# INTRODUCING CLICKERS IN THE CLASS. UNDERSTANDING THE ROLE OF INTERACTIVITY, COLLABORATIVE LEARNING AND ENGAGEMENT IN IMPROVING STUDENT LEARNING PERFORMANCE

LORENA BLASCO-ARCAS
ISABEL BUIL
BLANCA HERNÁNDEZ-ORTEGA
F. JAVIER SESÉ-OLIVÁN
lorena@unizar.es, ibuil@unizar.es, bhernand@unizar.es, javisese@unizar.es
*Universidad de Zaragoza*

**RESUMEN**

*As more and more educational institutions are integrating technology (e.g. audience response systems) into their learning systems to support the learning process, it becomes increasingly necessary to have a thorough understanding of the underlying mechanisms and ultimate consequences of these advanced technologies on relevant student learning performance outcomes. In this study, our primary objective is to investigate the effect of audience response systems (also known as clickers) on student learning performance. To do so, we develop a conceptual framework in which we propose that interactivity, active collaborative learning and engagement are three key underlying forces that explain the positive effects and benefits of clickers in enhancing student learning performance. We test empirically these relationships in a University class setting using data from a survey answered by students in a social sciences degree. The results provide strong support to our proposed framework and they reveal that the high interactivity with peers and with the instructor that is promoted by the use of clickers positively influences the student active collaborative learning and engagement, which in turn improves student learning performance.*

**Palabras clave:**

Clickers, Learning performance, Engagement, Collaborative learning, Interactivity

## *Introduction*

Information technology (IT) has been considered a strategic resource in many organizations (Nah et al., 2005; Sheng et al., 2005). If managed properly, it can become a key source of competitive advantage (Mata et al., 1995). Firms' adoption and integration of IT into their core processes has thus resulted in a significant improvement in commerce (Hoffman and Novak, 1996; Siau et al., 2004), services (Grant, 2006; Benaroch and Appari, 2011; Ladhari, 2011), and supply chain management (Eng, 2006; Lo et al., 2008; Daghfous and Barkhi, 2009), among other activities.

Although researchers have traditionally focused on the implications of IT on business activities, advanced technologies are increasingly being used in educational settings, offering educational institutions a unique opportunity to increase student interest and motivation and enhance student learning (Roblyer and Wiencke, 2003). Examples of technologies that have received considerable attention by educational institutions and have been addressed by prior research include WebCT, Blackboard, tablet PCs, instant messaging, or text messaging through cell phone. In this study, we focus on clickers, which have increasingly become an integral part of the student learning experience in some educational institutions and offer a high potential for further learning performance improvements. Studied under different names such as audience response systems (e.g. Robertson, 2000; Miller et al., 2003), voting machines (e.g. Reay et al., 2005), wireless keypad response systems (e.g. Burnstein and Lederman, 2001), and classroom communication systems (e.g. Dufresne et al., 1996; Paschal, 2002; Naismith et al., 2004; Roschelle et al., 2004a), clickers are interactive remote response devices that transmit and record student responses to questions providing immediate feedback to both the students and the instructor about the learning process (Homme et al., 2004).

Despite recent interest in the role of clickers from a student learning perspective, several challenges prevent researchers from fully understand the influence of clickers on student learning (see the meta-analysis of Kay and LeSage, 2009). First, existing knowledge comes primarily from qualitative analysis. These studies, while offering sound guidance and advice about the use of clickers in the educational context, provide little direction for understanding the mechanisms through which clickers may affect student learning. Thus, there is a lack of quantitative studies that, based on sound theory, may help to better understand the role of clickers in student learning and the underlying mechanisms that explain their ultimate impact on performance outcomes (Fies and Marshall, 2006; Kaleta and Joosten, 2007). Second, there is a noticeably lack of reliability and validity analysis of the measurement instruments used in the studies, which makes it difficult to have a rigorous understanding of the phenomenon. Kay and LeSage (2009) indicate that only 4 out of 67 papers included in their literature review consider these issues (these exceptions are Schackow et al., 2004; Siau et al., 2006; Penuel et al., 2007; Trees and Jackson, 2007). Finally, prior research has been conducted on a limited set of educational settings, mainly on technical and scientific subjects such as mathematics, chemistry, engineering or astronomy. Surprisingly, there is a remarkable lack of studies in the social sciences. Thus, there is a need of studying social science subjects in order to understand more broadly the general educational impact of clickers.

Addressing these gaps, our primary objective is to investigate the impact of clickers on student learning performance. To do so, we develop a conceptual framework in which we identify several critical mechanisms that underlie the effect of clickers on performance outcomes. Specifically, we propose that the level of interactivity among students, and between the instructor and the students as a result of using clickers affects student collaborative learning and engagement and, in turn, student's learning performance. To achieve this objective, we carried out a quantitative study with data collected from undergraduate students in a social sciences degree and study both the reliability and validity of the scales and the causal relationships between the proposed constructs. By doing so, we aim to bridge the identified gaps and contribute to existing research with an empirical application that provides interesting implications about the use of clickers for student learning that can be also applied to other learning contexts. Moreover, we aim to contribute to the existing discussion regarding engagement generation, as enhancing learner engagement and collaboration have been recently identified as a research priority in learning research (Oncu and Cakir, 2011).

The rest of the manuscript is structured as follows. The following section provides a brief description of the clickers and their most significant features. Section 3 reviews the relevant literature of the studied variables -active collaboration, engagement and interactivity-, explains the specific conceptualization required for this technology, and describes the hypotheses. Section 4 describes the data and the empirical analysis undertaken to test our proposed hypotheses: confirmatory and causal analysis. In Section 5 we discuss our results. Finally, section 6 provides the conclusions and implications of our research, outlining some limitations and opportunities for further research in the field.

## 1. What are clickers? Characteristics and advantages

Clickers are small transmitters that look similar to a television remote control. They are advanced technological devices that allow students to quickly answer to questions that are presented in-class. When the students answer the questions, the clicker's code appears on-screen, and students know that their response has been recorded. A computer summarizes the responses and the results are automatically displayed in chart form, usually a histogram. Responses can be anonymous or linked to specific students through the clicker unit ID, allowing the instructor to know who gave correct and incorrect responses. Clickers are interactive and able to speed-up didactic lectures when teaching adults and/or active learners.

This advanced learning technology was first introduced at Stanford University in 1966. However, they were too expensive and difficult to use so its introduction was not successful (Abrahamson, 2006; Judson and Sawada, 2002, 2006). In 1985 a new clicker prototype was launched. It was less expensive than the previous system and overcome some of the limitations detected in the previous model. During the 90s, clickers started to be broadly commercialized, and it was not until 2003 that they became extensively used in the educational context (Abrahamson, 2006; Judson and Sawada, 2002, 2006).

Clickers provide significant benefits to both the instructor and students (Bullock et al., 2002; Bergtrom, 2006; Simpson and Oliver, 2007). For the instructor, clickers provide immediate feedback about the student learning process and allow him/her to gauge the overall comprehension of the concepts while moving through all the material. Clickers are also very effective at engaging students in the class, assessing whether the students are following the course materials, and evaluating the students' overall understanding. For students, clickers promote interactions among them, provide immediate feedback on their understanding of the lessons, and facilitate their active participation in the learning process by discussing the answers given to the questions. These clickers' features stimulate the development of student-instructor relationships and lead students to perceive the activity as being entertaining, which in turn increases their willingness to actively participate in the class.

