to a constructivist approach, extending the benefits from questioning and simple feedback to those from social learning. Constructivism holds that knowledge is constructed through both individual efforts and social interaction, with the latter playing an even more significant role (Brown, Collins, & Duguid, 1989; Jonassen, 1991; Vygotsky, 1978).

While making a case for the power of peer discussion, Beatty et al. (2006b) argue that since thinking is often amorphous, the act of verbalizing it in front of peers can help students clarify their own reasoning. In addition, discussion exposes students to different points of view, some of which will challenge their own. Such confrontation with alternative ideas, according to the authors, will result in deeper understanding than merely telling students what the solutions are. Nicol and Macfarlane-Dick (2006) see the unique value of peer dialogue in that peers are often able to explain in a way that is more easily comprehensible than the instructor would due to the fact that they have just arrived at the correct reasoning.

It should be noted, however, that simply asking students to discuss among themselves may not be enough for students to make the best of this social learning experience. Lucas (2009) noted that peer discussion worked best when clear instructions were given to students. He also found that having his mathematics students use pencil and paper to write down their reasoning during discussion made the activity even more productive.

Important Pedagogical Considerations for Using CRS

Good clicker questions. The quality of clicker questions is crucial to the successful use of CRS. The criteria for a good clicker question may vary across disciplines, but there is some general agreement in the literature on what makes an effective CRS question: a) Qualitative, conceptual questions that require deep understanding and higher-order thinking are preferred to quantitative and factual questions that mainly involve calculation and recall (Beatty, 2004; Beatty et al., 2006b; Crouch et al., 2007); b) A good question should base incorrect answers (distracters) on common student misconceptions or difficulties (Cutts, Kennedy, Mitchell, & Draper, 2004; Wit 2003); c) A good question should be challenging enough but not overly difficult, targeting at a correct answer rate of 35%-70% (Crouch et al., 2007). A clicker question at such difficulty level is reflective of the constructivist Zone of Proximal Development theory (Vygotsky, 1978). Instructors can use peer discussion as scaffolding to help students close the gap in their understanding; d) The best clicker questions, in terms of their potential to stimulate discussion, are those open to multiple interpretations rather than limited to one single solution (Miller, Santana-Vega, & Terrell, 2006).

Some additional suggestions for clicker question design offered by Wit (2003) also merit consideration: The language used for questions and answer choices should avoid confusion between testing understanding of a jargon and understanding of the related concept; all answer options should be logical and credible in form and structure, and an "I don't know" option should be included to minimize strategic and random guessing for the obvious reason that guessing defeats the purpose of formative assessment.

Apart from the quality of question design, another critical part of creating a clicker question, according to Beatty et al. (2006b), is determining what the instructor wants the students to learn and be able to do by that question. The authors contend that every clicker question should be created with a clear instructional purpose, which includes a content goal, a process goal, and a metacognitive goal. For the content goal, questions should avoid merely testing memorization of facts but focus on understanding. For the process goal, questions should be able to foster certain cognitive skills that enable students to apply their knowledge in diverse contexts. Finally, an effective question should also contain a metacognitive goal that influences students' perspectives and approaches to learning.

Pre-class preparation. One of the reasons for students' reluctance to engage in peer discussion is poor preparation for class (Hoekstra, 2008). Research consistently reveals that only 20-30% of college students complete their reading assignments on any given day (Hobson, 2004). Reading compliance becomes a more compelling issue when CRS-based instruction is used. Successful CRS use depends on students' initial engagement with course material (especially introductory and factual material) prior to class since a considerable portion of class time will be devoted to exploring and integrating important concepts through CRS-facilitated discussion (Dufresne, Wenk, Mestre, Gerace, & Leonard, 1996). Students cannot expect their instructor to present course material at the level of detail typical in a traditional lecture class. Instead, they will be challenged with questions that require at least a cursory understanding of relevant course material for the related discussion to be useful and interesting to them.

Reading quiz and reading questions as incentives. Reading quiz, administered either before or at the beginning of class, is a common incentive used by instructors to encourage pre-class reading. While some instructors have had some success with it, others are frustrated by student apathy and the disappointing results. Discussing the challenges of creating reading quiz questions in the context of teaching physics, Henderson and Rosenthal (2006) state that simple factual questions may reinforce the already prevalent student conception that physics is all about memorizing and plugging numbers into equations, while deep conceptual questions are not fair to students, who encounter the material for the first time. They suggest using student self-created *reading questions* in the place of reading quizzes. These questions are formulated by students after reading the assigned material and therefore reflect students' perspectives and concerns about course topics.

The reading incentive Crouch and Mazur (2001) found most effective is, in fact, a combination of quizzing and probing questions – a three-question web-based assignment they have used since 1998. The first two questions have students grapple with what the instructor considers difficult in the material, while the last question solicits what *students* find most difficult or confusing.

Course-level solutions. Reading quiz and reading questions can work well if used strategically; however, looking at the issue of reading noncompliance from a holistic perspective (going beyond the "lazy students" view) may lead to even better results. After examining the teaching side of the "teaching and learning coin" for weaknesses in course design that are associated with poor reading compliance, Hobson (2004) offered some multi-dimensional solutions. Examples are: aligning reading assignments with learning objectives, students' reading abilities, and academic success (as reflected in a good final grade); assigning priority levels to reading materials so that only the absolutely essential material will be labeled "required" reading, meaning students can have more success with less work; providing reading guides targeting students with middle to low level reading capabilities; and most interestingly, shaping classroom experience to make reading preparation an absolute necessity.

The last suggestion can be followed by using a teaching method known as "Just-in-Time Teaching" (JiTT). JiTT uses the web for most of the content delivery and frees up class time for interactive, collaborative activities. Students are exposed to rich, up-to-date, hyperlinked, multi-entry, and multimedia-powered course resources. They can study at their own pace in an order that they prefer, and they can easily access real-world applications and examples of course concepts. After studying the assigned course content, students identify what is difficult for them and answer (or pose) their reading questions that are due shortly before class. Their responses will be used by their instructor to shape class activities. With JiTT, students tend to be more engaged and actively involved in class as the class activities are built "just in time" to address their difficulties (Novak, Patterson, Gavrin, & Christian, 1999).

JiTT works perfectly with CRS-based instruction. The PI pioneers adopted this teaching method as part of their PI package and found that it enhanced their implementation of PI (Crouch & Mazur, 2001).

Metacommunication. Students who like the flexibility in class attendance and participation, or who believe that learning means memorizing and regurgitating what is taught to get a good grade may not appreciate the use of CRS (Duncan, 2006; Trees & Jackson, 2007). Moreover, students who do not see the value of peer learning may just go through the motions during peer discussion while waiting impatiently for the correct answer from the instructor (Hoekstra, 2008). In fact, for most students (especially those who performed well under traditional instruction), the transition from a passive learning mode to an active one could be quite a challenge as it involves many drastic changes in how students approach studying in and out of class (Dufresne, Wenk, Mestre, Gerace, & Leonard, 1996). All these speak to the need for instructors to explain the benefits of using CRS and the accompanying pedagogical changes in order to "frame student perceptions of the technology" (Trees & Jackson, 2007, p. 38). Such explanation is termed "metacommunication" by Beatty (2004), who argues that articulating the rationale behind instructional decisions is the most influential factor in shaping student attitudes towards educational innovation.

Grading scheme. There seems to be no single best grading scheme for CRS questions. A particular grading scheme may work well in one context, but may not in another due to differences in student demographics, levels of motivation, class culture, etc. However, the general advice from the research literature is to avoid high-stakes grading (James 2006; James, Barbieri, & Garcia, 2008; Willoughby & Gustafson, 2009).

High-stakes grading may reduce the value of clicker questions as formative assessment, causing students to be more concerned about the correct answer than the correct reasoning behind it. Such emphasis on getting the correct answer may foster the adoption of performance goals (working for obtaining positive judgments or avoiding negative judgments) at the expense of mastery goals (working to build competence and master knowledge), as theorized by Dweck (1999) and Roschelle, Penuel, and Abrahamson (2004). As a result, students spend more energy in seeking out ways to get good grades than in improving learning, which often leads to their avoidance of academic risk-taking and independent thinking (Black & Wiliam, 1998; Dweck, 1999).

Based on a systematic review of research, Harlen and Crick (2003) conclude that frequent high-stakes assessment negatively impact students' motivation to learn.

These theories and findings are further corroborated by some recent studies examining the impact of clicker grading scheme on the dynamics of peer discussion. James (2006) and James et al. (2008) found that high-stakes assessment led to domination of dialogue by more knowledgeable or confident discussion partners while low-stakes grading practice contributed to a more balanced peer discourse. Furthermore, with low-stakes assessment, there was more disagreement in students' voting results after peer discussion, indicating that without concerns for grades, students were more likely to be honest with their own understanding. The display of responses, therefore, became a more truthful feedback to the instructor. These findings were echoed by Willoughby and Gustafson's (2009) study, which also found some negative influence of high-stakes grading practice on the nature and quality of peer discussion.

Instructors who do not find enough incentives in low-stakes grading (including giving participation points only) may consider Salemi's (2009) suggestion as an alternative. Distinguishing ConcepTests from "Are you with me" type of CRS questions, Salemi seems to say, "You can have the best of both worlds": encouraging free idea sharing by not grading the conceptests (higher-order conceptual questions), as suggested by Mazur (1997), but grading "Are you with me" questions (moderately challenging comprehension-checking questions) to provide incentives for attendance and participation.

Research on CRS Use in Psychology

Research on the use of CRS in Psychology is still in its infancy (Kelly, 2009), and existing research is mostly characterized by a technology-centered design focusing on the "if" (if CRS increases learning and engagement) rather than the "how" (how to use CRS to increase learning and engagement).

Technology-focused research design. Studies comparing student groups with and without CRS treatment have not yielded many impressive findings. For instance, in Poirier and Feldman's (2007) study, the clicker group only outperformed the non-clicker group by 1.31 points (Cohen's $d = .17$). In terms of student attitudes, nearly half of the students did *not* believe that clicker use had greatly increased their learning.

Stowell and Nelson (2007) gave a 30-minute simulated introductory psychology lecture to participants, who were assigned to one of four conditions – clickers, standard lecture, hand-raising and response cards. They found no differences between groups on learning outcome measures, although they did observe the highest participation in the clicker group, as mentioned earlier in this paper.

Morling et al. (2008) found a small positive difference on learning outcomes and no significant difference on students' self-reported level of engagement between their clicker groups and non-clicker groups (two sections of introductory psychology courses for each group). Morling et al. acknowledged that they made very limited pedagogical use of clickers and recommended using conceptual questions (they only used factual, quiz questions) and group discussion to augment the effects of CRS.

