Closing the Missing Links and Opening the Relationships among the Factors: A Literature Review on the Use of Clicker Technology Using the 3P Model

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ABSTRACT
Clicker technology is one of the most widely adopted communication systems in college classroom environments. Previous literature reviews on clicker technology have identified and thoroughly documented the advantages, disadvantages, and implications of the use of this technology; the current review is intended to synthesize those earlier findings and recast them in terms of the interrelationship between the “3 Ps” of the 3P model: Presage, Process, and Product factors. Using this guided framework enables the identification of the most up-to-date trends and issues in clicker studies published in peer-reviewed journals since 2009. The review shows that recent clicker studies have examined the effects of clickers in terms of student presage factors (cognitive, non-cognitive, background factors), instructor presage factors (instructor effects and the level of the course taught), process factors (delivery method, instructional activities, and assessment and feedback), and product factors (cognitive and non-cognitive outcomes). A heat-mapping approach is used to facilitate the interpretation of the results. The findings also discuss missing/unaddressed links and the untapped relationships among instructional factors in these studies. This study concludes that teaching and learning with the use of clicker technology is a complex and relational phenomenon; factors that are currently under-explored should be examined using more rigorous research methods to close gaps in the literature and to enhance understanding of the use of clickers in classroom learning environments.

Keywords
Clickers, Pedagogical approaches with technology, Information visualization methods, Interactive learning environments

Introduction

Research into teaching and learning in higher education consistently seeks answers to the following two questions: What is the best delivery method for enhancing student learning outcomes? How does a specific instructional strategy make student learning effective and efficient in a large classroom setting? (e.g., Biggs, 2003; McKeachie, 1990). These questions have led scholars to seek the best-fitting factors and identify interrelationships among the factors that enhance the quality of student learning. One possible workaround to resolve these issues is to create a “student-centered learning environment,” often described as a classroom setting in which students actively engage and interact within the classroom and with various instructional activities. Ultimately, a range of factors can be identified that have the potential to concurrently enhance the quality of various student learning outcomes.

The Classroom Communication System (CCS; hereafter referred to as “clickers”) is one of the most widely adopted interactive technologies used in classroom instruction worldwide (White, Syncox, & Alters, 2011). Clicker systems comprise two main components: the response device and the receiver system. Instructors introduce questions in various formats (multiple choice or right/wrong answers) to the students via the classroom projector, and they respond to the questions using the response device (e.g., smartphone or number keypad). All the student responses are collected in the instructor’s receiver system embedded in the computer; instructors can also immediately post (project) the student response results back to the class in a few different visual formats. Thus, the use of clickers can provide immediate feedback even to a large number of students and reduce the time spent on the feedback cycle between instructors and students (Liu, Chung, Chen, & Liu, 2009).

Studies (e.g., Caldwell, 2007) suggest that the potential benefits of clicker technology, including immediate feedback and assessment, may help to build student-centered classroom environments. More specifically, the use of clickers with appropriate pedagogical approaches may have the following positive impacts on teaching and learning in higher education: improved student involvement/engagement, clearer perceptions of learning/knowledge gains, and stronger affective learning outcomes (e.g., student attitudes). However, 2001 Physics Nobel prize recipient Carl Wieman suggests that the use of clicker technology can have deep and positive impacts on students only when the following specifications are met throughout: “…change in the classroom dynamic, the questions posed, and how they are followed up…and guided by an understanding of how people learn” (Wieman & Perkins, 2005, p. 39).
The specifications (or prerequisites) for improving student learning with clicker technology have been well documented in several literature reviews. For instance, Kay and LeSage (2009) reviewed 67 peer-reviewed journal articles and identify the following benefits and challenges of the use of clickers: assessment, classroom, learning benefits and technology-, teacher-, and student-based challenges. Since the most recently published literature review (Kay & LeSage, 2009) was done in 2009, it is important to review the clicker studies published after 2009 for the following reasons. First, in these studies, a wide range of new factors have been considered, including different groups of participants (e.g., multiple course levels; Dunn, Richardson, McDonald, & Oprescu, 2012), various types of interventions (e.g., different levels of clicker use; Elicker & McConnell, 2011), and instructional settings (e.g., different institutions; Lundeberg et al., 2011). These factors, however, have not been taken into account in any clicker literature reviews to date. Second, the most recently published literature review on this topic (Kay & LeSage, 2009) was conducted in 2009, and is, therefore, somewhat out of date. Third, previous literature reviews (e.g., Caldwell, 2007) were primarily interested in documenting the practical advantages of and barriers to adopting clickers into classrooms, rather than pursuing a concrete understanding of how the use of clickers is related to classroom instruction. Therefore, conducting new literature review is necessary and important to provide a more comprehensive understanding of this topic that has been published after 2009. All of these help educational technology practitioners and researchers to refresh and regain the most up-to-date information on the use of clickers and to synthesize new knowledge on clicker effects in relation to various instructional factors in classroom instruction.