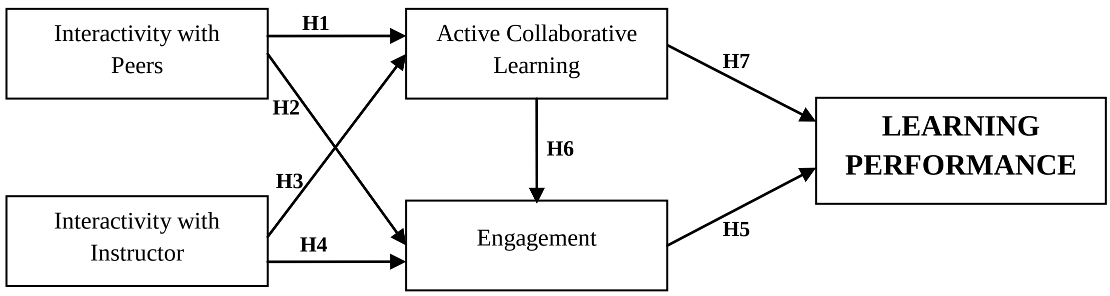
A recent meta-analysis about clickers provides support for the above-mentioned benefits and identifies additional advantages (Roschelle et al., 2004a, b). For example, they affect the classroom dynamic through directly involving students in the material presented, and the meaning of the question becomes a class-time focus to the student. Moreover, the individual and the group can share the response to the question, and everybody can participate in the discussion of the correct answer. Specifically, clickers heighten peer interactions, increase student understanding of complex subjects, achieve greater student engagement, and increase students' awareness of their individual progress and comprehension. Similarly, Judson and Sawada (2002) posit that the use of clickers in class allows collaborative activities and the use of higher-level conceptual questions to enhance discussion and promote learning.

On the basis of these benefits, we expect the use of clickers in the class to have a positive effect on student learning performance. In the next section, we develop a conceptual framework to identify and understand the underlying mechanisms through which clickers translate into enhanced learning outcomes: interactivity, active collaborative learning and engagement, and derive the research hypotheses about the relationships between these variables.

## 2. Conceptual framework and hypotheses

In this study, we provide a conceptual framework that identifies key mechanisms through which the use of clickers influences student learning performance outcomes. Figure 1 offers a graphical representation of the proposed conceptual framework. We consider that student perceptions of the interactivity with peers and with the instructor that result from the use of the clickers promote student active collaborative learning and engagement, which ultimately leads to enhanced student learning performance.

FIGURE 1
**Conceptual Framework**




As noted previously, by stimulating two-way communications during the process of answering the questions and in the discussions about the correct answers to the proposed questions, clickers increase the degree of perceived interactivity in the classroom both among students (interactivity with peers) and between the students and the instructor (interactivity with instructor) (Banks, 2006; Bergtrom, 2006; Caldwell, 2007; Mayer et al., 2009). In an educational context, interactivity is conceived as a critical element in the student learning process. It stimulates students in actively participating in the classroom (active collaborative learning) (Thalheimer, 2003; Guthrie and Carlin, 2004), and in developing a sustained behavioral involvement in learning activities (engagement) (Carnaghan and Webb, 2007; Kay and LeSage, 2009). The presence of these two elements is instrumental in enhancing student's learning performance. Only when students actively collaborate in the learning process the instructor can adapt the lecture pace, style and topic to better fit the student needs, identify any misunderstanding to properly and timely clarify it, and make sure that they have understood all the materials to continue with the next learning step. In addition, active learning promotes student involvement in the lessons potentially leading to a greater degree of student engagement. Engaged students have a high level of involvement that leads them to prepare themselves better for the class, pay more attention, take good notes, actively think and be able to recall material from previous lectures (Caldwell, 2007). Eventually, all this would result in achieving learning success, and therefore, student engagement is also a necessary condition to enhance learning performance outcomes.

Next, we offer the conceptual rationale for each of the proposed relationships between the studied variables.

### *3.1 Interactivity*

Traditional learning methods can hinder interactions in the classroom (Cotner et al., 2008). The breakdown of communication makes it difficult to gauge student conceptual understanding. The range of feasible assessment techniques is also constrained by the sheer number of students. Consequently students receive limited feedback on their learning. Limited class time, rigid seating arrangement, and students' reservations to speak out in class have also been identified as important barriers to achieve high levels of interactivity (Liu et al., 2003; Draper and Brown, 2004). However, advanced technology has changed the way students and the instructor interact in the classroom and provided new opportunities to enhance interactivity.

Promoting interactivity is critical as it leads to better and more effective learning (Bannan-Ritland, 2002; Erickson and Siau, 2003). Thus, it becomes a key source of success in education (Fulford and Zhang, 1993; Chou, 2003; Siau et al., 2006). This concept has long been considered one of the main pedagogical issues in the classroom, especially for larger classes and technology-related courses. According to Siau et al. (2006), four important issues related to interactivity can be identified: (1) active involvement of students, (2) bidirectional communication among students and instructor, (3) social, cooperative, and/or collaborative exchanges, and (4) instructional activities and technologies. When interactivity is present in the learning activity, students are not only more motivated to learn, but also more attentive, participative, and more likely to exchange ideas with others (Liu et al., 2003; Sims, 2003). Consequently, interactivity influences students' learning outcomes, such as attitude and achievement (Haseman et al., 2002).

It is important to distinguish between two types of interactivity: (1) interactivity between students (Interactivity with peers) and (2) interactivity between the students and the instructor (Interactivity with the instructor). Astin (1993) identifies interaction among students and interaction between students and faculty as the two environmental factors most predictive of positive change in students' academic and personal development. Thus, building these two types of interactivity becomes critical for achieving success in the learning process.

Interactivity with peers results from students' participation, discussion, and peer instructions, and it improves active processing of course material and higher-order learning (Slavin, 1991; Crouch and Mazur, 2001; Michaelson et al., 2004). Some students prefer hearing explanations from their peers who use a similar language and therefore can explain the problems and solutions more effectively than the instructor (Nicol and Boyle, 2003; Caldwell, 2007). Regarding interactivity with the instructor, building interactions with students in class is an important part of the instructor task and a critical component of the learning process (Mayer et al., 2009). This interactivity allows the instructor to assess students' understanding of materials and concepts, address questions and problems faced by students and develop closer relationships between the student and the instructor. Indeed, students-instructor interaction is ranked highly among factors influencing performance learning (Meltzer and Manivannan, 1996; Hake, 1998; Bullock et al., 2002). Overall, both types of interaction involve students actively in the classroom (Sims, 2003), provide information feedback to both parties, and ultimately improve learning performance (Wang et al., 1992; Higgins et al., 2002; Draper and Brown, 2004).

The use of technology in lectures, and more specifically, the use of clickers, can improve the existing interactions during the learning process, since they foster communication among the students and between the instructor and the students (Beatty, 2004; Banks, 2006; Bergtrom, 2006; Caldwell, 2007; Mayer et al., 2009). These two interactivities lead to significant improvements in the learning process including greater articulation of student thinking (Beatty, 2004), effective peer-to-peer discussion (Bergtrom, 2006; Kennedy et al., 2006), engagement (Marks, 2000; Fredricks et al., 2002; Anderson, 2003) and collaborative learning (Elliot, 2003; Kennedy et al., 2006). On the basis of the preceding discussion, we consider that student's engagement and active collaborative learning are two important consequences of interactivity. Therefore, the following four hypotheses are proposed:

*H1: Interactivity with peers as a result of using clickers increases students' active collaborative learning.*

*H2: Interactivity with peers as a result of using clickers increases students' engagement.*

*H3: Interactivity with the instructor as a result of using clickers increases students' active collaborative learning.*

*H4: Interactivity with the instructor as a result of using clickers increases students' engagement.*

### *3.2 Engagement*

The concept of engagement in the learning literature has been addressed from different perspectives. In fact, engagement has been considered as having high potential as a multidimensional construct that unites behavioural, emotional and cognitive components in a meaningful way (Fredricks et al., 2004). In the learning literature, engagement has been defined in three ways. Fredricks et al. (2004) established in their analysis that *behavioural engagement* is based on the idea of participation and involvement; *emotional engagement* includes positive and negative emotions towards teachers, peers and the school; and *cognitive engagement* incorporates investment as willingness to put effort in apprehend complex concepts.