Limited pedagogical vision. Examining the impact of the questioning method (implemented with CRS) on learning outcome, Campbell and Mayer's (2009) and Mayer et al.'s (2009) studies showed more concerns about pedagogy than the response technology per se. With two similar lab experiments, Campbell and Mayer compared a group of students that received a 25-slide PowerPoint lecture with four inserted multiple choice questions and an equivalent group that received the same lecture but with four corresponding statements embedded in the slides. Clickers were used to facilitate the questioning and feedback in the questioning group. Results showed that the test performance of the questioning group is only significantly higher than that of the control group on one of several measures in both experiments.

Mayer et al.'s (2009) study compared two treatment groups and one control group (all lower-division psychology majors but from three consecutive academic years): In the clicker group, CRS was used to implement 2-4 multiple-choice comprehension-checking questions; In the "no-clicker group", question sheet was used for collecting answers and hand-raising for tallying; In the control group, no questioning was used. The results revealed that the clicker group outperformed both the no-clicker/paper group ($d = 0.38$) and the control group ($d = 0.40$) by approximately 1/3 of a grade point. The lack of significant difference between the paper group and the control group was unexpected to the authors because they believed that it was the instructional method of questioning that caused improvement in student performance, not the technology. Their attempted explanation was that the effectiveness of questioning was compromised with the paper group by logistical disruption, which led to their conclusion that the clicker technology was more powerful in bringing out the benefits of the questioning method than the paper alternative.

Despite their adherence to pedagogy as the reason for increased learning, they seemed to have been limited by their vision about what pedagogical techniques can be used in conjunction with the clicker technology to improve learning. Maybe that is why they did not see another limitation of their study as a possible explanation of the results; that is, the instructional method was not held constant across the clicker and the paper group. According to their description, the clicker group used some peer discussion and the questions were periodically inserted into the lecture, while the paper-based group did not use peer discussion and all questions were administered at once at the end of the class. These variations were more likely to have contributed to the difference between the clicker group and the paper group and the lack of difference between the paper group and the control group, since the placement of clicker questions and peer discussion are both important pedagogical strategies.

Possible explanations for lack of impact of CRS use. There are three possible explanations for the lack of strong evidence in favor of CRS use in Psychology. First, the quality of clicker questions could have affected the impact of CRS use in Campbell and Mayer's (2009) and Morling et al.'s (2008) studies where factual questions rather than conceptual questions were used. Secondly, clicker questions were not used at strategic points throughout the lecture to form an integral part of instruction but treated as an add-on, such as using it only for quizzing (e.g. Morling et al., 2008) or to end an activity (e.g. Poirier & Feldman, 2007). Thirdly, CRS was not used in conjunction with active engagement techniques and did not capitalize on peer learning. For example, in Stowell and Nelson's (2007) study, after presenting a question and having students register an answer, the instructor simply stated the correct answer and moved on to the next topic without encouraging any peer discussion or class-wide discussion.

Research suggests that habitually revealing the correct answer right after student responded inhibits deep learning. As Beatty et al. (2006b) points out, having students articulate and confront other conceptions is “the fastest, most durable way to build understanding”, and “helping students develop a general understanding of the subject matter, not just learn the answer to the immediate question, is the instructor’s ultimate purpose” (p. 7). Similarly, only asking students to explain the correct answer without trying to elicit the reasoning behind their choice of incorrect answers means missing out on good opportunities to tackle and remove student misconceptions.

Research Questions & Hypotheses

The review of literature revealed a few gaps in CRS research. The majority of research was undertaken in natural sciences where CRS has been primarily used. Among the relatively few studies conducted in psychology, most involved non-major introductory courses. The present study may fill these gaps by recruiting upper-division psychology majors.

While successful CRS use in natural sciences abounds, research findings in the psychology discipline have not been as uplifting. Inspired by good clicker-based teaching practice in physics education, the instructor involved in the present study adapted the CRS-facilitated Peer Instruction method and piloted it on three of his psychology major courses. It is, therefore, of primary interest to this study to obtain students' perceptions on how the adapted PI influenced their learning and engagement.

Also, as part of the i>clicker pilot project led by the Centre for Teaching and Learning Services (CTLS) at Concordia University where clicker use just started gaining ground, the study aims to derive some practical implications to inform CRS use university wide. It is also the researcher's hope to provide some food for thought for first time clicker users and inspire some discussions among faculty members about what constitutes good practice in CRS use in their own subject areas.

The study also intends to address a weakness in educational innovation involving new technologies. As Witte (2007) so wittily points out, there is a dangerous tendency to equate innovation in education to product adoption in popular discourse about educational technology. He argues that when the technology is simple and designed to enhance a limited number of teaching innovations, it is not as critical to make the distinction; however, when a technology can be used to support diverse pedagogical practices, it becomes obscure whether people are talking about the same pedagogical application of the technology and whether they share the same vision about what the technology will help them achieve when they refer to the teaching innovation as the technology. This is exactly the issue with CRS adoption. Not only is the word "clickers" (or other names CRS goes by) often used in the place of related pedagogical terms in common discourse among faculty members, but a large strand of research studies was devoted to investigating the learning impact of the technology alone, despite some widely recognized view that media does not cause learning by itself (Clark, 1994).

In view of the harmful ramifications of product-oriented discourse and the unproductive research efforts in teasing out the impact of CRS from CRS-based pedagogies, this study treats the response technology and PI as one package. The bundle will be referred to as CRS-PI as a shorthand for CRS-facilitated PI used earlier. The researcher believes that a systematic pedagogy-oriented approach to CRS study will yield some unique insights as to how to use the technology effectively in the service of teaching and learning, and fill some serious gaps in existing literature where very few efforts have been made in this direction.

As part of a holistic approach, a detailed description of how CRS-PI was implemented in this study and how it fit in with other elements of the course will be provided in the Method section to give a frame of reference for the discussion of results to the following research questions, which probe student perceptions of the impact of CRS-PI on various aspects of their learning and engagement:

R.Q.1. To what degree do students believe that CRS-PI enhanced their mastery of subject matter in the course?

R.Q.2. To what degree do students believe that CRS-PI enhanced their metacognition?

R.Q.3. To what degree do students believe that CRS-PI enhanced their motivation?

R.Q.4. To what degree do students believe that CRS-PI made the class more enjoyable?

R.Q.5. To what degree do students believe that CRS-PI increased their involvement?

R.Q.6. What specific aspects of CRS-PI do students like/dislike?

Student perception research has indicated that student attitudes towards clicker use vary substantially, even in the same context. While some find clickers helpful, others think they take away from precious lecture time (Poirier & Feldman, 2007). Even in case of overwhelming acceptance, there is always a small subset of students who does not embrace the technology. This leads to the hypothesis that certain student characteristics have some bearings on student attitudes towards clicker-based instruction.

There have been some research efforts aimed to uncover the relationship between student attributes and their perceived usefulness of CRS, such as Graham, Tripp, Seawright, and Joeckel's (2007) examination of students' inclination to participate, MacGeorge et al.'s (2008) investigation on students' desire for involvement and engagement, view on traditional lecture, value placed on feedback, class standing (academic level), past experience with lecture courses, anticipated course grade and amount of clicker use, and Trees and Jackson's (2007) exploration of aptitude for learning, objective learning, subjective learning and conceptualizations of the learning process, etc. as influencing factors. Nonetheless, the dearth of research in this area can hardly make the available evidence conclusive. More research is needed to determine what characteristics of students influence their evaluations of CRS. The current study, therefore, attempts to add to this small pool of research findings. Due to the scope of this paper, only the following aspects will be investigated and the questions are framed in hypotheses based on existing research findings.

H1. Students' *age* will negatively predict their perceived usefulness of CRS-PI.

H2. Students' *academic level* (years in school) will negatively predict their perceived usefulness of CRS-PI.

H3. Students' *course performance* (as reflected in their final grade) will negatively predict their perceived usefulness of CRS-PI.

H4. Students' *preferences for learning and assumptions about how lecture courses should be taught* presumably more compatible with active learning will positively predict their perceived usefulness of CRS-PI.

H5. Students' *preferences for learning and assumptions about how lecture courses should be taught* presumably less compatible with active learning will negatively predict their perceived usefulness of CRS-PI.

Method

Participants

Ninety-six students from two 400-level and one 300-level university psychology courses (Memory & Attention; Cognitive Development; Cognitive Psychology) participated in the study. These were medium enrolment courses with 50-60 students for each class. All three classes were taught by the same instructor and met for 75 minutes twice per week. The way CRS-PI was used and the structure of the courses were essentially identical.

Of the 96 participants, 20 were male and 75 were female with one person's gender unknown due to missing data. Their academic levels varied, with 2.1% (N=2) in their first year, 31.3% (N=30) in their second year, 44.8% (N=43) in their third year, and 20.8% (N=20) in their fourth year. There was one (1%) independent student.

Procedure

Data were collected near the end of the semester in the last test review session (there were four tests during the semester). The instructor and the researcher chose that particular session because it was relatively easy to find 30 minutes for students to complete the survey given no lecturing was planned for the session other than the review (students were not informed about the survey ahead of time); however, we did not expect that approximately one third of the students in each class would be absent – they probably thought their time could be more productively used by studying on their own for the upcoming final exam. As a result, we were only able to collect data from 81 students, which included almost everyone that showed up in class. To reach more students, we set up an online survey with SurveyMonkey and obtained data from another 15 students.

Students were informed that the purpose of the survey was to invite them to evaluate the way clickers were used in class, nor the instructor, nor the course. They were given a consent form to sign, and also verbally reminded that participation was voluntary and confidential. They were asked to provide their student ID (should they choose to participate) but were reassured that their ID would only be used to link data and their instructor would not have access to their responses until after their final grade was submitted. The instructor was absent from the room during the entire process to ensure voluntary participation.

Instrument and Measures

The main instrument of the study was a self-created questionnaire (see Appendix I for the questionnaire per se and Appendix II for subscales and categories). The items in the questionnaire were either borrowed, adapted from, or inspired by survey questions used by previous studies (Bode, Drane, Kolikant, & Schuller, 2009; DeBourgh, 2008; Graham, Tripp, Seawright, & Joeckel, 2007; MacGeorge et al., 2008; Nicol, & Boyle, 2003; Pelton, Pelton, & Sanseverino, 2007; Trees & Jackson, 2007) addressing similar concerns. The inclusion criteria were consistent with the needs to answer the research questions proposed earlier. The questionnaire went through an expert review and a pilot test on six students who had taken the same courses with the same instructor and been exposed to CRS-PI in much the same way as the students under the present study. Revisions were made according to the feedback obtained from these sources.