This study aimed at (1) identifying the missing links within clicker studies in higher education, in order to arrive at a comprehensive understanding of research and development on clicker implementations and permit researchers and practitioners to work toward closing existing gaps, and (2) providing up-to-date theoretical and practical implications and issues for implementing clicker technology across academic disciplines in higher education by uncovering the various types of interrelationships among the factors. Because this work was conducted using the Presage-Product-Process (3P) Model (Biggs, 2003), the approach taken in the current review is deductive rather than inductive: the 3P model categorizes each identified construct as one of the 3P components and then synthesizes findings by focusing on the relationships among the factors examined in the studies.

The current review is organized as follows. First, a description of the criteria and selection process for retrieving articles from academic databases is provided and the guiding framework, the 3P model, is presented. The terms presage, process, and product are defined, and their possible interrelationships discussed. Next, results synthesized from the study review process are presented in terms of the 3P factors, using a heat-mapping information visualization method. Finally, practical implications for the design and implementation of clicker systems, together with implications for ongoing research, are presented in the conclusion.

Method

Literature search and selection approaches

The design of the current literature review was guided by recommendations and comments found in Boote and Belie (2005). Forward- and backward-citation tracking methods were employed to find articles on the use of clickers within the following academic databases: EBSCO, ERIC, ProQuest, PsycINFO, Scopus, and Google Scholar. In addition, Bruff’s (2014) bibliography of clicker studies was used to decrease the probability of articles being overlooked.

The following criteria were used to select the articles for review in the current study: (1) the articles were published in peer-reviewed journals between 2010 and 2013; (2) the studies examined more than one class session in a course as a unit of analysis (Trigwell, 2010) in college classroom instruction; (3) the studies examined the use of clickers in terms of instruction rather than other constructs (e.g., low-income mothers; Ginter, Maring, Paleg, & Valluri, 2013); (4) the studies provided descriptions of research design, data collection procedures, and results, rather than non-evidence-based pedagogical recommendations. Thus conference proceedings and institutional reports were not considered in this literature review.
In order to identify appropriate articles based on the criteria presented above, the following keywords and their combinations (AND and OR functions) were used during the retrieval process: Student*, Audience*, Class*, Comm*, Vot*, Response*, System*, and Clicker*.

**Framework of the study**

Objectives of the review are to (a) provide the most up-to-date information about the trends and issues in current research on the use of clickers in college instruction, and (b) identify implications for design and implementation of clickers for faculty, faculty developers, and educational technology staff who are involved in the use of clicker technology in higher education. The Presage-Process-Product (3P) model (Biggs, 2003) was adopted to guide the review process.

**Framework**

Using the 3P model as a framework facilitates the literature review process along several dimensions. First, the 3P model has been empirically examined and validated for virtually all academic disciplines worldwide (Biggs, 2003); as a result, this model can provide a more valid and reliable understanding of the relationship between the use of clickers and teaching and learning in higher education. Second, the 3P model emerged from context-specific studies on teaching and learning and therefore it conforms to the current study’s objective of understanding the use of clickers in college instruction. Third, the 3P model can provide a comprehensive understanding of the characteristics of the relationships among the constructs (i.e., presage, process, and product factors) of instruction with clickers. In other words, the 3P model framework can easily identify the relationship among or between the constructs, characterize the nature of those relationships, and provide a clear picture of how the constructs interact in the context of clickers use.

![Figure 1. Adopted framework from Biggs’ (2003) Presage-Process-Product (3P) model](image-url)
**3P model**

The framework (see Figure 1) was developed using the 3P model. The underlying assumptions of the 3P model are based on an understanding of teaching and learning as relational phenomena (Trigwell, 2010) that concurrently intertwine or interact with presage, process, and product factors in the learning environment as a closed system.

“Presage factors” are individual characteristics (of the student; of the instructor) that simultaneously affect and are affected by the process and product. Student presage factors include each individual student’s prior cognitive (e.g., knowledge) and non-cognitive (e.g., motivation) factors, which may or may not impact their learning processes and outcomes. Instructor/learning environment presage factors simultaneously affect student presage factors, learning processes and outcomes. The following themes are identified as instructor presage factors: course level, instructor/institutional effects, and pedagogical training.