Although engagement was first linked to aspects such as mere attendance and/or examination results, recently researchers are increasingly offering a more attitudinal-related conceptualization. For instance, Skinner and Belmont (1993) define the engaged student as one who "shows sustained behavioral involvement in learning activities accompanied by a positive emotional tone" (p.14). In a related study, Jones (1998) understands engagement as the relation between knowledge or intrinsic interest and external stimuli that promotes initial interest and desires of continuous learning. From this perspective, some key aspects related to engagement have been analyzed including involvement and learning as a cognitive process (Jones, 1998), holistic implication and cognitive process (Herrington et al., 2003), and interaction, continuous cognitive effort, concentration and active learning (Guthrie and Carlin, 2004). Students learn better when they engage in an appropriate cognitive processing (Mayer et al., 2009). Therefore, their engagement during the class time seems to be an important explanatory variable of their success (Pascarella and Terenzini, 1991). In fact, high engagement during activities in class has been considered an accurate predictor of continuing motivation, commitment and overall performance (Shernoff and Hoogstra, 2001). It has also been considered a predictor of learner achievement and individual development (Baker et al., 2004; Kuh, 2003), with other achievement-related outcomes (Marks, 2000), and it is believed that help to prevent dropping-out of school intentions (Connell et al., 1995).

Despite the importance and increasing attention that engagement has received in an educational context, few studies have quantitatively analyzed the influence of engagement on learning performance. Moreover, one of the weaknesses related to the conceptualization of this variable is the manifest overlap, duplication and lack of differentiation from other existing constructs. Engagement measurement is also considered as a critical point as "measures are rarely attached to specific tasks and situations, instead yielding information about engagement as a general tendency" (Fredricks et al., 2004, p.69). Anderson (2003) has specified that "engagement is developed through interaction" (p.129). Other authors have established that the classroom environment with teacher and peers promotes the development of higher engagement (Marks, 2000; Fredricks et al., 2002), and peer groups influence on the socialization of engagement (Ryan, 2000). In this sense, Ahlfeldt et al. (2005) highlights the importance of engagement development not only for student motivation but also for increasing the richness of the student's learning environment, in which interpersonal interactions play a key role. Consistent with this, we define engagement as the perception resulting from peers and teacher interactions during the learning experience that generates involvement and sense of belonging (Fredricks et al., 2002; Anderson, 2003).

In this context, the clickers are considered as a technology that improves engagement and learning outcomes (Carnaghan and Webb, 2007; Kay and LeSage, 2009) as well as promote interactions. Students who use clickers for discussing concepts and ideas with their peers develop a high interest in the subject matter, which improves student engagement (Bergtrom, 2006; Hu et al., 2006; Simpson and Oliver, 2007). Consistent with this, Gallini and Moely (2003) stated that using clickers in class fosters the interpersonal dimension of engagement. At the same time, engagement has a direct effect on the student learning performance (Brewer, 2004; Hu et al., 2006; Caldwell, 2007) and increases achievement for students (Caldwell, 2007; Kenwright, 2009). On the basis of the prior discussion, we consider that engagement is a key driver of learning performance and, thus, formally propose the following hypothesis:

*H5: Engagement of users as a result of using clickers improves students' learning performance.*

### *3.3 Active collaborative learning*

Active learning is defined as "the result of a deliberate and conscious attempt on the part of a teacher to cause students to participate overtly in a lesson" (Pratton and Hales, 1986, p. 211). Active learning techniques include class or group discussions, simulations, practical exercises and demonstrations. It can increase exam scores over traditional formats (Yoder and Hochevar, 2005). Moreover, this learning is especially beneficial due to the collaborative effect, which occurs when students generate the correct answer and participate in its explanation and justification, rather than simply giving the answer (Lantz, 2010). Students explain the question to each other and go deeper into the subject matter, which helps them build new associations and construct their understanding with respect to what they already know (Dufresne et al., 1996; Draper et al., 2002; Kennedy and Cuts, 2005). Likewise, students feel that they are collaborating in the creation of their own knowledge as they turn into active agents in their learning process instead of being mere listeners or passive agents. According to the generative theory of learning, students learn better when they participate in active cognitive processing (Wittrock, 1990; Mayer and Wittrock, 2006). Collaboration increases the ability to think critically (Garrison et al., 2001; Angeli et al., 2003) and it has been related to student involvement, satisfaction, engagement and higher-order learning (Hiltz et al., 2000; Khan, 2000).

Among the alternative strategies that might lead to improved student learning, increasing student participation has proven highly successful (Stowell and Nelson, 2007) and, notably, it is further enhanced when combined with the use of technology. Kryder (1999) offers support to this view by suggesting that as students use technologies, they are more collaborative in their learning process. Similarly, Fowler et al. (2001) note that students who are skilled technology users have a learning style that is both sensory and visual, and that 80% of all students are active learners. In this context, we analyze the role of clickers in enabling students to cognitively process questions asked by the instructor and increasing students' participation (Caldwell, 2007; Ribbens, 2007).

Clickers facilitate the integration of active learning in the classroom, fostering the mentally processing of new concepts and their integration with prior related knowledge (Mayer et al., 2009). Therefore, this technology facilitates students' contribution to knowledge creation and makes them active participants in their own learning, which results in an enhanced overall performance (Thalheimer, 2003; Guthrie and Carlin, 2004). In addition, research shows that students become engaged using clickers because they are more involved in the learning process (Wenk et al., 1997; Yourstone et al., 2008). Engagement is also enhanced when students discuss ideas and debate points of view critically (Guthrie and Wigfield, 2000). Therefore, we expect that the active collaborative learning resulting from the use of clickers improves students' engagement and learning performance. We propose these hypotheses:

*H6: Active collaborative learning as a result of using clickers improves students' engagement*

*H7: Active collaborative learning as a result of using clickers improves students' learning performance.*

## 3. Method: participants, procedure and measures

The sample consisted of 198 undergraduate business students enrolled in an introductory marketing course during the 2010–2011 academic year at a major university in Spain. Participants belonged to four different classes and were in their first-year of study. Their ages ranged from 18 to 36 years. The sample consisted of 89 males and 109 females.

Students attended classes 2 days a week for four hours during the first semester. In all classes, the course material, lectures and PowerPoint slides used were the same.

Clickers from Hyper-Interactive Teaching Technology (H-ITT) were used. All signals were collected by a receiver plugged into a laptop at the front of the classroom.

The method of instruction used during the tests sessions with clickers was peer learning. That is, students worked in small groups (4-5 people). Each group was assigned a clicker number at the beginning of the semester. At the start of each class when clickers were used, groups picked up the same clicker. The software recorded each group's response.

At the end of each of the six units of the marketing course, the groups were asked to prepare and send three multiple-choice questions to the instructors. As clickers' effectiveness to increase learning heavily depends on the design of the questions, special attention was paid to this stage. The guidelines and suggestions proposed in the literature to design questions were followed (e.g., Wit, 2003; Beatty, 2004; Beatty et al., 2006; Beekes, 2006). Therefore, before choosing the test questions, they were carefully analyzed and adapted by the instructors. In general, questions tried to assess understanding of material, students' ability to apply the knowledge to new situations, and review the content of each unit.