The first section of the survey requested demographic information. The second section included 40 five-point Likert-scale items (1 = strongly disagree to 5 = strongly agree). These items were designed to measure: students' perceived impact of CRS-PI on their learning and engagement, the extent to which students agree with commonly claimed benefits of peer discussion, and students' learning preferences and assumptions about lecture classes. The third section asked respondents to rate on the overall usefulness of CRS-PI (1 = very useful; 2 = somewhat useful; 3 = Neutral–no additional benefits, but no downsides either; 4 = Negative to some degree–somewhat a waste of time and resources; 5=Very negative overall–a complete waste of time and resources). The last section was an open-ended question, inviting students to comment on what they like best about the way CRS-PI was used and what improvement is needed.

Learning and Engagement measures. Two subscales were created for measuring perceived learning outcomes: Mastery of Subject Matter (MSM, 5 items) and Metacognition (5 items). Three subscales were created for measuring perceived engagement outcomes: Motivation (4 items), Enjoyment (4 items), and Involvement (4 items). At the analysis stage, one item (Q40) in Motivation was removed to improve Cronbach's α from .66 to .74 and one item (Q12) in Involvement was removed to improve Cronbach's α from .61 to .74, resulting in three items for each of these two subscales. Q17 and Q18 were reverse-coded so that higher scores reflected stronger agreement with the positive impact of CRS use. Table 1 reports inter-item reliability for all subscales.

Table 1 Internal Reliability for Learning and Engagement Subscales

Subscales	No. of Items	Inter-item Reliability
MSM	5	Cronbach's α: .79
Metacognition	5	Cronbach's α: .77
Motivation	3	Cronbach's α: .74
Enjoyment	4	Cronbach's α: .76
Involvement	3	Cronbach's α: .74

Learning preferences and assumptions measures. There are 10 items for measuring students' learning references and assumptions about lecture courses. Areas of investigation include: desire to participate, willingness to be involved and engaged, preference for individual vs. group learning, valuing of knowledge vs. grades, and assumptions about how lecture courses should be taught, etc. These items will be used as predictor variables to be regressed on the five subscales measuring learning and engagement to determine how these factors influence students' perceived benefits of CRS use.

Peer discussion specific items. As stated earlier, these six items were intended to measure to what extent students agree with commonly claimed benefits of peer discussion and the mechanisms (as identified in the literature) through which peer discussion helps increase understanding. These will be analyzed item by item.

The remaining two items were created to investigate if novelty effect was present with CRS use or if students like the technology better as they get more accustomed to it. It is excluded from analysis for this paper due to scope reasons, but will be discussed elsewhere.

How CRS-PI Was Implemented in the Current Study

Since an important goal of this paper is to contribute to a pedagogy focus in CRS research, a detailed description of how CRS-PI was used by the instructor in the current study is warranted. As Beatty and Gerace (2009) state, researchers, practitioners and alike should elaborate their pedagogical perspectives and methods in order to shift scholarly attention from technology to pedagogy. The following description is based on three classroom observations and an interview with the instructor.

The three courses involved in the study were semi-required for psychology majors (students were required to take three out of four such courses). As described earlier, one of the courses was at 300 level and the other two 400 level.

CRS-PI classroom procedure. Three or four times during a lecture, the instructor would pose a multiple-choice question, give students one or two minutes to ponder (time given varied depending on the difficulty level of the question), and then invite them to vote individually for an answer. Next, without displaying the response distribution graph, he would encourage students to discuss with 2 or 3 neighboring students and try to come to consensus. The reason for hiding the graph was to avoid influence on the discussion by the most popular answer. However, in cases where responses were more or less evenly distributed, the instructor would show the graph to stimulate more heated discussion. When peer discussion trailed off, the instructor would stop the discussion and ask students to reconsider the question and vote again. Some class-wide discussion on both correct and incorrect answers would usually ensue. The instructor tried to withhold the correct answer to the very end. Whenever possible, he tried to lead students to find the correct answer by themselves through discussion or through guiding questions he posed at them.

Clicker questions. Fully aware that creating good clicker questions entail a deep understanding of common student misconceptions and mistakes, the instructor used a few strategies to identify where students tend to stumble in the course material to make up for his lack of experience with these courses (he was teaching all three courses for the first time). One of them was to have students journal about what they found difficult in the text. He would browse through those online journals before coming to class, and then in class, he would adjust his delivery and occasionally ask on-the-fly clicker questions to address those difficulties revealed in student journals as well as issues identified real time during instruction. Another interesting way he used CRS was to co-create clicker questions with students in class. He would pose a question and have students provide possible answers for polling and discussion, yet another way to surface students' state of understanding.

Having students create their own clicker questions was one more strategy the instructor tried and found rewarding. He gave students some guidance on how to approach this challenging task, such as how to use Bloom's taxonomy (Bloom, 1956) to design questions at a specific level (Bloom's six level of cognitive learning are: knowledge, comprehension, application, analysis, synthesis and evaluation). This strategy had multiple benefits. It not only added to his knowledge of what students perceived as important or difficult, but prompted his students to approach the material at a deeper level and think more like an expert.

Grading scheme. The instructor assigned 7% of the final grade to clicker questions based on participation only (regardless of the correctness of answers).

Incentives for reading. Apart from the learning journals mentioned earlier, the instructor also gave online pre-class reading quizzes (using Moodle, a course management system used by the university) before starting a new chapter (one chapter was usually covered by two sessions). To give a boost to students discouraged by the difficulty in making sense of the text, he also provided some reading guides and tips for some of the chapters. There was also a post-chapter quiz at the end of each week to ensure the text was understood.

Online discussion forum. The instructor set up an online forum on

Moodle for students to post and answer questions. It was a good compensation for the reduced lecture time due to the implementation of CRS-PI. The forum traffic was satisfactorily busy, especially before tests and exams.

Metacommunication and metacognitive coaching. The instructor spent a fairly large portion of the first session explaining the learning benefits of using CRS-PI. To secure student buy-in and maintain student motivation, he repeated and varied his “sales pitch” many times during the semester. In fact, he intentionally made metacommunication an integral part of his instruction, making sure students not only follow class activities but know why they are doing what they are doing (what they can potentially get from doing it). He encouraged students to think about their own learning and what they could do to become a better learner by explicitly teaching them the concept of metacognition and modeling it through frequent meta-level talk.

The instructor’s holistic approach to integrating CRS-PI was met with wide enthusiasm and acceptance by the students. Although no experimental studies were conducted to measure objective learning outcomes, the survey results to be presented in the next section provides a comprehensive student evaluation of the various aspects of this pedagogical approach.

Results

Perceived Influence of CRS-PI on Learning and Engagement

The first five research questions investigate if and to what extent students perceive CRS-PI as a positive influence on their learning and engagement in the following five dimensions: Mastery of Subject Matter (MSM), Metacognition, Motivation, Enjoyment and Involvement. Note that the word "clickers" was used in the questionnaire instead of CRS-PI to ensure ease of communication, but it was explained both on the consent form and verbally by the researcher that students were invited to evaluate how clickers were used in combination with the Peer Instruction method.

Perceived influence on Mastery of Subject Matter (MSM). As can be seen from Table 2, the results indicate overwhelmingly positive evaluations on the MSM subscale. The grand mean, calculated after reverse-coding Q17, is 4.08. The percentages of students who agree and strongly agree with the first four claimed benefits are 84%, 85%, 82%, 81%, and 83% of students disagree and strongly disagree that clicker use took away from their learning (Q17).

Table 2 Perceived Influence on MSM (Grand Mean = 4.08)

Mastery of Subject Matter	SD	D	NT	A	SA	Mean	SD	N
Q1.Because we use clicker questions, I understood more than I would have otherwise.	1% (1)	5% (5)	9% (9)	59% (57)	25% (24)	4.02	0.81	96
Q6.The use of clickers has helped me learn the course material.	2% (2)	4% (4)	8% (8)	55% (53)	30% (29)	4.07	0.86	96
Q9.The use of clickers has helped me develop a deep understanding of concepts.	1% (1)	6% (6)	11% (10)	57% (54)	25% (24)	3.99	0.84	95
Q4.Using clickers has helped the instructor to tailor his teaching to class needs.	0% (0)	1% (1)	18% (17)	51% (49)	30% (29)	4.10	0.72	96
Q17.I would have learned more without the use of clickers.	43% (41)	40% (38)	15% (14)	3% (3)	0% (0)	1.78	0.81	96

Note: SD is short for "strongly disagree", D for "disagree", NT for "neutral", A for "agree" and SA for "strongly agree". These abbreviations hold true for the rest of the paper.

Perceived influence on Metacognition. As shown in Table 3, students who agree and strongly agree with the positive influence of CRS use on the five aspects of metacognition are also among the majority: 82%, 88%, 71%, 84%, 85%, resulting in a grand mean of 4.03. The one item that stands out from the rest is

Q21 (Clicker questions have helped me prepare for exams), which receives noticeably less agreement (71%), with 10% of students disagreeing and strongly disagreeing and 19% neutral.

Table 3 Perceived Influence on Metacognition (Grand mean = 4.03)

Metacognition	SD	D	NT	A	SA	Mean	SD	N
Q11.Clicker questions made me more aware of my weaknesses in my understanding of course material.	1% (1)	6% (6)	11% (11)	38% (36)	44% (42)	4.17	0.94	96
Q3.Clicker questions have helped me focus on key knowledge.	0% (0)	3% (3)	8% (8)	53% (51)	35% (34)	4.21	0.72	95
Q21.Clicker questions have helped me prepare for exams.	5% (5)	5% (5)	19% (18)	49% (47)	22% (21)	3.77	1.02	96
Q19.The use of clickers has helped me determine how well I have mastered course material.	2% (2)	6% (6)	7% (7)	57% (55)	27% (26)	4.01	0.89	96
Q14.The use of clickers has made me more aware of the instructor's expectations.	1% (1)	6% (6)	7% (7)	61% (59)	24% (23)	4.01	0.81	96

Perceived influence on Motivation. Compared with the results for the two learning subscales, students' perceived gains on Motivation is considerably lower, with a grand mean of 3.53. Table 4 suggests that 68% of students agree and strongly agree that clicker use has increased their desire to come to class. A little less than half (43%) agree and strongly agree that CRS use motivated them to spend more time preparing for class, with 26% disagreeing and strongly disagreeing and 31% neutral. Slightly more than half of the students (58%) agree and strongly agree that CRS use motivated them to ask more questions, with 14% disagreeing and strongly disagreeing and 28% neutral.