“Process factors,” for the purpose of this study, include both teaching and learning processes and the interaction between student approaches to learning and instructor approaches to teaching. Student approaches to learning can be viewed on a continuum from deep to surface approaches. Whether a student’s approach to learning is deep or surface depends on the method of learning and the learning-focused activities that students adopt and practice. Although there is considerable variation among instructors’ approaches to teaching, they tend to fall somewhere on a continuum from teacher-centered to student-centered. In teacher-centered approaches, instructors transmit information in a didactic way, while using student-centered approaches, instructors adopt instructional strategies that achieve qualitative changes in student conceptions (i.e., active learning strategies). In this review, process factors are used to identify what instructional activities and strategies are adopted when clicker technology is implemented in college classroom instruction.

"Product factors” are learning outcomes that arise through the interaction between presage factors and processes in the 3P model. Specifically, two types of learning-outcome “products” are included in this study: cognitive outcomes (e.g., GPA) and non-cognitive outcomes (e.g., engagement). In most studies, cognitive and non-cognitive learning outcomes are among those most frequently assessed in the evaluation of clicker technology (Han & Finkelstein, 2013). In the current review, product factors are used to identify the measures (learning outcomes) that each clicker-technology study used to assess or evaluate student learning.

Using the 3P model to review clicker-use studies will help us hone in on several components of these studies: (a) what aspects of instructor and student characteristics were considered when implementing clicker technology; (b) how instructional strategies and activities were designed and implemented to achieve instructional goals; (c) what learning outcomes the authors of each study sought to assess or evaluate.

**Analysis of studies and guiding protocols**

The analysis of the clicker studies and the guiding protocols of the current review are based on Biggs (2003) and Kane, Sandretto, and Heath (2002). The 3P model (Biggs, 2003) was used to identify the research focus of each clicker-use study and the relationships among the various research foci. Kane et al.’s (2002) guiding protocols were used to investigate the relationships among the research methods, data collection, and implications for the use of clickers in college classroom instruction. The following information is presented for each reviewed study on the supplements website (http://mapping-2014.weebly.com/): author(s) and year, research focus, number of participants, presage, process and product factors, research methods, references, etc.

**Visualization approaches**

Heat-mapping approaches were used to visualize the results of the literature review using tableau public (Version 8.2). The heat-mapping approach that uses an area-based visualization technique with multi-way contingency tables to show the frequency distributions of hierarchical data in relation to the complete data set. According to Auber (2013), these mapping approaches can provide snapshots that assist readers to intuitively understand the data and results. The heat-mapping technique (Wilkinson & Friendly, 2009) was used to provide an appropriate visual framework for contrasting and comparing the co-occurrences among the factors.
Results and discussion

Results of literature search and selection approaches

Of over 200 articles retrieved from the academic database search, 84 articles were selected to be reviewed using the 3P model. 78 of these 84 articles were carried out in a discipline-specific educational setting (e.g., Physics), and only four studies were conducted in a multiple-discipline setting. Over 80% of the studies were carried out in North America; the majority (75.90%) of the studies used quantitative methodology; over 55% of the studies were published in 2012 and 2013. Interactive-mapping (see Figure 2) is available on the website (http://mapping-2014.weebly.com/).

*Figure 2. Snapshot of the overview of clicker studies reviewed*
Presage student factors

Several studies have examined student presage factors in response to the use of clickers in classroom instruction. These factors are mostly related to Cognitive, Non-Cognitive and Individual Background aspects of students (see Table 1).

<table>
<thead>
<tr>
<th>Presage Student Factors (Frequency)</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive factors ($f = 8$)</td>
<td>Factors that evaluate student characteristics related to prior performance, metacognition (e.g., grade and academic ability).</td>
<td>Brady, Seli, &amp; Rosenthal (2013a,b), Freeman, Haak, &amp; Wenderoth (2011), Roth (2012), Sprague &amp; Dahl (2010), Trew &amp; Nelsen (2012)</td>
</tr>
<tr>
<td>Background factors ($f = 12$)</td>
<td>Factors pertaining to student demographic characteristics (e.g., campus location and gender)</td>
<td>Bright, Reilly Kroustos, &amp; Kinder (2013), Cline, Parker, Zullo, &amp; Stewart (2012), Dunn et al. (2013), Smith, Wood, Krauter, &amp; Knight (2011)</td>
</tr>
</tbody>
</table>

Cognitive factors

Eight studies examined the effects of clicker use on several cognitive factors associated with student learning: student metacognition, cognitive load, student prior achievement, and academic ability. Several of these studies examined the relationship between aspects of metacognition and student learning. Brady et al. (2013a, b) found that increased clicker use was closely related to increased levels of student metacognition, which successively affected student learning outcomes (measured by quiz scores). Jones et al. (2012) found that clicker-driven changes in students’ metacognition (i.e., regulation of cognition) were closely related to gender differences. Other studies have examined the relationships between academic ability and performance level, on the one hand, and student learning in response to the use of clickers, on the other (see Table 1). The results of these studies indicate that the use of clickers might be more effective with lower-performing students.