A total of 6 tests were given during the semester, one for each unit. Each test included 10 multiple-choice questions. A final test containing 10 multiple-choice questions and covering all the material was also given at the end of the semester.

The questions were displayed on PowerPoint slides. Once the clicker system was activated, a timer appeared on the screen. The system allowed a time limit to be set for responses. According to the nature and difficulty of the questions, groups of students were given 60-90 seconds to answer the question using their clicker. The number of groups who have responded at any point in time was displayed. Once the voting was closed, student responses were displayed as a bar graph with the distribution of answers (shown as a percentage). Students were then encouraged to ask questions, justify their answers and discuss the alternative answers. Next, an indication of the correct answer was shown.

Participation in clickers was included as part of the student's grade (5% of the student's grade), but students were not graded on their actual performance on the clicker questions.

At the end of the semester (January 2011), a survey was administered to assess student's opinions about the use of clickers. The questionnaire was administered in class. It was made clear that participation in the survey was voluntary and anonym.

A literature review was carried out to measure the constructs in this study (see Table 1). In all cases, seven-point scales were used. The interactivity with peers and the instructor was measured using a subset of four items from Liu (2003) and McMillan and Hwang's (2002) works. Measures of active collaborative learning were adapted from So and Brush (2008). Engagement was measured using three seven-point Likert scale items adapted from Gallini and Moely (2003) and Medlin and Green's (2009) works. Learning performance was assessed following MacGeorge et al. (2008).

The results reported in this paper are part of a larger study. As such, in addition to the variables of interest in this research, the survey included questions about the student's overall impressions of clickers (e.g. perceived usefulness, perceive easy of use, enjoyment, overall attitude, satisfaction, etc.), social benefits of using clickers (e.g. share of knowledge, sense of belonging, recognition, etc.), and other questions regarding their perceptions of and behaviors related to clickers' contributions to learning processes. Finally, the survey included questions asking for demographic information (i.e., age and gender).

## 5. Analyses and results

### *5.1 Confirmatory analysis*

Confirmatory factor analysis (CFA) using the robust maximum-likelihood estimation method was performed to test the dimensionality, reliability and validity of the constructs in the model (Bentler, 1995). The goodness-of-fit indices exceeded the optimal levels recommended by Hair et al. (2006): NFI = .919; NNFI = .958; CFI = .966; IFI = .966; RMSEA= .058; $X^2$ normed= 1.66, thus providing evidence that the measurement model fits the data appropriately.

Factor loadings of the indicators for each construct were statistically significant and sufficiently large (see Table 1). Moreover, the coefficients also had a clear relation with the underlying factor ($R^2 > .50$). The internal validity of the measurement model was examined by calculating the composite reliability coefficient (CRC) and the average variance extracted (AVE) (Fornell and Larcker, 1981; Bagozzi and Yi, 1988). As can be seen in Table 1, for all factors, CRCs were above the recommended .70 and AVE exceeded .50.

The discriminant validity of the measures was examined in two ways. First, the AVE was compared with the squared correlation among the latent variables (Fornell and Larcker, 1981), testing that for any two constructs it was always greater than the correlation estimate (see Table 2). Furthermore, all the confidence intervals around the correlation estimate between any two factors were tested. None of the confidence intervals included one, suggesting that discriminant validity is supported (Anderson and Gerbing, 1988).

TABLE 1
**Scale items and Confirmatory Factor Analysis Results**

| **Measures** | **Standardised factor loading** | **$R^2$** | **CRC** | **AVE** |
|---|---|---|---|---|
| **Interactivity with peers** (Liu, 2003; McMillan and Hwang, 2002) | | | .90 | .69 |
| Using the clickers in class... | | | | |
| INT_P1. Facilitates interaction with peers | .846 | .716 | | |
| INT_P2. Gives me the opportunity to talk back with peers | .902 | .814 | | |
| INT_P3. Facilitates dialogue with peers | .855 | .731 | | |
| INT_P4. Allows the exchange of information with peers | .707 | .500 | | |
| **Interactivity with the instructor** (Liu, 2003; McMillan and Hwang, 2002) | | | .93 | .78 |
| Using the clickers in class... | | | | |
| INT_T1. Facilitates interaction with the teacher | .891 | .794 | | |
| INT_T2. Gives me the opportunity to talk back with the teacher | .899 | .790 | | |
| INT_T3. Facilitates dialogue with the teacher | .900 | .810 | | |
| INT_T4. Allows the exchange of information with the teacher | .843 | .711 | | |
| **Active collaborative learning** (So and Brush, 2008) | | | .90 | .70 |
| In this course... | | | | |
| ACL1. I felt that I actively collaborated in my learning experience | .807 | .651 | | |
| ACL2. I felt that I have collaborated in creating my own learning experience | .861 | .742 | | |
| ACL3. I felt that I had free reign to create my own learning experience | .856 | .732 | | |
| ACL4. I felt that I had freedom to participate in my own learning experience | .812 | .659 | | |
| **Engagement** (Gallini and Moely, 2003; Medlin and Green, 2009) | | | .86 | .68 |
| Using the clickers... | | | | |
| ENG1. I felt that my opinions have been taken into account in this course | .859 | .737 | | |
| ENG2. In this course, my peer and faculty interactions made me feel valuable | .875 | .765 | | |
| ENG3. This course has favored my personal relationships with my peers and teachers | .726 | .528 | | |
| **Learning performance** (MacGeorge et al., 2008) | | | .94 | .83 |
| The use of clickers... | | | | |
| LP1. Have improved my comprehension of the concepts studied in class | .880 | .775 | | |
| LP2. Have eased a better learning experience in this module | .911 | .829 | | |
| LP3. Have allowed me to better understand the concepts in this module | .947 | .896 | | |

TABLE 2
**Descriptive Statistics and Correlations**

| | M | SD | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|

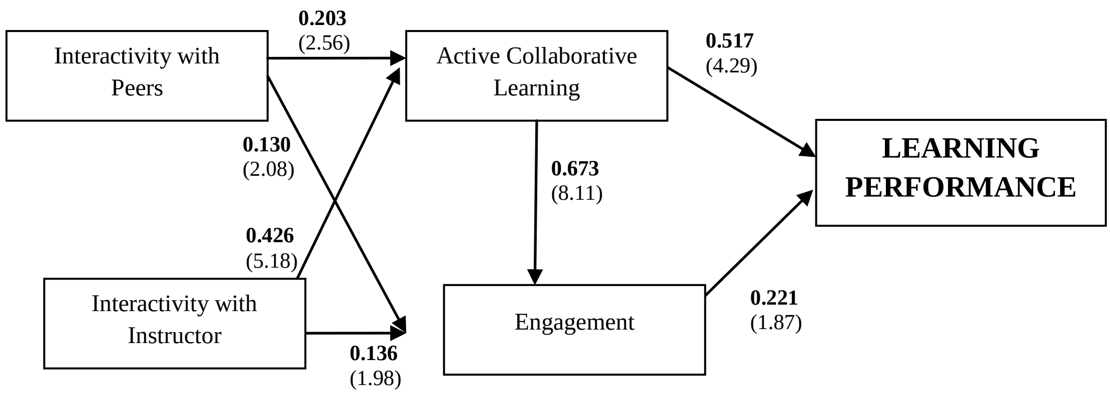
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1. Interactivity (peers)** | 5.78 | .92 | .69 | | | | |
| **2. Interactivity (teacher)** | 5.09 | 1.08 | .29 | .78 | | | |
| **3. Active collaborative learning** | 5.61 | .94 | .15 | .24 | .70 | | |
| **4. Engagement** | 5.65 | .89 | .20 | .27 | .61 | .68 | |
| **5. Learning performance** | 5.73 | 1.00 | .19 | .27 | .48 | .39 | .83 |

Note: Means and standard deviations are based on summated scale averages. Values on the diagonal are the AVE. Off-diagonal elements are the squared correlations among constructs.