Table 4 Perceived Influence on Motivation (Grand mean = 3.53)

Motivation	SD	D	NT	A	SA	Mean	SD	N
Q5.The use of clickers has increased my desire to come to class.	4% (4)	5% (5)	23% (22)	42% (40)	26% (25)	3.80	1.02	96
Q7.The use of clickers has motivated me to spend more time preparing for class.	5% (5)	21% (20)	31% (30)	28% (27)	15% (14)	3.26	1.11	95
Q2. Learning with clickers motivates me to ask more questions.	5% (5)	9% (9)	28% (27)	42% (40)	16% (15)	3.53	1.04	96

Perceived influence on Enjoyment. Among all Learning and Engagement subscales, Enjoyment enjoys the highest scores (grand mean = 4.39). As high as 88%, 93%, and 90% of students agree and strongly agree to the first three statements, and 89% disagree and strongly disagree to the negatively worded item (Q18). Students who do not find CRS use enjoyable are only among the 1%, 2% and 3%. The details are presented in Table 5.

Table 5 Perceived Influence on Enjoyment (Grand mean = 4.39)

Enjoyment	**SD**	**D**	**NT**	**A**	**SA**	**Mean**	**SD**	**N**
Q8.Class time passes more quickly when we use clickers.	0% (0)	1% (1)	10% (10)	34% (33)	54% (52)	4.42	0.72	96
Q20.Using clickers to answer questions is fun.	0% (0)	1% (1)	6% (6)	42% (40)	51% (49)	4.43	0.66	95
Q10.I would like to use clickers in other courses, too.	2% (2)	0% (0)	8% (8)	39% (37)	51% (49)	4.36	0.81	96
Q18.I find clicker questions somewhat boring.	48% (46)	41% (39)	8% (8)	3% (3)	0% (0)	1.67	0.76	96

Perceived influence on Involvement. The first two interest-related items (see Table 6) are met with fairly high agreement (89% and 84%). In contrast, fewer students (62%) agree and strongly agree to the third item (Q23.Using clickers has helped make my input an important part of class), although the remaining votes are mainly distributed in the neutral category (31%), with only 7% in the disagreement categories. The grand mean for this subscale is 3.98.

Table 6 Perceived Influence on Involvement (Grand mean = 3.98)

Involvement	SD	D	NT	A	SA	Mean	SD	N
Q16.The use of clickers has helped me to stay interested during class time.	0% (0)	1% (1)	11% (10)	58% (55)	31% (29)	4.18	0.65	95
Q22.The use of clickers has heightened my interest in class discussions and lectures.	0% (0)	6% (6)	9% (9)	54% (52)	30% (29)	4.08	0.80	96
Q23.Using clickers has helped make my input an important part of class.	2% (2)	5% (5)	31% (30)	44% (42)	18% (17)	3.70	0.90	96

Global Rating of CRS-PI

For the overall rating question, 64% of students think CRS-PI is very useful, 31% think it is somewhat useful, 2% perceive no additional benefits but no downsides either, 3% believe it is somewhat a waste of time and resources, and nobody considers it a complete waste of time and resources. Both Table 7 and Figure 1 present the results to this question.

Table 7 Results to the Overall Rating Question

Which statement best reflects your OVERALL IMPRESSION of clickers and peer discussion?	Frequency	Percentage
1. Very useful	61	64%
2. Somewhat useful	29	31%
3. Neutral – no additional benefits but no downsides either	2	2%
4. Negative to some degree – somewhat a waste of time and resources	3	3%
5. Very negative overall – a complete waste of time and resources	0	0%

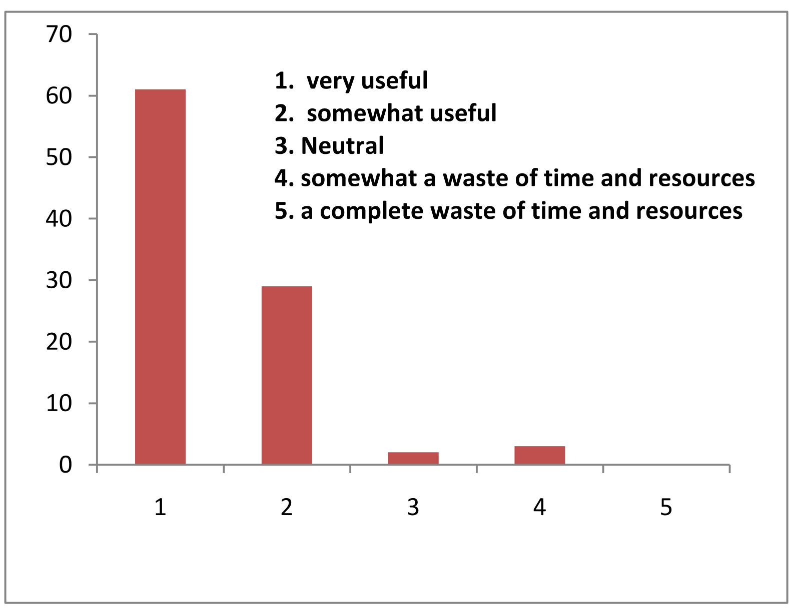

Figure 1 Results to the Overall Rating Question

Specific Benefits of Peer Discussion

Six peer discussion specific items are analyzed item by item. The item that receives the most agreement is Q29: As high as 91% of students agree and strongly agree that explaining their reasoning during peer discussion helps organize their thinking. A vast majority of students also agree and strongly agree that hearing peers' perspectives help them learn (86%), that peer discussion makes them pay more attention to the subsequent class-wide discussion and instructor explanation (87%), and that peer discussion helps them understand even if no one in the group initially knew the correct answer (85%). The only statement that receives less than half agreement (49%) is Q25 (I am more likely to speak up in a class-wide discussion after discussing the topic in small groups than I would otherwise). Another item that has fairly spread responses is Q26 (Having a number of different viewpoints during peer discussions often leads to confusion). Sixteen percent of students agree that peer discussion often confuses them. Both Table 8 and Figure 2 present the response statistics of PI-specific items.

Table 8 Responses to Peer Discussion Specific Items

PI Items	SD	D	NT	A	SA	Mean	SD	N
Q24. Hearing other students explain their reasoning during peer discussion has helped me to learn.	2% (2)	4% (4)	8% (8)	43% (41)	43% (41)	4.20	0.91	96
Q29. Trying to explain the reasoning behind my choice during peer discussion has helped organize my own thinking.	0% (0)	3% (3)	6% (6)	55% (52)	36% (34)	4.23	0.71	95
Q27. Discussing a clicker question in small groups makes me more attentive to the subsequent class-wide discussion and instructor explanation.	0% (0)	2% (2)	10% (10)	52% (50)	35% (34)	4.21	0.71	96
Q25. I am more likely to speak up in a class-wide discussion after discussing the topic in small groups than I would otherwise.	8% (8)	16% (15)	27% (26)	31% (30)	18% (17)	3.34	1.19	96
Q28. Small group discussions help with my understanding even if no one in the group originally had the correct answer.	1% (1)	3% (3)	10% (10)	54% (52)	31% (30)	4.11	0.79	96
Q26. Having a number of different viewpoints during peer discussions often leads to confusion.	13% (12)	49% (47)	23% (22)	13% (12)	3% (3)	2.45	0.97	96

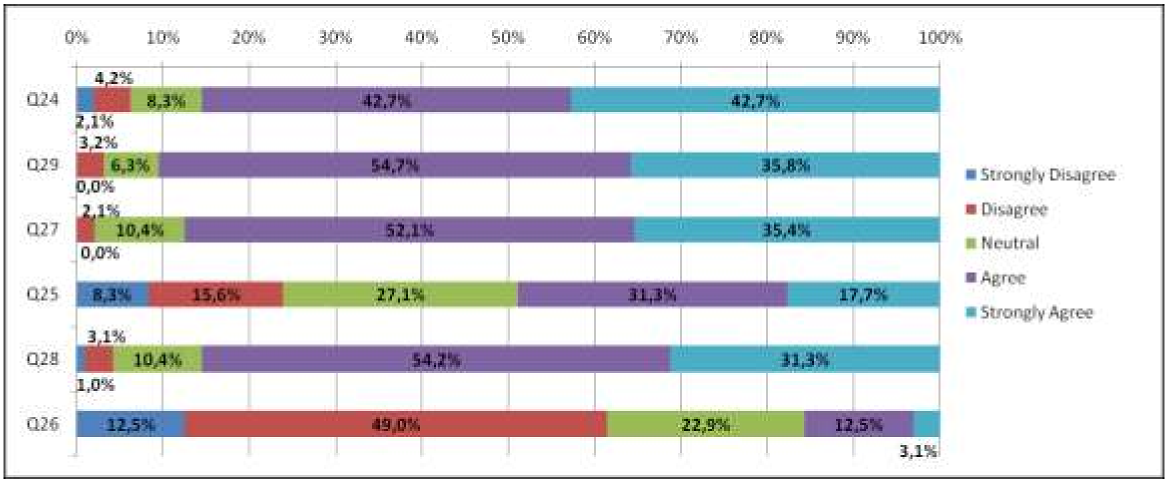

Figure 2 Responses to Peer Discussion Specific Items

Participants' Verbal Comments

The sixth research question focuses on specific aspects that students like about CRS-PI and their opinions on how to improve it. It is answered through content analysis of responses to the open-ended question in the questionnaire.

Data analysis is conducted through in vivo coding: a form of open coding that allows conceptual categories (themes) to emerge from the data. Coding and analysis are done by hand.

Among the 96 participants, 90 (94%) responded to the open-ended questions: What did you like best about your experience using clickers in this class? Which aspect about the use of clickers is most in need of improvement?

Student responses are highly positive. Among the 231coded comments provided by the 90 respondents, 177 are positive. The remaining 54 are more suggestions than negative remarks. In fact, only four out of the 90 respondents are more negative than positive.

Eight themes emerge from the 177 positive comments and two major findings are derived from the negative comments. Table 9 and Table 10 provide the themes, frequencies as well as some examples of participant comments.

The most common suggestion (by 8 respondents, 9%,) is to increase the number of clicker questions. For example:

> "In need of improvement would be that there needs to be more clicker questions!! Because it really helps us to test our knowledge."

The next common suggestion (by 5 respondents, 6%) is to post answers to clicker questions. For example:

> "The only possible improvement I could see for clickers is perhaps including the answers in the powerpoint presentations when it comes time for studying for the exam (sometimes I forget the answer and didn't write it down, etc.)."