Non-cognitive factors

Thirteen studies have examined the relationships between the following non-cognitive factors and student learning with clicker technology (see Table 1): students’ academic emotions (e.g., Filer, 2010), students’ attitudes toward technology use (e.g., Dallaire, 2011), and students’ apprehension regarding communication (e.g., Fortner-Wood, Armistead, Marchand, & Morris, 2013). In Sutherlin et al.’s (2013) study, student attitudes toward clicker use did not significantly change over the course of the semester; however, other studies have consistently found a positive relationship between students’ attitudes, perceived engagement, learning (e.g., Evans, 2012), and final grades (e.g., Dallaire, 2011).

Background factors

Even though most studies examined some aspect of background factors for pre-test screening, only 12 studies focused on the relationship between background factors and student learning. Studies examining gender effects on learning with clickers have found mixed results. Two studies (Jones et al., 2012; Kang et al., 2012) found that female students were more likely than male students to favor clicker-based cooperative instruction, while other studies (e.g., Dunn et al., 2013) did not find gender effects. However, Trew and Nelsen (2012) examined the interaction between two primary background factors (gender and year of enrollment) and course grades, it was reported that these
Presage factors taken together predicted positive student-perceived learning and outcomes in clicker-based instruction.

**Presage instructor factors**

Table 2. Description and examples of presage instructor factors

<table>
<thead>
<tr>
<th>Presage Instructor Factors (Frequency)</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course level ($f = 3$)</td>
<td>Factors related to the context in which the clickers were implemented.</td>
<td>FitzPatrick, Finn, &amp; Campisi (2011), Lee, Garcia, &amp; Porter (2013)</td>
</tr>
<tr>
<td>Instructor/Institutional effects ($f = 5$)</td>
<td>Factors that explain the broader contextual factors (e.g., the relationship between the different institutions and the clicker effects on instruction).</td>
<td>Cline, Zullo, Duncan, Stewart, &amp; Snipes (2013), Emenike &amp; Holme (2012), Lundeberg et al. (2011)</td>
</tr>
<tr>
<td>Pedagogical training ($f = 1$)</td>
<td>Factors pertaining to instructors’ preparedness and knowledge about teaching with the use of clickers.</td>
<td>Han &amp; Finkelstein (2013)</td>
</tr>
</tbody>
</table>

Although presage instructor factors have not often been examined in relation to the use of clickers, several studies have reported interesting relationships among instructor factors, instructor perceptions, and student learning (see Table 2). Emenike and Holme (2012) found a significant difference in instructors’ perceived efficacy with clicker-based pedagogy across types of institutions and suggested that this difference may arise because instructors at doctoral universities are more likely to teach large-enrollment courses. Thus, it may be class size rather than institution type that is truly affecting the efficacy in this context. Han and Finkelstein (2013) also found that individual instructors’ pedagogical training experience was positively related to student-perceived engagement and learning. However, no significant relationship between course-level and student learning was found in the clicker-use studies (FitzPatrick et al., 2011).

**Process factors**

Table 3. Description and examples of process factors

<table>
<thead>
<tr>
<th>Process Factors (Frequency)</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery methods ($f = 25$)</td>
<td>Factors that compare the effectiveness of clicker use versus other delivery methods (e.g., raising hands and lecturing)</td>
<td>Bachman &amp; Bachman (2011), Evans (2012)</td>
</tr>
<tr>
<td>Instructional activities/Course design ($f = 45$)</td>
<td>Factors that examined the effects of clicker use on students regarding the implementation of various types of instructional strategies and course design (e.g., specific types of clicker questions)</td>
<td>Anthis (2011), Bunce, Fiens &amp; Neiles (2010), Dallaire (2011), Elicker &amp; McConnell (2011), Gray, Owens, Liang, &amp; Steer (2012)</td>
</tr>
<tr>
<td>Assessment and feedback ($f = 8$)</td>
<td>Factors that examined a high- or low-stakes testing and methods of evaluating student responses in relation to the use of clickers (e.g., formative/summative assessment and feedback)</td>
<td>Chen &amp; Lan (2013), Gachago, Morris, &amp; Simon (2011), James &amp; Willoughby (2011)</td>
</tr>
</tbody>
</table>

*Delivery method*

Although use of clicker technology (in comparison to non-use) was generally found to have a positive outcome on student non-cognitive learning outcomes (Caldwell, 2007), some studies did not report any significant effects of clickers over any other type of delivery method (e.g., clickers, flashcards, and raising hands); Elicker & McConnell, (2011) reported a negative relationship between clicker use and student exam scores (e.g., Anthis, 2011). The current study supports the finding of other literature review articles (e.g., Kay & LeSage, 2009) that the use of clicker...
technology is related to students’ positive perceptions of their engagement and learning; however, it remains unclear whether this positive perception correlates with enhanced student performance.

