MILLENNIALS PERCEPTION OF USING CLICKER TO SUPPORT AN ACTIVE CLASSROOM ENVIRONMENT: AN EARLY ADOPTION PERSPECTIVE

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Abstract

This paper presents a multi-year study of students' perception associated with the introduction of a technology tool, personal response systems (colloquially known as clickers), starting from its initial stage to date. The goal is to provide a reflective perspective of this topic that intertwines the instructor's and students' views associated with the adoption of this technology tool. The results of the data collected with an in-class clicker survey for six semesters indicated that it took students on average two semesters to significantly shift their perceptions and view clickers as being supportive of activities both inside and outside the classroom. The study indicates that both a well-crafted strategy to introduce innovative technology tools at the organizational level and the instructor's clear focus on using clickers as a tool to increase and support active learning will reduce students' resistance to the tool itself at the course level.

Introduction

In educational settings in general, and in higher education in particular, changes associated with generational shifts typically produced tension over issues related to the structure of the educational process for both students and instructors. The spreading of computer and information technology in both social and educational environments stimulated a more focused research on the instructional needs of those generations that either were early exposed or were born with advanced technology tools. Researchers identified, among others, the "Net Generation"[1], the "Millennials"[2,3,4] or "Me Generation"[5,6], depending on the main characteristics used to define the generational group. Among these, the Millennials attracted a significant body of research that extended from general characteristics[7,8] to learning[4] and to work-related issues and strategies[9,10].

From the learning and instruction perspectives, the above-mentioned generations share several characteristics with impact on how educational environments have to be shaped to stimulate learner motivation and engagement. Of these, Millennials' high confidence combined with a significant external-driven achievement and pressure to quickly building strong resumés place new requirements on an educational context. Educational organizations started to address these requirements by creating an instructional environment in which: a) success criteria are clearly set, b) feedback tools associated with the attainment of success are available, c) instructional process provides multiple equivalent learning tools and strategies, and d) the content is modularized and flexible allowing both teamwork and individual work.

Technology tools and their associated instructional strategies have played an important role in shaping Millennials' learning environment. This paper presents a longitudinal study of students' perception associated with the introduction of a technology tool, personal response systems or "clickers," starting from its initial stage to date.

The goal is to provide a reflective perspective of this topic that intertwines the instructor's and students' views associated with the adoption of a technology tool that addresses Millennials' need for quick feedback and active engagement into their learning experience.

Instructional Context

Course description and goals

Structural geology, a course that focuses on quantifying the response (strain) of natural earth materials (i.e., minerals and rocks) to imposed stress, is the context for this study. The course covers deformation from the atomic scale (e.g., dislocations, grain boundary diffusion, etc.) to the formation of mountain chains along the boundaries of colliding lithospheric plates (e.g., the Himalayas) at time scales ranging from "instantaneous" (e.g., meteorite impacts) to tens of millions of years (e.g., continental rifting). Structural geology courses with similar content are essential components of the core curriculum for the bachelor of science degree in geology, geological engineering, mining engineering, and petroleum engineering in the United States.

At Missouri University of Science and Technology (Missouri S&T), structural geology is a required course for all undergraduates of these degree programs, and commonly several civil engineering students elect to take the course as well. That is, both scientists (geologists/geophysicists) and engineers enroll in the same course. Therefore this course provides these students with an early exposure to collaboration among the different disciplines that better prepare them to participate in multidisciplinary teams – now commonplace in the work force (e.g., energy and materials sectors).

The course is typically taken in the first semester of the junior year, but many sophomores and seniors enroll in the course as well. Students are expected to have already completed a course in physical geology and preferably a course in mineralogy and petrology. The structural geology course may also include graduate students who are meeting deficiency requirements or desire to refresh their background knowledge. Students enrolled in structural geology meet three times a week for a 50-minute lecture and attend a three-hour lab once a week. Lecture attendance is strongly encouraged but not mandatory, however, missed in-class assignments for unexcused absences cannot be made up.

The major goals for this course have been divided into three categories: 1) *technical skills* which pertain directly to becoming proficient in the subject of Structural Geology; 2) *scientific skills* which provide an opportunity for students to adopt the approach research scientists and engineers use to solve problems, and 3) *personal skills* which are essential to success in their professional career and to lifelong learning.

The technical and scientific skills are emphasized in the course as all students enrolled in the course need a basic level of proficiency in structural geology to proceed with additional course work towards their chosen BS degree (e.g., mining, geology and geophysics, etc.) as well as be successful in their professional careers. However, some students enrolled in this course will pursue advanced graduate degrees or will engage in the petroleum industry as, for example, geologists or drilling engineers. These students will be involved at one point in higher-level projects such as: a) designing lab or field experiments or b) collecting and analyzing quantitative and qualitative data associated with difficult "fuzzy" problems. The complexity of these problems requires multiple types of expertise to solve them, typically achieved in the industry through multi-disciplinary teams. To answer the needs of this type of challenges, the instructor explicitly included the third category of course goals, the development of personal skills. That is, the course is assisting students in the development of personal skills that are important to success in any career: curiosity and imagination, independent thinking, pride in their work, confidence in their abilities, and finally respect for themselves and their peers.