Table 9 Positive Findings from Participants' Comments

Themes (N = 90)	Percentage (n)	Example Comments
Engagement (attention, interest, active involvement, mental efforts)	30% (27)	"I liked what using clickers did to the class! We talked, we discussed, it kept me interested, I followed the class, came to class… It kept me up to date with the class material!" "Overall, the clicker questions were very helpful in grasping more difficult topics as they force you to think about what's being lectured on vs. being a passive listener in class."
Better/deeper understanding and retention	22% (20)	"The honest truth is that because of the use of clickers and overall how the class operates I have learnt the most in this class. But not only have I learnt the most but I remember the most. …"
Enjoyment	24% (22)	"Best part about using clickers is combining fun with studying – almost like a game where you actually gain knowledge, too."
Mutual awareness, sense of community & exposure to multiple perspectives	21% (19)	"It was a good indicator as to where my knowledge lets me stand among the others in my class." "What I liked the most about the clickers was that it gave me a chance to see what other students were thinking. It's nice knowing that you're not the only person confused."

		"The class discussions based on the material were enjoyable and valuable for the cohesiveness of the classroom experience." "Discussing the questions help clarify a lot of information but also opened my mind to new ideas I wouldn't have thought of on my own."
Assessment and feedback (formative, stress-free assessment & instant, informative feedback)	18% (16)	"I enjoy getting immediate feedback on my understanding of the material without the stress of an exam." "What I liked best about the clicker use was the opportunity to monitor progress continually instead of having a surprise at the real examination." "What I liked about clickers is that I actually test my knowledge without risk of embarrassment in front of the class."
Low pressure participation (reduced shyness and easier participation marks for reticent students)	16% (14)	"My favourite aspect was that it enabled anonymous class participation, because I don't like speaking in front of a class, and the peer discussions allowed for a less intimidating opportunity to comment and provide ideas." "As a shy person it gives me the opportunity to talk with other students and become less shy." "I am a very quiet student, I tend to never ask questions but this class, thanks to the clicker questions and peer

		discussions enabled me to come out of my shell." "What I liked best about the clickers is that you can gain all of you[r] participation points by not having to speak up in front of the whole class. This can be intimidating for certain people and in other classes where active participation is required; ... In this class, I was able, for the 1st time, to gain all of my participation percentages, which is great and very helpful."
Focus on key points and concepts	10% (9)	"It's also beneficial because it focuses on the main concepts of the material which helps you in the understanding of the course." "They also emphasize the concepts that students are most hazy about which gives the teacher the chance to re-explain it." "Discussions explain theories or concepts we might not have paid proper attention to during the readings."
Preparation for exams	8% (7)	"Also, clicker questions often resembled exam questions or the format in which the teacher wrote his exams. Thus, they gave us an insight on what type of questions we should expect to be asked by the teacher."

Table 10 Negative Findings from Participants' Comments

Themes (N=90)	Percentage (n)	Example Comments
Peer discussion taking too long and/or occasionally confusing rather than enlightening	8% (7)	"The only downside was that sometimes the discussions went on a little too long." There was a couple times where I felt confident on a topic and then class discussion would cause confusion, but overall I found this beneficial as I was forced to think about the topic more deeply.
Clicker questions being vague and not having a single best answer.	6% (5)	"…The only thing that brought me to confusion was when some of the clicker questions didn't have a solid answer, ie it could be one or the other, the best ones for my learning were the one's that had a concrete answer. "Some answers were [not] concrete "could be this, could be that", which made it a little difficult when studying for tests." My only hesitation is that the clicker questions could be ambiguous, or with discussion more than one answer could be argued which was confusing.

Influence of Student Characteristics on Perceived Usefulness of CRS-PI

Multiple regression was used to test all five hypotheses, with the first three hypotheses tested using one analysis and the fourth and fifth using two separate ones. Stepwise was the method selected for each of the three separate analyses as shown in Table 11. Note that the variables within each group were entered simultaneously and the numbering does not signify a particular order.

For group 1 variables, the five age groups were coded as 1, 2, 3, 4 and 5 in ascending order. Academic level was coded as 1, 2, and 3, again in ascending order. Since there were only two first-year students, they were combined with the 30 second-year students and together coded as 1. The third-year students were coded as 2 and the fourth-year as 3. Final examination grades were used as course performance scores.

Table 11 Groups of Predictor Variables for Multiple Regression Analysis

Multiple Regression Analyses	Predictor Variables
Group 1 *(Demographics and academic performance)*	1. Age 2. Academic level 3. Course performance
Group 2 (*Learning Preferences and Assumptions Presumably More Compatible with CRS Use)*	1. I prefer classes where I have the opportunity to participate. (Q30) 2. Gaining knowledge is more important to me than the grades I receive. (Q32) 3. I enjoy working with a group of fellow students on class materials. (Q33) 4. In large classes, I prefer to be involved and engaged. (Q37) 5. If I had a choice, I would avoid classes where the instructor just lectures. (Q39)
Group 3 (*Learning Preferences and Assumptions Presumably Less Compatible with CRS Use)*	1. I prefer classes where I am not required to participate. (Q 38) 2. I'm reluctant to share my opinions in class. (Q34) 3. I prepare more thoroughly when my participation is graded than when it is not. (Q35) 4. Generally, I prefer to learn individually rather than with a group of fellow students. (Q36) 5. The best way to teach large enrolment courses is with the traditional lecture style. (Q31)

Age, academic level, course performance. The first three hypotheses state that students' *age, academic level* and *course performance* will negatively predict their perceived usefulness of CRS-PI. H1 is partly supported – *age* only significantly predicts the scores for one of the five subscales: Mastery of Subject Matter (MSM), explaining 6% of the variance in this subscale. H2 is better supported – *academic level* significantly predicts scores in Metacognition, Motivation, Enjoyment and Involvement, explaining 7%, 8%, 11% and 9% of the variance in these subscales respectively, but does not significantly predict MSM scores. As for H3, *course performance* as reflected in final exam scores does not predict any of the criterion variables. Detailed statistics are presented in Table 12.

Table 12 Significant Predictor Variables I

Criterion Variables	**Significant Predictor Variables**
Mastery of Subject Matter	Age (β = -.25, p = .017) R^2 = .06; Adjusted R^2 = .05; F(1, 91) = 5.96, p = .017
Metacognition	Academic level (β = -.26, p = .010) R^2 = .07; Adjusted R^2 = .06; F(1, 92) = 6.86, p = .010
Motivation	Academic level (β = -.28, p = .006) R^2 = .08; Adjusted R^2 = .07; F(1, 92) = 7.81, p = .006
Enjoyment	Academic level (β = -.33, p = .001) R^2 = .11; Adjusted R^2 = .10; F(1, 92) = 11,01, p = .001
Involvement	Academic level (β = -.30, p = .003) R^2 = .09; Adjusted R^2 = .08; F(1, 91) = 9.15, p = .003

Learning Preferences and Assumptions Presumably More Compatible with CRS Use

The fourth hypothesis proposes that students' desire for participation, involvement and engagement, their valuing of knowledge over grades, their preference for working in groups, and their dislike of traditional lecture style will positively predict the degree to which they report positive perceptions of CRS use. H4 is also partly supported. Details are shown below (Note that the statements were coded for easier presentation of results):

Both Q39 *dislike of traditional lecture style* ($\beta = .40$, $p < .001$) and Q33 *preference for group learning* ($\beta = .19$ $p = .042$) demonstrate significant influence on MSM scores. Together, they account for 24% of the variance in MSM scores [$F(2,91) = 14.34$, $p < .001$].

For Metacognition, *Q39 dislike of traditional lecture style* ($\beta = .31$, $p = .002$) and *Q32 valuing of knowledge over grades* ($\beta = .20$ $p = .042$) both turn up as significant predictors. Together they explain 14% of the variance in Metacognition scores.

Only *Q39 dislike of traditional lecture style* appears as a significant positive predictor for Motivation and Enjoyment scores, explaining 6% of the former and

14% of the latter scores. Both Q*37 desire to be involved and engaged* and Q39 *dislike of traditional lecture style* demonstrated significant positive influence on Involvement scores, together accounting for 20% of the variance in this subscale. Note that Q39 shows up as significant predictor on all five subscales. Detailed analyses are shown in Table 13.

Table 13 Significant Predictor Variables II

Criterion Variables	**Significant Predictor Variables**
Mastery of Subject Matter	Q39 *dislike of traditional lecture style* (β = .40, $p < .001$) Q33 *preference for group learning* (β =.19 $p = .044$) $R^2 = .24$; Adjusted $R^2 = .22$; F(2, 91) = 14.34, $p < .001$
Metacognition	Q39 *dislike of traditional lecture style* (β = .31, $p =. 002$) Q32 *valuing knowledge over grades* (β =.20 $p = .042$) $R^2 = .14$; Adjusted $R^2 = .12$; F(2, 92) = 7.40, $p = .001$
Motivation	Q39 *dislike of traditional lecture style* (β = .25, $p = .016$) $R^2 = .06$; Adjusted $R^2 = .05$; F(1, 93) = 6.06, $p = .016$
Enjoyment	Q39 *dislike of traditional lecture style* (β = .37, $p < .001$) $R^2 = .14$; Adjusted $R^2 = .13$; F(1, 93) = 14.76, $p < .001$
Involvement	Q37 *desire to be involved and engaged* (β =.28 $p = .006$) Q39 *dislike of traditional lecture style* (β = .25, $p = .013$) $R^2 = .20$; Adjusted $R^2 = .18$; F(2, 91) = 11.08, $p < .001$

Learning Preferences and Assumptions Presumably Less Compatible with CRS use

The fifth hypothesis predicts that all five items in this category will be negative predictors of students' perception scores on all Learning and Engagement subscales. This hypothesis, again, is partially supported. Moreover, the direction of prediction for *Q35 Grade-driven participation* is opposite to what is initially hypothesized. It *positively* predicts the scores of all three Engagement subscales (but none of the Learning subscales), explaining 13%, 25%, 33% of the variance in Motivation, Enjoyment and Engagement, respectively. Another interesting finding is that, similar to item Q*39 dislike of traditional lecture style* in the previous regression analysis, item Q*31 assumptions in favor of traditional lecture style* shows up on all five subscales. *Q34 reluctance to share opinions* also demonstrates significant negative influence on all but the Motivation subscale. Detailed analyses can be seen in Table 14.