**Instructional activities with clickers**

Several studies explored the effects of different instructional strategies and course design approaches on student learning in response to the use of clickers (e.g., Levesque, 2011). These studies primarily examined teaching approaches with clickers (e.g., Jones et al., 2012), design of clicker questions (e.g., Hogan & Cernusca, 2013), and ways of representing questions using clickers (Perez et al., 2010). The results of these studies remain mixed; Rush et al. (2013) did not find any significant difference in student learning performance regardless of the use of peer-instruction and individual-knowledge clicker questions, while Smith et al. (2011) found that peer-instruction approaches (with instructor explanation) were more closely related to overall student performance than any other methods using clickers.

**Assessment and feedback approaches with clickers**

The merits of formative versus summative assessment and feedback approaches are still under debate. White et al. (2011) suggested that a policy of awarding grade points for student clicker answers would be inappropriate due to the possibility of cheating; Han and Finkelstein (2013) confirmed White et al.’s (2011) assessment that instructors’ use of formative feedback was positively related to student-perceived engagement and learning (whereas summative feedback was not). Nevertheless, several studies (e.g., FitzPatrick et al., 2011) have indicated that students’ clicker answers are often collected for participation marks rather than right answers. These results suggest the need for a deeper understanding of how the policy of awarding grade points for clicker answers might influence student learning processes and outcomes (White et al., 2011).

**Product factors**

<table>
<thead>
<tr>
<th>Product Factors (Frequency)</th>
<th>Description</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Cognitive outcomes (f= 11)</td>
<td>Factors that were used to evaluate the effects of clicker technology (e.g., engagement)</td>
<td>Hogan &amp; Cernusca (2013), Holland, Schwartz-Shea, &amp; Yim (2013), King (2011), Laxman (2011), Oakes &amp; Demaio (2013)</td>
</tr>
<tr>
<td>Cognitive and Non-Cognitive outcomes (f = 28)</td>
<td>These combined factors were used to assess both aspects of cognitive and non-cognitive outcomes.</td>
<td>Johnson &amp; Lillis (2010), Nielsen, Hansen, &amp; Stav (2013), Patterson, Kilpatrick &amp; Woeckenberg (2010), Quinn (2010), Yeh &amp; Tao (2013), Velasco &amp; Ćavdar (2013)</td>
</tr>
</tbody>
</table>

**Cognitive outcomes**

Cognitive learning outcomes were used to assess and evaluate the effects of clicker technology on student knowledge, learning, and changes in knowledge and learning (see Table 4). Exam scores, quiz scores, overall performance, or a combination thereof was used to examine the effectiveness of clicker use on student learning. Although some studies (e.g., Bright et al., 2013) reported some degree of positive correlation between the use of clickers, perceived learning,
and quiz, exam, or specific test results, other studies indicated that these positive student learning outcomes should not be attributed to the use of clickers (e.g., Anthis, 2011).

Non-cognitive outcomes

Non-cognitive outcomes comprise the following two types: Engagement and Attendance. Since there is no clear conceptual agreement across studies on the definition of engagement (Fredricks, Blumenfeld, & Paris, 2004), the current study used the term Engagement to cover student involvement and attention. Attendance (with participation) was also frequently included as a non-cognitive measure in the studies (e.g., Bright et al., 2013). Most studies consistently reported that the use of clicker technology or different pedagogical approaches with clickers had an impact on students’ positive perception of their engagement (Freeman et al., 2011), involvement (Bright et al., 2013), attention (Gachago et al., 2011), participation (Denker, 2013), and attendance (Fortner-Wood et al., 2013). These findings align with those of previous literature reviews (Kay & LeSage, 2009), which reported that the use of clicker technology had an impact on student non-cognitive outcomes, such as an increase in student class attendance and a decrease in course failure rate (Freeman et al., 2011).