### *5.2. Structural model*

We tested the structural relationships presented in the proposed model with the use of EQS 6.1 (see Figure 2). The model yielded a good overall fit: NFI= .896; NNFI= .932; CFI= .943; IFI= .944; RMSEA= 0.073; $X^2$ normed= 2.05.

FIGURE 2
**Results for the proposed model**




The results indicate that interactivity with peers positively and significantly influences both collaborative learning (β= .203, p<0.01) and engagement (β= .130, p<0.01), which provide strong support for H1 and H2, respectively. This result highlights the importance of promoting interactivity among students in the class through the use of clickers in order to increase students' engagement and their active collaborative learning. The estimation results show that interactivity with the instructor has a positive and significant effect on collaborative learning and engagement (β= .426, p<0.01 and β= .136, p<0.05, respectively), providing support for H3 and H4. Thus, the higher level of interactivity between the students and the instructor promoted by the use of clickers (through clarifying student's questions, guiding the discussion about the correct answer and/or offering additional explanations about the topics covered by the questions) enhances the student's level of involvement and her/his collaborative learning. The indirect effects of interactivity with peers on learning performance are 0.16, and of interactivity with the instructor are 0.31.

We also find that active collaborative learning and engagement positively and significantly affect student learning performance (β= .517, p<.01, and β= .221, p<0.1, respectively), which provides support for H5 and H7. Consistent with H6, we find that active collaborative learning has a positive and significant effect on engagement. These results emphasize the critical role played by engagement and active collaborative learning in improving student learning performance. Also, we should note that engagement and collaborative learning both mediate the influence of interactivity on the learning performance. Overall, the explanatory power of the model is 0.49 and active collaborative learning has the biggest impact on final behavior (.67).

In sum, the results demonstrate that interactivity with peers and with the instructor that results from the participation in clickers is critical to promote active collaborative learning and to increase student engagement. By favouring the development of closer relationships among students and between the students and the instructor, and promoting the development of active collaborative learning and student engagement, clickers reveal themselves as a powerful technological tool to enhance student learning performance.

## 6. Conclusions

As more and more educational institutions integrate clickers into their learning systems to support and enhance the learning process, it becomes increasingly necessary to have a thorough understanding of the underlying mechanisms and ultimate consequences of these advanced technologies on relevant student learning performance outcomes. Despite the increasing interest in recent years among academics and educators in studying and understanding the impact of clickers in the student learning process, several gaps remain that prevent us from having a complete understanding of the phenomenon and that offer researchers new opportunities to further advance existing knowledge in critical ways.

In this study, our primary objective was to identify and understand the mechanisms that underlie the effect of clickers on learning performance outcomes. Drawing upon sound theories of student behavior and learning and existing empirical research, we develop a conceptual framework in which we propose that the interactivity with peers and with the instructor that results from the use of clickers influences the student engagement and active collaborative learning, which ultimately determines student learning performance. We test the framework using a sample of 198 undergraduate business students. The results of our empirical study provide strong support for the proposed model and they enable us to contribute to existing research in several critical ways.

First of all, it is important to highlight that the descriptive results from our study reveal that the mean of all the studied constructs is higher than the average scale level. This finding is revealing by itself, as it shows that students perceive high levels of the constructs when using the clickers, and especially high levels of learning performance. This result also suggests that students believe that using clickers in the class facilitates the understanding of the concepts and class materials and improves significantly their learning process.

A more rigorous analysis of the data using econometric techniques allows us to understand more deeply the associations and underlying processes behind the positive association between clickers and learning performance suggested by these descriptive analyses. The results from the causal model indicate that interactivity plays a critical role in the effect of clickers in student learning. By fostering student communication with their peers and instructors and promoting social and collaborative exchanges among them, clickers help students to develop communication abilities and a cooperative spirit. This likely happens because clickers involve students in sharing ideas, in searching for the correct answer to the questions and in explaining and justifying their decisions, all of which contributes to increase their interactions with peers and the instructor and, through this process, to better understand the course materials. Likewise, by using the clickers, students perceive that their answers and opinions are taken into account by the instructor and their peers, and understand better that this process helps them improve their learning performance. At the same time, instructors can see the percentage of students that understand the concepts, which helps them identify any misunderstanding to properly and timely clarify it, and adapt the lecture pace, style and topic to better fit the student needs. These results strongly recommend the use of clickers in educational contexts as a means to promote interactivity and to enhance the learning experience. This technology can also help in breaking educational barriers and bringing equal opportunities to the participants of the learning process.

A notable result from our study is the important consequences of interactivity for improving and enhancing student learning performance. The importance of promoting interactivity from the use of clickers is grounded in the result that interactivity with peers and with the instructor is a critical determinant of a student's active collaborative learning and engagement. To the extent that students interact with their peers and with the instructor during the use of the clickers, they feel their active role in the learning process and perceive their contribution to build new knowledge. This promotion of active collaborative learning has proven critical in enhancing the student learning experience, as our results indicate that it is a central determinant of engagement and learning performance. This is because it allows students to critically think about the material to understand the alternative answers, and to achieve a deeper processing of knowledge. Reflection and review require processing the material in some depth (Lantz, 2010) and, according to our results, students consider that clickers allow them to apply such techniques in class. Again, these results show the benefits of using clickers in the class and indicate that it can be considered a good technical tool to engage students and encourage their active collaborative learning, all of which results in enhanced student learning performance.

Our study presents some limitations that need to be addressed in further research First, our sample consists only of students who have used clickers and, thus, cannot compare the results that we obtain with a control group of non-users. This prevents us from ruling out other potential explanations for our results such as the liking or affinity of the student toward the subject. Thus, a promising avenue for further research would be to develop a quasi-experiment to test the proposed framework across two different student groups: clicker users and non-users.

Second, given that the marketing course in our empirical application is the pioneer in the introduction of this technology for educational purposes in the University under study, we acknowledge that there is a potential for novelty effects since the use of clickers is a relatively new phenomenon. Moreover, for all the students in the empirical study, this was the first time they used clickers. Future research should examine the effect of clickers longitudinally in order to determine whether the obtained effects diminish with the increase in clicker experience.

In sum, we can conclude that clickers enhance student's learning performance by increasing interactivity with peers and the instructor. This interactivity, subsequently, promotes customer active participation and collaborative learning, which increases the student involvement and engagement in the learning process. Overall, these results provide strong support for the use of clickers in the class as a tool to enhance the learning experience.

## References

ABRAHAMSON, A.L. (2006). A brief history of networked classroom: Effects, cases, pedagogy, and implications. In D.A. Banks (Ed.) *Audience response systems in higher education*, pp. 1-25. Hershey, PA: Information Science Publishing.

AHLFELDT, S.; MEHTA, S. AND SELLNOW, T. (2005). "Measurement and Analysis of Student Engagement in University Classes Where Varying Levels of PBL Methods of Instruction Are in Use", *Higher Education Research and Development*, Vol. 24, nº 1, pp. 5-20.

ANDERSON, T. (2003). Modes of interaction in distance education: Recent developments and research questions. In M. G. Moore, & W. G. Anderson (Eds.), *Handbook of distance education* (pp. 129–144). Mahwah, New Jersey: Lawrence Erlbaum Associates Inc.