Table 14 Significant Predictor Variables III

Criterion Variables	Significant Predictor Variables
Mastery of Subject Matter	Q31*Assumptions in favor of traditional lecture style* (β = -.49, $p < .001$) Q34 *Reluctance to share opinions* (β = -.20 $p = .025$) $R^2 = .27$; Adjusted $R^2 = .25$; F(2, 92) = 16.55, $p < .001$
Metacognition	Q31*Assumptions in favor of traditional lecture style* (β = -.29, $p = .004$) Q34 *Reluctance to share opinions* (β = -.25 $p = .011$) $R^2 = .14$; Adjusted $R^2 = .12$; F(2, 93) = 7.27, $p = .001$
Motivation	Q35 *Grade-driven participation* (β = .27, $p = .007$) Q31*Assumptions in favor of traditional lecture style* (β = -.24, $p = .014$) $R^2 = .13$; Adjusted $R^2 = .11$; F(2, 93) = 7.02, $p = .001$
Enjoyment	Q31*Assumptions in favor of traditional lecture style* (β = -.41, $p < .001$) Q35 *Grade-driven participation* (β = .22, p=.018) Q34 *Reluctance to share opinions* (β = -.22 $p = .019$) $R^2 = .25$; Adjusted $R^2 = .23$; F(3, 92) = 10.40, $p < .001$
Involvement	Q34 *Reluctance to share opinions* (β = -.41 $p < .001$) Q31*Assumptions in favor of traditional lecture style* (β = -.37, $p < .001$) Q35 *Grade-driven participation* (β = .22, p=.012) $R^2 = .33$; Adjusted $R^2 = .31$; F(3, 91) = 14.74, $p < .001$

Discussion of Results and Implications

The purpose of the study was 1) to investigate to what extent the participating students perceive the way CRS was used by their instructor as a positive influence on their learning and engagement, more specifically, their mastery of subject matter, metacognition, motivation, enjoyment and involvement; 2) to examine if some student characteristics, namely *age, academic level, course performance, preferences for learning* and *assumptions about lecture courses* affect the students' perceived helpfulness of CRS use in the above-mentioned five dimensions. The results indicated that overall, the vast majority (95%) considered CRS-PI as useful and somewhat useful; evaluations on specific aspects of CRS-PI were also highly positive (mostly more than 80% of students agreed and strongly agreed to the various stated benefits). Multiple regression analysis yielded some significant predictors among student characteristics when regressed on the five subscales of Learning and Engagement.

The following sections will discuss the findings and their implications, explain the limitations of the study, and make recommendations for future research.

Perceived Influence of CRS-PI on Learning and Engagement

In view of the extremely positive evaluations, items or subscales with scores that could be considered fairly high elsewhere but are substantially lower in comparison with scores for other items or subscales within this study are considered reasons for concern and discussion.

CRS use and motivation. A subscale with a considerably lower grand mean (3.53) is Motivation. Voluminous research has reported dramatic increase in attendance due to CRS use, especially when quizzes and high-stakes grading is used (Caldwell, 2007; Homme, Asay, & Morgenstern, 2004; Jackson & Trees, 2003), but it is not certain whether the increased attendance is due to students' extrinsic motivation for getting marks or intrinsic motivation to get involved and learn. In cases where clicker marks force a large number of students to attend when they otherwise would not, the disruption caused by these inattentive students can severely disturb the learning environment for students who come to class to learn (Jackson & Trees, 2003).

In an attempt to investigate students' intrinsic motivation, the current study revealed increased desire to come to class and ask questions for more than half of the students (68% and 58%). Slightly less than half (43%) of them agreed and strongly agreed that CRS use motivated them to spend more time preparing for class. Considering that these aspects of intrinsic motivation involve substantial changes in academic behavior and habits, these numbers are quite satisfactory. The theoretical debate of extrinsic and intrinsic motivation being antagonistic or coexisting on a continuum with the former reinforcing the latter (Hayamizu, 1997) seems relevant. CRS seems to work well in getting students to come to class, but what happens next no longer depends on the technology itself. If the class is able to stimulate and sustain students' interest, the extrinsic motivation of not losing marks will lead to real pleasure in learning; if the class is not perceived to be worth their time, they will either come without mentally being involved (mindlessly click or blindly follow) or have their classmates traffic in their clickers and click for them without even bothering to show up. Unfortunately, the latter type of cheating has been widely observed (Jackson & Trees, 2003). As Jackson and Trees (2003) contend, witnessing cheating by peers on a daily basis could negatively affect students' attitude towards CRS and hurt their motivation and morale.

CRS use and examinations. There was relatively less agreement on the helpfulness of clicker questions in preparing for exams (Q21, 71%). The participants' verbal comments were examined for possible explanations. It turned out that seven students (8%) explicitly mentioned that clicker questions helped them study for exams (for example, “The questions also helped me prepare for the kinds of questions that would be asked on the exams”), one student mentioned that not many of the clicker questions helped prepare for exams, and one suggested that clicker questions should relate more to the testing materials. It seems that the degree of perceived helpfulness has much to do with different levels of student expectations. The relatively low rating on this item, therefore, could be attributable to the generally high expectations for clicker questions to contribute to a high grade, as students tend to be heavily concerned about what GPA they will take away upon completion of a course.

A follow-up simple regression analysis (regressing Q21 on the overall rating question) showed that students’ perceived helpfulness of clicker questions in preparing for exams is a strong positive predictor of their evaluations of the overall usefulness of CRS use (R^2 = .25; Adjusted R^2 = .24; F(1, 93) = 30.40, p < .001, β =.50). This finding points to the importance of aligning the types of questions asked on exams with in-class clicker questions in shaping student attitude towards CRS use.

A large body of research shows that assessment, rather than teaching, is the most influencing factor on how students study, hence the term “hidden curriculum” (Gibbs & Simpson, 2004). Since an important purpose of implementing CRS-PI is to foster deep learning, examinations that mainly test memorization, recall and computation will undermine the impact of this teaching innovation. The PI pioneers (Crouch et al., 2007) set a good example by including conceptual questions in their exams that used to be dominated by quantitative, problem-solving questions, considering it a good strategy in calling students' attention to the importance of conceptual understanding. Luckily, the instructor involved in the current study has a great deal of flexibility in writing exam questions. For multiple-section coordinated introductory courses, however, students often have to take common mid-term and final exams. In such cases, more efforts at the curriculum/departmental level is needed to coordinate the way CRS-PI is used across sections taught by different instructors as well as the way exam questions relate to CRS questions asked in class.

CRS use and feeling of involvement. Q23 (Using clickers has helped make my input an important part of class) under the Involvement subscale received relatively lower agreement (62%), suggesting that the classroom is still not perceived as safe enough for some students to freely express their ideas. Maybe more efforts are needed on the part of the instructor to build a learning environment where students feel safe to venture ideas with less apprehension about their validity and more focus on participation and sharing.

Global rating of CRS-PI. For the global rating question, only five out of 96 students indicated neutral and negative on the overall usefulness of CRS-PI. The verbal comments given by these five students were analyzed for possible explanations. Their negative perceptions were associated with: 1) not feeling comfortable enough to express opinions during peer discussion for fear of looking stupid; 2) clicker questions not being "complicated" enough; 3) clicker questions not helping with tests/exams; 4) preference for working alone; 5) perception that group discussion confuses more than clarifies; 6) clickers being too costly to purchase. Although these perceptions were held by only a small minority of students in the current study, they do resonate with problems often reported in the existing literature.

Asking the "why" behind student evaluations. These issues can help formulate a series of important questions researchers and instructors could ask themselves. For example, what makes some students still feel uncomfortable about sharing their thoughts, when the use of CRS-PI has made the environment less intimidating for many shy and quiet students (as evidenced by the comments provided by many participants in this study)? Is it poor preparation for class that leads to less confidence in their own reasoning or is it imbalanced group dynamics that favors domination by one or two group members? Another question could be, if student learning preferences (such as preference for individual learning vs. group learning) affect their perceived usefulness of CRS-PI, are they fixed psychiatric properties that instructors can do nothing about, or they can be changed? If learning preferences can be changed, what can instructors do to make students alter their learning preferences so that they can be more compatible with the pedagogical innovation they are implementing? If it is hard to change student learning preferences, what can instructors do within their pedagogy to accommodate students with those preferences so they will not be left out of the benefits of the new approach? Or is it possible to work in both directions to achieve better results?

Extensive reading on the research literature and frequent communication with students may help find answers to the above and more related questions. For example, Hoekstra (2008) found through her interviews with students that some preferred to work alone because they did not want to "lead someone astray" with their own problematic reasoning while others were afraid that the incorrect ideas shared by their peers would stick with them. If this is the case, more metacommunication about the benefits of social learning and how wrestling with ideas and struggling through faulty reasoning is a valuable part of learning might help remove those doubts and get those students to also embrace the instructional innovation.

Specific Benefits of Peer Discussion

Generally high perception scores on the six peer discussion specific items indicated that some commonly identified PI-related benefits and mechanisms through which PI improves learning were also recognized by the students in the current study. It is especially interesting to see high agreement on Q28 (Small group discussions help with my understanding even if no one in the group originally had the correct answer).

The only two items that have rather spread responses are Q25 (I am more likely to speak up in a class-wide discussion after discussing the topic in small groups than I would otherwise) and Q26 (Having a number of different viewpoints during peer discussions often leads to confusion). The results of Q25 resonate with those of Q23 (Using clickers has helped make my input an important part of class) discussed a few paragraphs earlier. It seems that peer discussion was *not* able to warm up nearly half of the students for public sharing. These students may need more encouragement to participate in class-wide discussion.

Concerning the perception that PI leads to confusion, it is normal for confusion to occur with any kind of discussion; what is important is how to prevent students from being discouraged by less than fruitful peer discussions to the extent that they see little value in peer learning. As argued earlier, more explanation about how confrontation with different ideas (correct or incorrect) is essential to conceptual change is needed. Furthermore, some guidelines for productive group discourse may be provided to students to help minimize their sense of confusion.

Participants' Verbal Comments

The two negative themes – *peer discussion taking too long* and *clicker questions not having one single best answer* both merit some in-depth discussion. As part of a systematic approach, both sides of the teaching and learning coin should be examined for possible explanations.

Peer discussion taking too long. On the student side, this perception is explicable by the following two factors. The first is poor preparation for class. As discussed in the *Important Pedagogical Considerations for Using CRS* section, the employment of PI inevitably reduces instructional time on introductory content. If students do not do preparatory work on their own, they may not have much to contribute to discussion, and it would be hard to follow what others have to say. When students do not feel they are part of the conversation, the discussion will understandably feel too long for them. Secondly, students who are accustomed to the transmissionist approach to teaching may view PI as something that takes away from normal lecture time. The correlation between students' assumptions about lecture courses and students' perceived usefulness of CRS-PI found in the regression analysis supports this explanation. These findings call attention to the importance of providing more incentives for students to read before class and managing student expectations about lectures using CRS-PI.

On the teaching side, there could be a problem with the management of peer discussion, such as lack of strategy about when and how to quickly reconvene the entire group. Walking around and listening in may help determine the best time for ending the discussion and using a signal such as turning off the lights may help quickly call the group's attention back to the front.