Relationships among presage, process, and product factors

The heat-mapping visualization approach was used to identify missing links in the existing clicker studies. The frequencies of all factors and tabulated factors were categorized into Presage-Student and Presage-Instructor factors in the left column and Process-Product factors in the first row in Figure 3. All cross-tabulated information was presented using multi-way contingency tables, which clearly indicated the frequency percentage of co-occurrences of factors in this study. For instance, the results clearly indicated that the relationship between pedagogical training and all other process and product factors was infrequently examined in relation to learning with the use of clickers; thus,
cross-tabulated cells connected to pedagogical training were not colored except in the Assessment and Feedback column. By contrast, the relationship between cognitive learning outcomes and instructional activities/course design factors was frequently examined and thus marked with a large, red rectangle between the cross-tabulated cells in Figure 3. The heat-mapping visualization approach was used to facilitate the comprehensive understanding of the factors examined in this study and the relationships among these factors. The results of heat-mapping indicated that the following relationships were frequently examined in the clicker studies: the relationships between instructional activities/course design as a process and student cognitive outcomes as a product (18.92%); delivery methods and student cognitive outcomes (14.86%); and instructional activities/course design and both cognitive and non-cognitive learning outcomes (9.46%).

**Relationships among student presage, process, and product factors**

<table>
<thead>
<tr>
<th>Presage, Student</th>
<th>Process</th>
<th>Cognitive outcomes</th>
<th>Product Cognitive and Non-cognitive outcomes</th>
<th>Non-cognitive outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/C</td>
<td>Delivery methods</td>
<td>10.49%</td>
<td>2.92%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instructional activities/course design</td>
<td>21.13%</td>
<td>11.27%</td>
<td>8.46%</td>
</tr>
<tr>
<td></td>
<td>Assessment and Feedback</td>
<td>5.63%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background factors</td>
<td>Delivery methods</td>
<td>1.41%</td>
<td>4.23%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instructional activities/course design</td>
<td>5.63%</td>
<td>1.41%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assessment and Feedback</td>
<td>2.82%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive factors</td>
<td>Delivery methods</td>
<td>1.41%</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Non-Cognitive factors</td>
<td>Delivery methods</td>
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<tr>
<td>Background and cognitive factors</td>
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</tr>
<tr>
<td>Background and Non-Cognitive factors</td>
<td>Instructional activities/course design</td>
<td>1.41%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background, Cognitive, and Non-Cognitive factors</td>
<td>Instructional activities/course design</td>
<td>1.41%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: N/C refers to Not Considered*

*Figure 4. Results of heat-mapping: The Relationships among all 3P factors*

The heat-mapping method (Figure 4) was used to identify the missing relationships among the 3P factors. It should be noted that presage instructor factors were excluded in the further heat-map results because the frequency of instructor presage factors ($f = 9$) was small and thus may have scattered the presentation focus. The results of heat-mapping highlighted the most frequently and least frequently examined relationships in the clicker studies. Overall, the following three relationships were the most widely investigated in clicker-use studies: the relationships between instructional activities and cognitive outcomes (21.13%), delivery methods and cognitive outcomes (15.49%), and instructional activities and both cognitive and non-cognitive outcomes (11.27%). In other words, nearly 64.8% of the studies did not consider presage student factors, while 35.2% of studies did consider presage factors as variables in their studies. However, students’ non-cognitive outcomes were not considered as either process factors or as student presage factors in the studies.

**Relationships between student presage and process factors**

The results indicated that almost 41% of studies examined instructional activities/course design without taking into account student presage factors, whereas student background (7.04%) and non-cognitive factors (7.04%) were frequently examined in relation to instructional activities/course design (see Figure 5). Even though over 5% of studies examined more than one student presage factor in connection to process, non-cognitive, and background factors, these combined presage factors were not examined in connection with assessment and feedback.
Relationships between student presage and product factors

Figure 6 highlights the results pertaining to the relationship between presage student and product factors in the clicker-use studies. Specifically, 64.79% of studies examined all three types of learning outcomes without considering student presage factors. Conversely, both cognitive and non-cognitive outcomes were often investigated in the context of all presage student factors (21.13%). Interestingly, no study examined all the presage student factors in relation to non-cognitive outcomes. Cognitive outcomes were likewise not examined in relation to more than one presage student factor in any of the clicker studies.

Relationships between process and product factors

The results indicated that the relationship between process and product factors was broadly examined in clicker studies (Figure 7). Even so, relationships between non-cognitive outcomes and delivery methods, and between non-cognitive outcomes and assessment and feedback, were missing from the studies. In addition, in comparison to delivery methods, assessment and feedback approaches, instructional activities (8.45%) were minimally explored in relation to product factors.
Evidence of learning outcomes: Perceptions and achievement

The heat-mapping method generated a cross-tabulation between three types of learning outcomes and products (Figure 8). Although some studies (22.37%) assessed student cognitive learning based on both student achievement (e.g., quiz score, exam score, performance) and student-perceived learning, nearly 16% of studies measured student cognitive learning using only their perceptions. Student perceptions were also used to assess both cognitive and non-cognitive outcomes (22.68%). Overall, a collection of student perceptions (using survey items and instrument measurement) was the most frequently used method of assessment for student learning in clicker-use studies.