Major instructional challenges

Structural geology presents some unique challenges. For the students, under-developed 3D-spatial visualization skills initially limit their ability to comprehend the geometry of geologic structures, especially in the subsurface, that form during deformation[11]. These skills are enhanced over the course of the semester by working on various types of problems that involve 3D visualization, for example constructing geologic cross-sections[12]. In addition, the ability to successfully integrate qualitative and quantitative observations and measurements made in the field on rock formations (e.g., measurements of strike and dip with a geologic compass along road cuts, etc.) with theory presented in lab and lecture (stereonets – a graphical calculator for determining the orientation of planes and lines and angles in space, Mohr Circle Analysis, Buckle Theory, etc.) to solve problems is a relatively new experience for many of the engineering students.

In a required course with a multiplicity of majors represented, students scrutinize content for relevance, wondering how the knowledge they are being taught applies to their major and future profession. The "Why do I (geological, mining, petroleum, civil engineer) need to know this?" attitude, if left unchecked, leads to student disengagement from the lecture topic. This is a challenge shared by both small and large enrollment courses.

Large lecture courses have long been known to present their own challenges to learning[13,14]. While economically efficient, large lecture courses lean towards a depersonalized learning environment that can have several deleterious effects on student learning[15], including: 1) faculty reliance on passive lecturing, 2) reduction in faculty-student interaction, 3) a concomitant increase on passive learning and reduction of in-depth thinking during lecture, 4) reduction in feedback to the students during lecture. All these factors lead to an overall reduction in levels of learning and performance.

In response to the high demand and high salaries for graduates in these professions[16], enrollment in structural geology at Missouri S&T has grown from an average of 50 to 60 students prior to 2005 to over 170 students in 2011. For students, such an environment can facilitate and reinforce behavior leading to disengagement thereby short-circuiting the lecturer-student learning connection. This paper presents the implementation of personal response devices, i.e., "clickers," during lecture as one of the teaching strategies adopted to meet the challenge of engaging students attending a large lecture for an "*outside of your major*" required course.

Implementation of Clicker Strategies

As with many instructional technology tools, the classroom implementation of personal response systems, commonly known as clickers, stimulated educational research regarding the impact of this tool on both the learning and teaching processes. Most of the research followed an empirical approach that included quantitative methods such as surveys[17,18,19] or quasi and full experiments[20,21,22]. Along with the empirical research, some of the clicker researchers engaged in more descriptive conceptual research focusing on the nature of clicker questions and their impact on learning and motivation[23,24,25] as well as reviews of existing clicker research findings[26,27,28]. Clicker research also covers a significant number of discipline-specific audiences well covered by the "Vanderbilt's Center for Teaching" bibliography on this instructional tool[29].

While these studies cover students perceptions in individual courses[30,31] or in groups of courses in a given academic area[32,17], only a few research studies[33] follow the implementation of clickers throughout various stages of their adoption as instructional tools. This study is trying to add to the latter type of research on clickers, by analyzing changes in students' perceptions throughout six consecutive semesters. The instructor's decision to adopt this tool was also part of a much larger early adoption strategy of clickers at the university level. Even if students acted as a captive audience throughout the clicker adoption process, their perception and attitude toward this tool had a significant impact on: a) instructor's decision to keep the clickers and b) his approach on how to utilize clickers more effectively as part of the course activities. The context of the study is a structural geology course offered once a year during the fall semester.

<u>Organizational Context of Clicker Adoption</u>

At Missouri S&T during the early 2000's a small group of faculty acted as innovators[34] in introducing clickers as instructional tools to stimulate active learning in large courses such as introductory chemistry and physics. The positive results of using clickers in a large classroom convinced the Information Technology (IT) department to initiate, in 2003, a more focused analysis of this instructional technology at the university level. The IT department looked for the following major keys of a successful implementation: a) the ability of the technological solution to address instructors' needs across the entire campus, b) the level of support offered by the vendor, and c) the ability of the technology to allow a seamless procurement and registration of clickers for both students and instructors. The selected vendor was Turning Technologies and using its technology the IT department deployed a large-scale pilot implementation in the fall semester of 2004.

The major goal of this pilot was to create the conditions that would stimulate the early adoption of this technology throughout the campus in the shortest time possible after its full deployment in the fall 2005 semester. The effectiveness of this activity is confirmed by the increasing number of student seats using clickers during the seven years of full implementation of this instructional strategy.

As shown in Figure 1, the trend line resulting from the evolution of student seats using clickers has the typical shape of the early adoption stage proposed by the diffusion of innovation model (Rogers, 2003, p.410).

The divergence of the actual student-seats number from the trend line around 2008 was generated mainly by a temporary drop of clicker use in a series of large introductory courses. The sharp increase of this metric during the last two years can be explained partially by the overall increase of the class sizes due to an increased student admission at the organizational level, a current phenomena in American higher education.