Clicker questions not having one single best answer. On the student side, the preoccupation with correct answers may come from the strongly felt need to answer similar questions correctly on examinations, as reflected by many student requests for putting correct answers on lecture slides for examination/test review. However, it could also be reflective of the stage of intellectual development they are at, where they believe in the existence of absolute truth and tend to exhibit unease with multiple plausible answers, a stage of dualism, as theorized by Williams Perry (as explained in Lang, 2008). Since disputable questions are among the most beneficial types of questions for deep learning (Beatty & Gerace, 2009), and undue focus on getting the correct answers can inhibit critical think (Mollborn & Hoekstra, 2010), it is important that instructors preempt this kind of thinking through meta-level communication, explaining why such type of questions is chosen and the benefits of answering and discussing it. Such explanation will not only improve students' learning of the subject matter, but also give a boost to their intellectual development.

On the teaching side, there could be unintentional ambiguity in the wording of clicker questions. Testing the questions on a small group of students or discussing with colleagues might help minimize the problem.

A Systematic Perspective.

"For us, the clicker isn't the whole game; it's a piece of the puzzle…All the pieces fit together to give a solid educational experience". Those were the words shared by T. Stelzer (Personal Communication, April 30, 2010) at a faculty workshop he gave at Concordia University on the topic of how to organically integrate clickers into a course, where each course element does what it excels at and at the same time facilitates other components of the course.

This observation is echoed by Crouch et al. (2007) who recognize that "Learning gains are greatest when PI is complemented by other strategies that increase student engagement…" (p.49). In that spirit, they kept refining not only the ConcepTests and in-class questioning and discussion strategies but text, reading assignments, other group activities and exam questions.

Such systematic perspective is further validated by student comments in the current study. Many students mentioned the crucial role *online reading quiz, online discussion forum, instructor's teaching style and skills, and the entire course design* played in their improved learning experience associated with CRS-PI. What is interesting is that they gave these comments completely out of their own desire to share them because no questions were asked of them regarding this aspect. It seems that students felt the benefits from the holistic approach by which CRS-PI was integrated into the course and they very much appreciated the interrelated and mutually reinforcing relationship between the various course elements. Some relevant comments are presented below:

> "The *online quizzes* is key for me to appreciate the inclass clickers…it makes me want to learn the material".

> "It was also great that we had done the *online quiz* because I felt more confident in the answers [to clicker questions]".

"The discussion was useful, and it helped to get a better understanding of some concepts. Sometimes it took up a lot of time which could have been bad if people had questions on other material (which was why *the online discussion* was a good idea)."

"I like that it makes students get involved, and creates a more inviting atmosphere. That being said, I don't know how much of this is attributable to *the teacher's own characteristics* or to the use of clickers themselves".

"However, it would be interesting to see how enjoyable and "lively" clicker usage would be *with different teachers*, as this one seemed to prove having all or most necessary skills to make the use [of] clickers helpful and interesting".

"The honest truth is that because of the use of clickers and *overall how the class operates* I have learnt the most in this class. But not only have I learnt the most but I remember the most."

Influence of Student Characteristics on Perceived Usefulness of CRS-PI

Academic level is a negative predictor. Consistent with previous research findings (Preszler, Dawe, Shuster, & Shuster, 2007; Trees & Jackson, 2007), the present study also found *academic level* as a negative influencing factor on student evaluation of CRS-PI (on all subscales but MSM): Upper-level students had less favorable perceptions of CRS-PI than their lower-level counterparts. Trees and Jackson (2007) attributed the less positive attitude of upper-division students to more previous experience with lecture courses. The results of two follow-up correlation analyses in the current study between *academic level* and *Q39 dislike of traditional lecture style*, and between *academic level* and Q31 *assumptions in favor of traditional lecture style* (significant negative correlation for the former, $r = -.267$, $p < .01$, one tail; significant positive correlation for the latter, $r = .246$, $p < .01$, one tail) lend support to this explanation. Students showed more preference for traditional lecture as they spent more time in university. When students have more preference for traditional lecture, they tend to give less favorable evaluations of CRS use, as indicated by two multiple regression analyses that found *39 disliking of traditional lecture style* (positive) and *31 assumption in favor of traditional lecture style* (negative) to be significant predictors for perception scores across all five subscales of Learning and Engagement.

Nevertheless, one should be careful about always associating upper-division students with apathy towards CRS use, especially considering the encouraging results of Perkins and Turpen's (2009) CRS student perception study conducted with upper-division physics students. The authors reported that at the University of Colorado at Boulder (CU), CRS had been used 24 times in 10 different upper-division courses by 14 different instructors. Their student survey of 16 of those classes suggested that 77% of the students recommended using CRS for upper-division courses. Interestingly, the majority of students recommending CRS use had previous experience with CRS while taking lower-division courses. This seems to suggest (consistent with the results of the current study) that the underlying factor affecting upper-division students' acceptance of CRS use is more likely to be students' comfort with traditional lecture due to long-time exposure than their being at advanced levels. Such distinction is critical because it means that these students can be reconditioned to a new mode of instruction and embrace it, given some time and strategies that can quickly open their eyes to the benefits of the new way of learning.

The above discussion has important implications for instructors teaching upper-division courses. Considering that CRS-based instruction has great potential in addressing student conceptual difficulties, which have been reported to also widely exist in upper-level major courses (Perkins & Turpen, 2009), instructors teaching these courses might consider adopting some CRS-based pedagogies. The sparse research conducted in this area and the not-so-encouraging findings by existing studies should not be a disincentive, as existing research (including the present study) has mostly pointed to students' past lecture experience as a possible influencing factor on their attitude towards CRS-based teaching rather than the nature or the class size of advanced-level courses. Nonetheless, it does signify that instructors teaching upper-division courses have more work to do in managing students' expectations and shaping their attitudes if they decide to adopt CRS-based instruction. For those who do not habitually practice metacommunication in class, they might need some communication support in how to get student buy-in.

Preference for participation is not a significant predictor. Another interesting finding from the regression analyses is that Q30 (I prefer classes where I have the opportunity to participate) and Q38 (I prefer classes where I am not required to participate) never showed up as a significant predictor on any of the five subscales of Learning and Engagement, suggesting that CRS use was not perceived as any more or less helpful by students with or without a preference for participation. This is supported by some of the student comments, such as the following:

> *"What I liked best about the clickers is that you can gain all of you[r] participation points by not having to speak up in front of the whole class. This can*

be intimidating for certain people and in other classes where active participation is required; ... In this class, I was able, for the 1st time, to gain all of my participation percentages, which is great and very helpful."

In traditional lecture classes, speaking up in class was the main, if not the only way of participation. Such public sharing is intimidating to many students. It seems that CRS-PI provides less threatening and more varied ways for participation, such as anonymous voting and sharing ideas with a small number of peers as well as public speaking. It is not surprising that both shy and outspoken students appreciate its use.

Grade-driven participation is a positive predictor of Engagement, contradicting the original hypothesis. In the regression analysis, Q35 (I prepare more thoroughly when my participation is graded than when it is not) was put in the category with items hypothesized as negative predictors of Learning and Engagement. However, it turned out to be a positive significant predictor for all three subscales of Engagement, namely Motivation, Enjoyment and Involvement, indicating that grade-driven participation did not negatively affect students' perceived value of CRS-PI, as originally surmised. In fact, it suggests that grading can be used as an incentive to promote intrinsic motivation and active involvement (not just behavioral improvement in attendance and participation) in cases where CRS is used in a way that is perceived as valuable and beneficial by students. It does not necessarily take a knowledge-oriented student to appreciate the benefits of CRS-PI, students who work harder for external incentives when they otherwise would not apply themselves to the same extent could also embrace CRS use for its various intrinsic rewards. This supports the theory that extrinsic motivation can enhance intrinsic motivation in the right circumstances. However, a caveat is that the relatively high percentage of grades assigned to clicker participation (7%) may not have the same effect anywhere else, especially when the pedagogical aspect of CRS use fails to provide much learning satisfaction for students.

Limitations of the Study

The study has a number of limitations. First, self-selection bias may be present due to the way participants were included. Whereas the original intention was to include all students from the three classes, only two thirds of the students in each class attended the particular test review session where we administered the survey for the study. Students who were excluded from the study due to their absence from that particular class could share some characteristics that were systematically different than those shared by students who showed up.

It is possible that students missing that session were less motivated and had a less positive attitude about the course than those who came to class. It is also possible that they were more self-directed learners and preferred to study for the upcoming final exam on their own. Due to constraints in resources, the researcher did not make further investigation on the absentees. Hopefully, various reasons for the unusually low attendance rate for that particular session coexisted and balanced each other off.

Self-selection bias is more likely to have been introduced when the online version of the survey was administered and only about 1/5 (as opposed to nearly 100% response rate for the in-class paper survey) of the remaining students responded. It is likely that only students with strong opinions (positive or negative) went through the questions in their own free time.

Another limitation of the study lies in the survey questionnaire. The subscales were created by the researcher herself. Their validity and reliability were not tested on a large enough sample to make it a rigorous instrument.

A third limitation is that there is a lack of variability in the data (perception scores were generally very high). Although it is desirable to have a landslide on the positive side of the evaluation scale, it could have compromised the results of the regression analyses. For some demographic data used in the analyses, such as academic level, lower-division students were disproportionally represented. This could also have affected the regression results to some extent.

The last limitation is that the study has low generalizability. On the one hand, it is a common limitation for self-report survey studies – no causal relationship can be established. On the other hand, it is not the intent of the study to generalize the findings about CRS use to the entire undergraduate population, not even psychology majors like those involved in the current study simply because CRS use is never generalizable unless the "population" receives the same pedagogical treatment of CRS as the sample, which not only involves the specific teaching techniques used around the technology, such as Peer Instruction, but also concerns how CRS use fits in with other elements of the course. That is why the present study shifts away from experimental comparisons between using and not using the clicker technology but focuses on the discussion of the pedagogy that makes use of CRS. By making a link between how CRS is used and how it is perceived by students, the study aims to inspire discussions on what works and what does not work with the pedagogy, rather than the technology.

Future Research Recommendations

Although existing research on student perceptions far outnumber studies measuring objective learning outcomes, there is a general tone in the literature that somewhat devalues the contribution of perception studies to the understanding of CRS-based instruction. The arguments resemble the following: a) Students' belief that they learned more does not equal the fact that they actually learned more (MacGeorge et al., 2008); b) Student enthusiasm about a technology may not necessarily lead to improved learning but in some cases could be harmful to learning (Mayer & Moreno, as cited in MacGeorge et al., 2008). There might be some truth in those opinions, but student perception research is just as valuable as experimental research if conducted properly. As Perkins and Turpen (2009) stated, student reaction and objective impact on student learning are both important factors to consider before adopting a teaching innovation. If students do not see value in the new approach and the new technology, they are not likely to get involved and therefore learning benefits will be minimal.