ANDERSON, J.C. AND GERBING, D.W. (1988). "Structural equation modelling in practice: a review and recommend two-step approach", *Psychological Bulletin*, Vol. 103, nº 3, pp. 411-423.

ANGELI, C.; VALANIDES, N. AND BONK, C. J. (2003). "Communication in a web-based conferencing system: the quality of computer-mediated interaction", *British Journal of Educational Technology*, Vol. 34, nº1, pp. 31–43.

ASTIN, A. (1993). *What Matters in College? Four Critical Years Revisited*, San Francisco, Cal.: Jossey-Bass.

BAKER, K. Q.; SPIEZIO, K. E., AND BOLAND, K. (2004). "Student engagement: transference of attitudes and skills to the workplace, profession, and community", *The Industrial-Organizational Psychologist*, Vol. 42, nº2, pp. 101–107.

Bagozzi, R.P. and Yi, P.R. (1988). "On the evaluation of structural equation models", *Academy of Marketing Science*, Vol. 16, nº 1, pp. 74-94.

Banks, D.A. (2006). Reflections on the use of ARS with small groups. In D.A. Banks (Ed.), *Audience response systems in higher education*, pp. 373-386. Hershey, PA: Information Science Publishing.

Bannan-Ritland, B. (2002). "Computer-mediated communication, e-learning, and interactivity: A review of the research", *Quarterly Review of Distance Education*, Vol. 3, nº 2, pp. 161-169.

Beatty, I. (2004). "Transforming student learning with classroom communication systems", Boulder, Colo: EDUCASE Center for Applied Research, Issue 3, p. 5, available: <http://www.educase.edu/LibraryDEtailPage/666?ID=ERB0403>

Beatty, I.D.; Gerace, W.J.; Leonard, W.J. and Dufresne, R.J. (2006). "Designing effective questions for classroom response system teaching", *American Journal of Physics*, Vol. 74, nº 1, pp. 31-39.

Beekes, W. (2006). "The 'millionaire' method for encouraging participation", *Active Learning in Higher Education*, Vol. 7, pp. 25–36.

Benaroch, M. and Appari, A. (2011). "Pricing e-service quality risk in financial services", *Electronic Commerce Research and Applications*, in press.

Bentler, P.M. (1995). *EQS structural equations program manual*, Multivariate Software, Inc., C.A.

Bergtrom, G. (2006). "Clicker sets as learning objects". Interdisciplinary Journal of Knowledge and Learning Objects", Vol. 2, Available in: http://ijklo.org/Volume2/v2p105-110Bergtrom.pdfRetrieved 03.11.07.

Brewer, C.A. (2004). "Near real-time assessment of student learning and understanding in biology courses", *BioScience*, Vol. 54, nº 11, pp. 1034-1039.

Bullock, D.W.; LaBella, V.P.; Clingan, T.; Ding, Z.; Stewart, G. and Thibado, P.M. (2002). "Enhancing the student-instructor interaction frequency", *The Physics Teacher*, Vol. 40, pp. 535-541.

Burnstein, R.A. and Lederman, L.M. (2001). "Using wireless keypads in lecture classes", *The Physics Teacher*, Vol. 39, pp. 8-11.

Caldwell, J.E. (2007). "Clickers in the large classroom: Current research and beast-practice tips", *CBE Life Sciences Education*, Vol. 6, nº 1, pp. 9-20.

Carnaghan, C. and Webb, A. (2007). "Investigating the effects of group response systems in student satisfaction, learning, and engagement in accounting education", *Issues in Accounting Education*, Vol. 22, nº 3, pp. 391-409.

Chou, C. (2003). "Interactivity and interactive functions in web-based learning systems: A technical framework for designers", *British Journal of Educational Technology*, Vol. 34, nº 3, pp. 265-279.

Connell, J.P.; Halpern-Felsher, B.L.; Clifford, E.; Crichlow, W. and Usinger, P. (1995). "Hanging in there: Behavioral, psychological, and contextual factors affecting whether African American adolescents stay in school", *Journal of Adolescent Research*, Vol. 10, pp. 41–63.

Cotner, S.; Fall, B.; Wick, S.; Walker, J. and Baepler, P. (2008). "Instant Feedback Assessment Methods: Can we improve engagement, enjoyment, and preparation for exams in large-enrollment biology courses?", *Journal of Science Education and Technology*, Vol. 17, pp. 437-443.

Crouch, C.H. and Mazur, E. (2001). "Peer instruction: Ten years of experience and results", *American Journal of Physics*, Vol. 69 nº 9, pp. 970-977.

Daghfous, A. and Barkhi, R. (2009). "The strategic management of information technology in UAE hotels: An exploratory study of TQM, SCM, and CRM implementations", *Technovation*, Vol. 29, nº 9, pp. 588-595.

Draper, S.W. and Brown, M.I. (2004). "Increasing interactivity in lectures using an electronic voting system", *Journal of Computer Assisted Learning*, Vol. 20, pp. 81-94.

Draper, S.W.; Cargill, J. and Cutts, Q. (2002). "Electronically enhanced classroom interaction", *Australasian Journal of Educational Technology*, Vol. 18, pp. 13-23.

Dufresne, R.J. and Gerace, W.J. (1996). "Assessing-to-learn: Formative assessment in physics instruction", *The Physics Teacher*, Vol. 42, pp. 428-433.

Elliot, C. (2003). "Using a personse system in economics teaching", International Review of Economics Education, Vol. 1, nº 1, Available in: <http://www.economicsnetwork.ac.uk/iree/i1/elliot.htm>

Eng, T. (2006). "Mobile supply chain management: Challenges for implementation", *Technovation*, Vol. 26, nº 5/6, pp. 682-686.

Erickson, J. and Siau, K. (2003). "E-ducation", *Communications of the ACM*, Vol. 46, nº 9, pp. 134-140.

FIES, C. AND MARSHALL, J. (2006). "Classroom response systems: A review of the literature", *Journal of Science Education and Technology*, Vol. 15, nº 1, pp. 101-109.

FORNELL, C. AND LARCKER, D. (1981): "Structural equation models with unobserved variables measurement error", *Journal of Marketing Research*, Vol. 36, nº 3, pp. 39-50.

FOWLER, L.; ARMAREGO, J. AND ALLEN, M. (2001). "CASE tools: Constructivism and its application to learning and usability of ostware engineering tools", *Computer Science Education*, Vol. 11, nº 3, pp. 261-272.

FREDRICKS, J.A.; BLUMENFELD, P.C. AND PARIS, A.H. (2004). "School Engagement: potential of the concept, state of the evidence", *Review of educational research*, Vol. 74, pp. 59-108.

FREDRICKS, J.A.; BLUMENFELD, P.B.; FRIEDEL, J. AND PARIS, A. (2002). "Increasing engagement in urban settings: An analysis of the influence of the social and academic context on student engagement", paper presented at the annual meeting of the American Educational Research Association, New Orleans.

FULFORD, C.P. AND ZHANG, S. (1993). "Perceptions of interaction: The critical predictor in distance education", *American Journal of Distance Education*, Vol. 7, nº 3, pp. 8.21.

GALLINI, S.M. AND MOELY, B.E. (2003). "Service-learning and Engagement, academic challenge and retention", *Michigan Journal of community service learning*, Vol. fall, pp. 5-14.

GARRISON, D.R.; ANDERSON, T. AND ARCHER, W. (2001). "Critical thinking, cognitive presence, and computer conferencing in distance education", *American Journal of Distance Education*, Vol. 15, nº 1, pp. 7–23.