While most clicker studies reported cognitive outcomes as their concrete measure of student learning (see Table 4), many studies (e.g., Fortner-Wood et al., 2013) also investigated student perceptions of learning. Several studies (e.g., Sprague & Dahl, 2010; Schmidt, 2011) identified an interesting and somewhat positive relationship between student perceptions of learning (as measured by survey items such as “I learned a lot of content”) and cognitive learning.
outcomes (e.g., quiz results). Entwistle (2010) provided insight for understanding the nature of the relationship between perceptions and concrete results: he concluded that students’ perceptions of their learning (or learning environments) could be informative when evaluating the degree to which one instructional factor was synchronized with student learning outcomes. Specifically, students’ perceptions might not have a direct effect on student cognitive learning, but were mediated by teaching and learning processes (Trigwell, 2010).

Methodological issues

The following five methodological issues and concerns emerged from the literature review. First, most studies on the use of clickers do not report or specify the effect size. Reporting effect size can facilitate the process of interpreting the results and understanding the magnitude or estimated power of the variables in relation to the population (Cohen, 1994). Second, validity and/or reliability test results were not reported in most studies, even when new designs or instruments were developed to measure the effects of learning outcomes. Other reports on clicker studies (e.g., Han & Finkelstein, 2013) have pointed out that a lack of validity and reliability in the scales used may decrease in the credibility of the constructs. Third, although measuring a single factor (such as “satisfaction”) with a single item has met with success (Wanous, Reichers, & Hudy, 1997), it is not clear that measuring a complex construct (e.g., engagement and learning) with a single item can be equally valid. Using multiple items to measure these complex constructs would be preferable. Fourth, some studies that have chosen to explore the effects or mechanism of clickers through qualitative methodologies have failed to fully describe or specify the trustworthiness of the chosen measures (Lincoln, Lynhan, & Guba, 2011). In particular, inter-rater reliability and coding procedures are very often not clearly described, an oversight which decreases the credibility of the study results. Fifth, although parametric analysis is the most frequently used method in most clicker studies, normality tests or descriptions about the normal distribution are generally not elaborated upon. Failure to test normality in studies using parametric analysis may threaten the credibility of the results and interpretation.

Summary

While other literature reviews on clicker use have provided insights on the advantages and barriers involved in the practical aspects of designing and implementing clicker technology, the current review extends those insights by examining clicker studies in the context of the 3P model, which has been conceptually and practically validated internationally. The current review is also distinct in its use of information visualization methods, including heat mapping, to analyze hierarchical data in the review results. A primary goal of this review is to provide the tools necessary for achieving a better, more integrated understanding of clicker studies. The 3P model and heat-mapping approaches recursively enable us to comprehend the relationships among student and instructor presage factors, process factors (instructional activities), and product factors (outcomes) within the context of clicker use in classroom instruction.

This study showed that the incorporation of guided review protocols from previous systematic literature review studies allows us to pinpoint outstanding methodological concerns related to the rigorous use of research methods in clicker-use studies. This study confirmed the findings of Kay and LeSage (2009) that most studies to date have not reported appropriate information regarding reliability and validity, and thus their results might be anecdotal (Caldwell, 2007). The current review extended these findings by providing evidence that most clicker studies also did not provide effect sizes or description of scale development. Thus, it seems likely that the fault does not lie in a failure to adopt a specific research design, but in a failure to specify and describe the appropriate procedures for enhancing the quality of the evidence.

Specifically, the current review found that recently published studies relied concurrently on perceptions and cognitive/non-cognitive outcomes, rather than either factor in isolation, to measure the effects of clickers on student learning. Past clicker literature reviews (e.g., Kay & LeSage, 2009) have indicated that about a third of the studies reviewed used only learning outcomes as a measure for determining the effect of clickers on student learning; however, the current study found that more than half of studies published after 2009 used more than one measurement method to enhance the validity of their findings. Furthermore, the product factors (cognitive and non-cognitive outcomes) were also simultaneously used as measures to assess clicker effects on learning.
Conclusions and implications

Several studies have adopted distinctive research methods and approaches to explore the impact of clicker use on student learning; the focus of these studies has shifted from the comparison of different methods toward an examination of the relationships among clicker question design, instructional activities, and course design, on the one hand, and various types of learning outcomes, on the other. A relationship between student non-cognitive and/or cognitive learning outcomes and process factors (e.g., clicker question design) was consistently identified in these studies; it may be concluded that more effective process factors enable student to adopt deeper approaches to learning and to actively engage in instructional activities with the use of clickers. All of the findings from the current survey of clicker studies reinforce the message that a balanced understanding of the use of clicker technology in higher education has yet to be achieved. In other words, there are still missing links in our understanding of the relationship between clicker use and education; future studies should address these links in order to enhance our understanding of relationships among the factors.