However, a general approach to student perception study may not be fruitful. The investigation should systematically probes specific pedagogical aspects of CRS use, such as frequency, placement and types of clicker questions used, discussion strategies, etc. In addition, more qualitative or mixed method research is needed as quantitative research often fails to give the entire picture of why students perceive CRS use the way they do and therefore fall short of its goal to inform teaching practice involving CRS.

Judging from student responses to the *Metacognition* related items and to the open-ended question, the metacognitive gains from CRS-PI in the present study was quite impressive. Since metacognition is one of the most desirable advanced outcomes of CRS use, and research in this area is quite barren, future research in this direction would be highly valuable.

Another recommendation for future research is to direct research consumers' attention to CRS pedagogies rather than the clicker technology itself by avoiding the use of technology names, such as clickers or CRS, while actually referring to the instructional method that makes use of the technology. Perkins and Turpen (2009) set an interesting example for addressing this issue. For convenience's sake, they still use the word "clickers" as if it is the method but were clear upfront about its denotation – *"'clickers' here and throughout means 'clickers with challenging conceptual questions and peer instruction'"* (p. 226).

Conclusion

CRS is an instructional medium. It enables, facilitates, enhances… but does not cause learning. This perspective is critical to the successful application of CRS, or any other technology for that matter. To avoid putting the cart in front of the horse and getting students nowhere, researchers and practitioners alike should work towards building more pedagogy-oriented CRS research and implementation models instead of focusing energy on the technology per se for the purpose of informing adoption decisions. As many researchers have acknowledged, whether CRS enhances learning or not, and to what extent it augments learning depends not on the technology but how it is used pedagogically. Moreover, introducing CRS into the classroom does not simply mean trying a few new teaching techniques, however effective they have proven elsewhere. Good implementation of CRS transforms the entire learning environment by making CRS use an organic part of the course design where all course elements complement one another and work together synergistically.

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Appendix I: Clicker Use Survey

Demographic Information

1. Student ID: ______________________

2. Gender (circle one). Male Female

3. Age (circle one).

18-22 23-27 28-32 33-37 38+

4. Ethnicities: _______________________

5. Class Standing (circle one).

1st year 2nd year 3rd year 4th year

6. How many hours do you spend per week preparing for this class? ____________

7. How many hours per week do you work for pay? ___________

8. How many courses are you taking this semester? ___________

9. What is your reason for taking this course?

____

10. What previous degree(s) do you have?

None Bachelor's Master's

11. How many courses that you took prior to this semester used clickers in the classroom?

____

12. How many courses that you are taking this semester use clickers in the classroom (excluding this class)?

____

Clicker Use Survey

The purpose of this survey is to evaluate the effectiveness of clickers and the Peer Discussion teaching method. Only honest responses will be truly valuable in improving teaching practice, hence your learning experience. Your participation is very much appreciated. Your responses are confidential and only anonymous comments and aggregate results will be disclosed.

**Please think in the context of this particular class while going through all the items on this questionnaire.*

I. Please respond to each question by circling one number that best describes your opinion.

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
1. Because we use clicker questions, I understood more than I would have otherwise.	1	2	3	4	5
2. Learning with clickers motivates me to ask more questions.	1	2	3	4	5
3. Clicker questions have helped me focus on key knowledge.	1	2	3	4	5
4. Using clickers has helped the instructor to tailor his teaching to class needs.	1	2	3	4	5
5. The use of clickers has increased my desire to come to class.	1	2	3	4	5
6. The use of clickers has helped me learn the course material.	1	2	3	4	5
7. The use of clickers has motivated me to spend more time preparing for class.	1	2	3	4	5
8. Class time passes more quickly when we use clickers.	1	2	3	4	5

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
9. The use of clickers has helped me develop a deep understanding of concepts.	1	2	3	4	5
10. I would like to use clickers in other courses, too.	1	2	3	4	5
11. Clicker questions made me more aware of my weaknesses in my understanding of course material.	1	2	3	4	5
12. I always tried to answer the clicker questions correctly.	1	2	3	4	5
13. At first, learning with clickers was enjoyable but later I was bored.	1	2	3	4	5
14. The use of clickers has made me more aware of the instructor's expectations.	1	2	3	4	5
15. At first, I didn't like using clickers but later it became enjoyable to me.	1	2	3	4	5
16. The use of clickers has helped me to stay interested during class time.	1	2	3	4	5
17. I would have learned more without the use of clickers.	1	2	3	4	5
18. I find clicker questions somewhat boring.	1	2	3	4	5
19. The use of clickers has helped me determine how well I have mastered course material.	1	2	3	4	5
20. Using clickers to answer questions is fun.	1	2	3	4	5
21. Clicker questions have helped me prepare for exams.	1	2	3	4	5

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
22. The use of clickers has heightened my interest in class discussions and lectures.	1	2	3	4	5
23. Using clickers has helped make my input an important part of class.	1	2	3	4	5
24. Hearing other students explain their reasoning during peer discussion has helped me to learn.	1	2	3	4	5
25. I am more likely to speak up in a class-wide discussion after discussing the topic in small groups than I would otherwise.	1	2	3	4	5
26. Having a number of different viewpoints during peer discussions often leads to confusion.	1	2	3	4	5
27. Discussing a clicker question in small groups made me more attentive to the subsequent class-wide discussion and instructor explanation.	1	2	3	4	5
28. Small group discussions help with my understanding even if no one in the group originally had the correct answer.	1	2	3	4	5
29. Trying to explain the reasoning behind my choice during peer discussion has helped organize my own thinking.	1	2	3	4	5
30. I prefer classes where I have the opportunity to participate.	1	2	3	4	5
31. The best way to teach large enrolment courses is with the traditional lecture style.	1	2	3	4	5
32. Gaining knowledge is more important to me than the grades I receive.	1	2	3	4	5

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
33. I enjoy working with a group of fellow students on class materials.	1	2	3	4	5
34. I'm reluctant to share my opinions in class.	1	2	3	4	5
35. I prepare more thoroughly when my participation is graded than when it is not.	1	2	3	4	5
36. Generally, I prefer to learn individually rather than with a group of fellow students.	1	2	3	4	5
37. In large classes, I prefer to be involved and engaged.	1	2	3	4	5
38. I prefer classes where I am not required to participate.	1	2	3	4	5
39. If I had a choice, I would avoid classes where the instructor just lectures.	1	2	3	4	5
40. I dislike having to attend class for the participation marks.	1	2	3	4	5

II. Which statement best reflects your OVERALL IMPRESSION of clickers and peer discussion?

1. Very useful
2. Somewhat useful
3. Neutral – no additional benefits but no downsides either
4. Negative to some degree – somewhat a waste of time and resources
5. Very negative overall – a complete waste of time and resources

III. What did you like *best* about your experience using clickers in this class? Which aspect about the use of clickers is most in need of improvement? Please also provide any additional comments or suggestions you may have on this topic.

Appendix II Composition of the Questionnaire

OUTLINE

Part I Demographic Information

Part II Likert-scale Items (40 items)

Learning (10 items)

Mastery of Subject Matter (5 items)
Metacognition (5 items)

Engagement (12 items)

Motivation (3 items)
Enjoyment (4 items)
Involvement (3 items)

Novelty effects (to be analyzed item by item) (2 items)

PI-specific items (6 items)

Learning Preferences & Assumptions (10 items)

Part III Global Rating Question

Part IV Open-ended Question

Likert-Scale Item Subscales and Categories

Learning

Mastery of Subject Matter

1. Because we use clicker questions, I understood more than I would have otherwise. (no. 1)
2. The use of clickers has helped me learn the course material. (no.6)
3. The use of clickers has helped me develop a deep understanding of concepts. (no. 9)
4. Using clickers has helped the instructor to tailor his teaching to class needs. (no.4)
5. I would have learned more without the use of clickers. (no. 17 Reversed)

Metacognition

1. Clicker questions made me more aware of my weaknesses in my understanding of course material. (no.11)
2. Clicker questions have helped me focus on key knowledge. (no.3)
3. Clicker questions have helped me prepare for exams. (no.21)
4. The use of clickers has helped me determine how well I have mastered course material. (no.19)
5. The use of clickers has made me more aware of the instructor's expectations. (no.14)

Engagement

Motivation

1. The use of clickers has increased my desire to come to class. (no. 5)
2. The use of clickers has motivated me to spend more time preparing for class. (no.7)
3. Learning with clickers motivates me to ask more questions. (no.2)

Enjoyment

1. Class time passes more quickly when we use clickers. (no.8)
2. Using clickers to answer questions is fun. (no.20)
3. I would like to use clickers in other courses, too. (no. 10)
4. I find clicker questions somewhat boring. (no. 18 Reversed)

Involvement

1\. The use of clickers has helped me to stay interested during class time. (no.16)

3\. The use of clickers has heightened my interest in class discussions and lectures. (no.22)

4. Using clickers has helped make my input an important part of class. (no. 23)

Peer Discussion Specific Items

1. Hearing other students explain their reasoning during peer discussion has helped me to learn. (no. 24)
2. Trying to explain the reasoning behind my choice during peer discussion has helped organize my own thinking. (no.29)
3. Discussing a clicker question in small groups makes me more attentive to the subsequent class-wide discussion and instructor explanation. (no. 27)
4. I am more likely to speak up in a class-wide discussion after discussing the topic in small groups than I would otherwise. (no. 25)
5. Small group discussions help with my understanding even if no one in the group originally had the correct answer. (no. 28)
6. Having a number of different viewpoints during peer discussions often leads to confusion. (reversed) (no. 26)

Learning Preferences & Assumptions

More Compatible with CRS-PI

1. I prefer classes where I have the opportunity to participate. (no. 30)
2. Gaining knowledge is more important to me than the grades I receive. (no. 32)
3. I enjoy working with a group of fellow students on class materials. (no. 33)
4. In large classes, I prefer to be involved and engaged. (no. 37)
5. If I had a choice, I would avoid classes where the instructor just lectures. (no. 39)

Less Compatible with CRS-PI

1. I prefer classes where I am not required to participate. (no. 38)
2. I’m reluctant to share my opinions in class. (no. 34)
3. I prepare more thoroughly when my participation is graded than when it is not. (no. 35)
4. Generally, I prefer to learn individually rather than with a group of fellow students. (no. 36)
5. The best way to teach large enrolment courses is with the traditional lecture style. (no. 31)