GRANT, I. (2006). "The mobile revolution: The making of mobile services worldwide", *International Journal of Mobile Communications*, Vol. 1, nº ½, pp. 3-14.

GUTHRIE, R.W. AND CARLIN, A. (2004). "Waking the dead: using interactive technology to engage passive listeners in the classroom", *Proceedings of the AMCIS*, paper 358, New York, August.

HAIR, J. F.; BLACK, W. C.; BABIN, B. J.; ANDERSON, R. E. AND TATHAM, R. L. (2006). *Multivariate Data Analysis* (6th Ed. ed.). Prentice Hall: Upper Saddle River, New Jersey.

HAKE, R.R. (1998). "Interactive-engagement versus traditional methods: A six-thousands student survey of mechanics test data for introductory physics courses", *American Journal of Physics*, Vol. 66, pp. 64-74.

HASEMAN, W.D.; POLATOGLU, V.N. AND RAMAMURTHY, K. (2002). "An empirical investigation of the influences of the degree of interactivity of user-outcomes in a multimedia environment", *Information Resources Management Journal*, Vol. 15, nº 2, pp. 31-48.

HERRINGTON, J.; OLIVER, R. AND REEVES, T. (2003), "Patterns of engagement in authentic online learning environments", *Australian Journal of Educational Technology,* Vol. 19 nº 1, pp. 59-71.

HIGGINS, R.; HARTLEY, P. AND SKELTON, A. (2002). "The conscientious consumer; reconsidering the role of assessment feedback in student learning", *Studies in Higher Education*, Vol. 27, nº 1, pp. 53-64.

HILTZ, S. R.; COPPOLA, N.; ROTTER, N. AND TUROFF, M. (2000). "Measuring the importance of collaborative learning for the effectiveness of ALN: a multi-measure, multi-method approach", *Journal of Asynchronous Learning Networks*, Vol. 4, nº 2, pp. 103–125.

HOFFMAN, D.L. AND NOVAK, T.P. (1996). "Marketing in hypermedia computer-mediated environments: conceptual foundations", *Journal of Marketing*, Vol. 60, nº 3, pp. 50-68.

HOMME, J.; ASAY, G. AND MORGENSTERN, B. (2004). "Utilisation of an audience response system", *Medical Education*, Vol. 38, nº 5, pp. 575.

HU, J.; BERTOL, P.; HAMILTON, M.; WHITE, G.; DUFF, A. AND CUTTS, Q. (2006). "Wireless interactive teaching by using key-pad ARS", In D.A. Banks (Ed.). *Audience response systems in higher education*, pp. 209-221. Hershey. PA: Information Science Publishing.

JONES, F.R. (1998). "Self-instruction and success: a learner-profile study", *Applied Linguistics,* Vol. 19, nº 3, pp. 378-406.

JUDSON, E. AND SAWADA, D. (2002). "Learning from past and present: Electronic response systems in college lecture halls", *Journal of Computers in Mathematics and Science Teaching*, Vol. 21, nº 2, pp. 167-181.

JUDSON, E. AND SAWADA, D. (2006). Audience response systems: Insipid contrivances or inspiring tools? In D.A. Banks (Ed.) *Audience response systems in higher education: Applications and cases* (pp. 26-39). Hershey, PA: Information Science Publishing.

KALETA, R. AND JOOSTEN, T. (2007). "Student Response Systems: A University of Wisconsin Study of Clickers", *Educause Center for Applied Research Bulletin*, Issue 10 (May 8,) at http://www.blog.utoronto.ca/in_the_loop/files/ClickersERB0710.pdf

KAY, R.-H. AND LESAGE, A. (2009). “Examining the benefits and challenges of using audience response systems: A review of the literature”, *Computers & Education*, Vol. 53, pp. 819-827.

KENNEDY, D.; HYLAND, A. AND RYAN, N. (2006). *Writing and Using Learning Outcomes: a Practical Guide*. In the Bologna Handbook. Available in: <http://www.bologna.msmt.cz/files/learning-outcomes.pdf >

KENNEDY, G. AND CUTS, Q. (2005). “The association between students use and electronic voting system and their learning outocomes”, *Journal of computer Assisted Learning*, Vol. 21, pp. 260-268.

KENWRIGHT, K. (2009). “Clickers in the classroom”, *TechTrends*, Vol. 53, nº 3, pp. 74-77.

KHAN, B. H. (2000). “Discussion of resources and attributes of the web for the creation of meaningful learning environments”, *Cyber Psychology & Behavior*, Vol. 3, nº 1, pp. 17–23.

KRYDER, L.G. (1999). “Integrating computer literacy: Why and what can be done”, *Business Communication Quarterly*, Vol. 62, nº 2, pp. 81-86.

KUH, G. D. (2003). “What we’re learning about student engagement from NSSE”. *Change*, Vol. 35, nº 2, pp. 24–32.

LADHARI, R. (2011). “Developing e-service quality scales: A literature review”, *Journal of Retailing and Consumer Services*, Vol. 17, nº 6, pp. 464-477.

LANTZ, M.E. (2010). “The use of Clickers in the classroom: teaching innovation or merely an amusing novelty?”, *Computers in Human Behavior*, Vol. 26, pp. 556-561.

LIU, Y. (2003). “Developing a scale to measure the interactivity of websites”, *Journal of Advertising Research*, Vol. 43, nº 3, pp. 207-216.

LIU, T.; LIANG, J.; WANG, H.; CHAN, T. AND WEI, L. (2003). “Embedding educlick in classroom to enhace interaction” in *Proceedings International Conference Computers in Education* (ICCE), Hong Kong, China, pp. 117-125.

LO, W.-S.; HONG, T.-P. AND JENG, R. (2008). “A framework of E-SCM multi-agent systems in the fashion industry”, *International Journal of Production Economics*, Vol. 114, nº 2, pp. 594-614.

MACGEORGE, E.L.; HOMAN, S. R.; DUNNING JR., J.B.; ELMORE, D.; BODIE, G.D.; EVANS, E.; KHICHADIA, S. AND LICHTI, S. M. (2008). “The influence of learning characteristics on evaluation of audience response technology”, *Journal of Computing in Higher Education*, Vol. 19, pp. 25-46.

MATA, F.J., FUERST, W.L. AND BARNEY, J. (1995). “Information Technology and Sustained Competitive Advantage: A Resource-Based Analysis”, *MIS Quarterly*, Vol. 19, nº 4, 487–505.

MARKS, H. M. (2000). “Student engagement in instructional activity: Patterns in the elementary, middle, and high school years”. *American Educational Research Journal*, Vol. 37, pp. 153–184.

MAYER, R.E. AND WITTROCK, M.C. (2006). “Problem solving”, In P.A. Alexander & P.H. Winne (Eds.), *Handbook of educational psychology*: Second edition, pp. 287-304.

MAYER, R.E.; STULL, A.; DELEEUW, K.; ALMEROTH, K.; BIMBER, B.; CHUN, D.; BULGER, M.; CAMPBELL, J.; KNIGHT, A. AND ZHANG, H. (2009). “Clickers in collage classrooms: Fostering learning with questioning methods in large lecture classes”, *Contemporary Educational Psychology*, Vol. 34, pp. 51-57.

MCMILLAN, S. J. AND HWANG, J. (2002). “Measures of perceived interactivity: An exploration of the role of direction and communication, user control and time in shaping perceptions of interactivity”, *Journal of Advertising*, Vol. 31, nº 3, pp. 29-42.

MEDLIN, B. AND GREEN JR, K.W. (2009) “Enhancing performance through goal setting, engagement, and optimism”, *Industrial Management & Data Systems*, Vol. 109, nº 7, pp. 943-956.