Missing links and opening the relationship among the factors

Rather than seeking to identify strict cause-effect relationships, the 3P model allows us to focus on interactions between multiple personal, interpersonal, technological and environmental factors related to clicker technology. The use of heat-mapping supports this relational understanding of clicker use and enables us to identify the following three missing links and gaps in the relationships that affect learning:

- One of the most important missing links concerns presage factors related to student learning. Since only a few studies have seriously considered and examined these factors, it is unclear how those factors are synchronized with instructional processes and learning outcomes in the context of clicker use. In other words, the benefits that students derive from clicker use may vary according to their previous achievement levels and their levels of motivation and metacognition (Brady et al., 2013a). It thus is essential to develop a comprehensive understanding of the relationship between the use of clickers and learning.

- Another missing link is the relationship between instructor presage factors and student learning. It is worth noting that instructor-related presage factors have been under-examined in most clicker studies. As a result, the effect of instructor presage factors on student learning processes and outcomes is not yet fully understood, despite the fact that these factors obviously play a key role in the implementation of clicker technology use in the classroom.

- A final missing link to be taken into consideration is the relationship between process and product factors. Specifically, the following process factors might help explain why and how clicker use influences student engagement and learning: types of student interaction with peer groups (Macarthur & Jones, 2013), difficulty level and types of clicker questions (e.g., Cline et al., 2013). Investigating different instructional activities and course designs incorporated with clicker technology may help us to understand what types of instructional strategies show the best-fitting results, and lead to a richer understanding than an investigation that focuses exclusively on the binary effect of use/non-use of clickers on instruction.

Based on the missing links identified above, we suggest that seeking answers to the following research questions will enhance our collective understanding of the use of clickers in higher education: How do the following unexamined factors relate to the use of clickers in classroom learning environments? How do these factors (in conjunction with previously examined ones) influence the process of teaching and learning with clicker technology?

- Student presage factors: individual student goals, interests, and epistemic beliefs
- Instructor presage factors: pedagogical development and course design experience
- Process factors: student (deep/surface) approaches to learning and instructor (content-/student-centered) approaches to teaching
- Product factor: the (coherent or contradictory) relationship between student perceptions and objective evidence of learning
Relationship between the effective use of clickers and the pedagogical issues

Research into the effects of clicker technology tends to have as its goal the identification of implications for the design and implementation of clickers in college classroom instruction. The studies examined in this review have commonly indicated that effective use of clickers is closely related to instructors’ pedagogical view and/or knowledge; thus, the use of clickers may be seen either as “teacher-centered” or “student-centered.” For instance, clickers may be incorporated into active learning strategies to enhance engagement and learning, or they may be used in a more teacher-centered way - for instance, to monitor student attendance rather than to encourage student participation. This issue may be closely related to instructors’ preparedness for clicker use, instructors’ approaches to teaching, and instructors’ pedagogical and technological views and knowledge.

One workaround to resolve the issues stemming from a lack of instructors’ pedagogical and technological knowledge and skills is to provide instructors with the appropriate training and instruction (e.g., Han, 2014). A few studies have suggested that pedagogical training will allow instructors to re-examine their teaching approaches and to enhance their course design knowledge while keeping clicker technology in mind. In terms of specific pedagogical advice, the studies commonly suggest that clickers should be able to collect student logs and data regarding student actions (e.g., participation, answers to the questions); using clickers in this way allows instructors to identify places where student understanding is lagging or to identify misconceptions or naïve conceptions concerning course content. Additional training on clicker data analytics could give instructors the opportunity to re-examine their instructional activities and realign their course design to optimize the course content, goals, and pedagogical approaches with clickers.

Concluding remarks

The current study reviewed the literature regarding the use of clickers in higher education by using the 3P model for teaching and learning. Although research into clicker technology has shown fairly clearly that clicker technology as a pedagogical tool impacts both teaching and learning in classroom instruction, it is still not fully apparent how and why the use of clicker technology affects student learning. Using the 3P model and two visualization methods, the current literature review identified several missing links among presage, process, and product factors and the use of clicker technology. Since teaching and learning with clicker technology is a complex as well as relational phenomenon, a comprehensive understanding of how and why these factors are synchronized or out of sync with other instructional factors will close the missing links and help to fill new gaps that emerge through further studies.

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