MELTZER, D.E. AND MANIVANNAN, K. (1996). “Promoting interactivity in lecture classes”, *Physics Today*, Vol. 34, pp. 72-74.

MICHAELSON, L.K.; KNIGHT, A.B. AND FINK, L.D. (2004). *Team-based learning: A transforming use of small groups in college teaching*, Sterling, VA: Stylus.

MILLER, R.G.; ASHAR, B.H. AND GETZ, K.J. (2003). “Evaluation of an audience response system for the continuing education of health professionals”, *The Journal of Continuing Education in the Health Professions*, Vol. 23, nº 2, pp. 109-115.

NAH, F.; SIAU, K. AND SHENG, H. (2005). “The value of mobile applications: A utility company study”, *Communications ACM*, Vol. 48, nº 2, pp. 85-90.

NAISMITH, L.; LONDSALE, P.; VAVOULA, G. AND SHARPLES, M. (2004). *Literature Review in Mobile Technologies and Learning*, Report 11, Future Lab Series.

NICOL, D. AND BOYLE, J. (2003). “Peer instruction versus class-wide discussion in large classes: a comparison of two interaction methods in the wored classroom”, *Studies of Higher Education*, Vol. 28, pp. 457-473.

ONCU, S. AND CAKIR, H. (2011). “Research in online learning environments: priorities and methodologies”, *Computers & Education*, Vol. 57, pp. 1098-1108.

PASCARELLA, E. AND TERENZINI, P. (1991). *How college affects students: Findings and insights from twenty years of research*. San Francisco: Jossey Bass.

PASCHAL, C.B. (2002). “Formative assessment in physiology teaching using a wireless classroom communication system”, *Advances in Physiology Education*, Vol. 26, nº 4, pp. 299-308.

PENUEL, W.E.; BOSCARDIN, C.K.; MASYN, K. AND CRAWFORD, V.M. (2007). “Teaching with student response systems in elementary and secondary education settings: A survey study”, *Educational Technology Research and Development*, Vol. 55, pp. 315-336.

PRATTON, J. AND HALES, L. (1986). “The effects of active participation on student learning”, *Journal of Educational Research*, Vol. 79, pp. 210-215.

REAY, N.W.; BAO, L.; LI, P.; WARNAKULASOORIYA, R. AND BAUGH, G. (2005). “Toward the effective use of voting machines in physics lectures”, *American Journal of Physics*, Vol. 73, nº 6, pp. 554-558.

RIBBENS, E. (2007). “Why I like personal response systems”, *Journal of College Science Teaching*, Vol. 37, nº 2, pp. 60-62.

ROBERTSON, L.J. (2000). “Twelve tips for using a computerized interactive audience response system”, *Medical Teacher*, Vol. 33, nº 3, pp. 237-239.

ROBLYER, M.D. AND WIENCKE, W.R. (2003). “Design and use of a rubric to assess and encourage interactive qualities in distance courses”, *American Journal of Distance Education*, Vol. 17, nº 2, pp. 77-98.

ROSCHELLE, J.; ABRAHAMSON, L.A. AND PENUEL, W.R. (2004a). “DRAFT Integrating classroom network technology and learning theory to improve classroom science learning: a literature synthesis”, paper presented at the *Annual Meeting of the American Educational Research Association*, San Diego, CA.

ROSCHELLE, J.; PENUEL, W.R. AND ABRAHAMSON, L.A. (2004b). “Classroom response and communication systems: Research review and theory”, paper presented at the *Annual Meeting of the American Educational Research Association*, San Diego CA.

RYAN, A. M. (2000). “Peer groups as a context for the socialization of adolescents’ motivation, engagement, and achievement in school”. *Educational Psychologist*, Vol. 35, pp. 101–111.

SCHACKOW, E.; CHAVEZ, M.; LOYA, L. AND FRIEDMAN, M. (2004). “Audience Response System: Effect on Learning in Family Medicine Residents”. *Family Medicine*, Vol. 36, nº 7, pp. 496-504.

SHEMOFF, D.J. AND HOOGSTRA, L. (2001). “Continuing motivation beyond the high school classroom”, *New Directions in Child and Adolescent Development*, Vol. 93, pp. 73-87.

SHENG, H.; NAH, F. AND SIAU, K. (2005). “Startegic implications of mobile technology: A case study using value-focused thinking”, *Journal Strategic Information Systems*, Vol. 14, nº 3, pp. 269-290.

SIAU, K.; SHENG, H. AND NAH, F.F.-H. (2006). “Use of classroom response system to enhance classroom interactivity”, *IEEE Transactions on Education*, Vol. 49, nº 3, pp. 398-403.

SIAU, K.; SHENG, H.; NAH, F. AND DAVIS, S. (2004). “A qualitative investigation on consumer trust in mobile commerce”, *International Journal of Electronic Business*, Vol. 2, nº3, pp. 283-300.

SIMPSON, V. AND OLIVER, M. (2007). “Electronic voting systems for lectures then an now: A comparison of research and practice”, *Australasian Journal of Educational Technology*, Vol. 23, nº 2, pp. 187-208.

SIMS, R. (2003). “Promises of interactivity: Aligning learner perceptions and expectations with strategies for flexible and online learning”, *Distance Education*, Vol. 24, nº 1, pp. 87-103.

SKINNER, E.A. AND BELMONT, M.J. (1993). “Motivation in the Class-room: Reciprocal Effects of Teacher Behavior and Student Engagement Across the School Year”, *Journal of Educational Psychology*, Vol. 85, nº 4, pp. 571-81.

SLAVIN, R.E. (1991). *Educational psychology*, Englewood Cliffs, NJ: Prentice Hall.

SO, H.-J. AND BRUSH, T.A. (2008). “Students perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: relationships and critical factors”, *Computers & Education*, Vol. 51, nº 1, pp. 318-336.

STOWELL, J.R. AND NELSON, J.M. (2007). “Benefits of electronic audience response systems on student participation, learning and emotion”, *Teaching of Psycholohy*, Vol. 34, pp. 253-258.

THALHEIMER, W. (2003). “The learning benefits of questions (white papers)”, Someville, MA: Work Learning Research.

TREES, A.R. AND JACKSON, M.H. (2007). "The learning environment in clicker classrooms: student processes of learning and involvement in large university-level courses using student response systems", *Learning, Media and Technology*, Vol. 32, pp. 21-40.

WANG, M.C., HAERTEL, G.D. AND WALBERG, H.J. (1992). "What influences learning? A content analysis of review literature", *Journal of Educational Research*, Vol. 84, nº 1, pp. 30-43.

WENK, L.; DUFRESNE, R.; GERACE, W.; LEONARD, W. AND MESTRE, J. (1997). "Technology-assisted active learning in large lectures", In: *Student-active science: Models of innovation in college teaching*, A.P. McNeal and C. D'Avanzo (eds) Fort Worth, Tx, Saunders College Publishing, pp. 431-451.

WIT, E. (2003). "Who wants to be. . .The use of a personal response system in statistics teaching", *MSOR Connections*, Vol. 3, pp. 14–20.

WITTROCK, M.C. (1990). "Generative processes of comprenhension", *Educational Psychologist*, Vol. 24, pp. 354-376.

YODER, J.D. AND HOCHEVAR, C.M. (2005). "Encouraging active learning can improve students' performance on examinations", *Teaching of Psychology*, Vol. 32, pp. 91-95.

YOURSTONE, S.A.; KRAYE, H.S. AND ALBAUM, G. (2008). "Classroom questioning with immediate electronic response: Do clickers improve learning?" *Decision Sciences Journal of Innovative Education*, Vol. 6 nº 1, pp. 75-88.