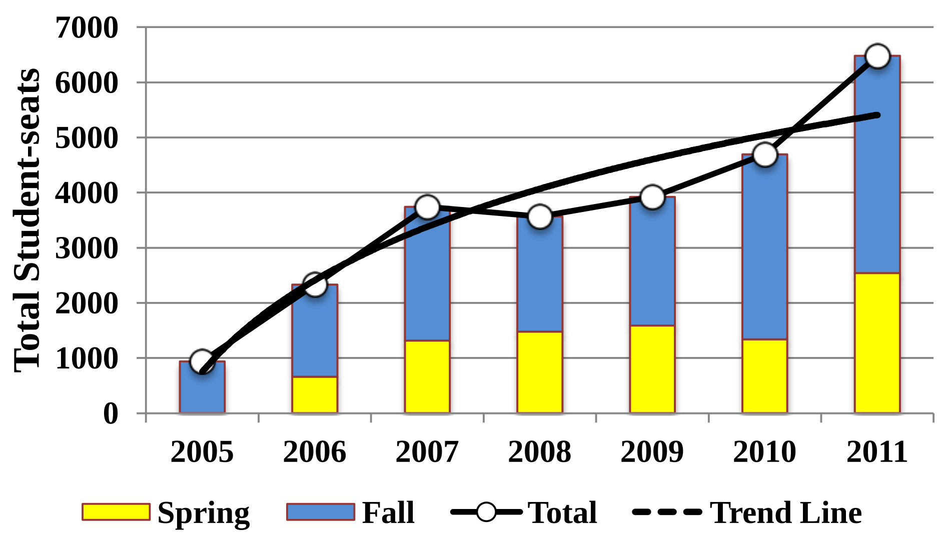


Figure 1. Early adoption of clickers to support active learning, as reflected by the evolution of student-seats using clickers across campus.

Clicker Strategies in Structural Geology Course

The impetus for adopting clicker technology was to create a more engaging and active learning environment for students during structural geology lectures. Anecdotal evidence suggests that students enrolled at Missouri S&T, as well as many others, were initially suspicious of "clickers" as simply a convenient means for taking attendance and forcing them to attend class rather than a tool to enhance learning. In order to promote student "buy-in" to this technology as a tool to enhance learning, a slide introducing the topic, "Why I am using clickers in the classroom," is presented and discussed by the instructor during the first lecture of the semester.

This slide is immediately followed by a simple example clicker slide polling the audience with the question "What is your major area of study" with answers that include the common science and engineering disciplines in the course. The use of clickers is also explicitly discussed in the course syllabus.

For the first year (fall 2006) of clickers' implementation in structural geology, only correct answers earned a point. The total points accumulated over the course of the semester, up to 100 points, represented 10% of the final grade. In addition, students had the opportunity to earn more than 100 points during the course of the semester for various challenge questions. However, comments from the final student evaluation indicated that clicker points in every lecture carried with it a heightened level of stress, normally associated with taking a test. This unintended result was diametrically opposed to the original purpose of introducing clickers, that is, to create a more active and engaging learning environment. In addition, the predicted outcome that inclusion of the clicker grade would represent an easy means for students to improve their final grade in the course proved to be incorrect – the clicker questions were indeed challenging!

Starting with the second year (fall 2007 – fall 2011) this policy was immediately changed. Clicker points accumulated during lecture counted as "bonus points" rather than as a "test" grade. Students still earned points, typically one point but up to five points (on rare occasions), for the clicker questions they answered correctly. The total number of clicker points accumulated was added to the number of points students earned completing in-class and homework assignments. In the end, the "bonus points" contribute to typically an increase of 2% in the final average grade for students who participated in using clickers.

In addition, students were encouraged to discuss the questions with other students in the class prior to locking-in their final answer. This approach removed the angst that some students expressed with using the clickers every day in class. With the large number of clicker questions (164 questions asked in 2011), students concentrated more on answering the questions as best they could and less on the impact of the correct or incorrect answers on their grade. An immediate benefit to the instructor was the possibility to institute a "no-makeup" policy for clicker points regardless of the excuse (e.g., clicker not working, forgot to bring it, overslept). That was possible because clicker points were bonus points, and missing them for not attending class did not impose a negative penalty on the grade. This strategy, therefore, eliminates one of the major inconveniences for the instructor interested in adopting clickers in the classroom.

Categories of Clicker Strategies Used in Structural Geology Course

The major goal of introducing clicker technology into the structural geology lecture was to reduce passive lecturing. That is, throughout the lecture clickers enhanced faculty-student and student-student interactions with provocative, challenging, and discussion-oriented questions. In addition, discussions among students prior to locking-in their final clicker answer stimulated in-depth student learning during lecture through active collaboration.

The ability to display the distribution of answers selected as well as the correct answer, allows for immediate feedback to both the students and instructor as to the progress being made in learning. To use these benefits, clicker questions were "designed" with the intention of emphasizing one or more of these goals: 1) review of material from previous lecture or textbook readings; 2) introduce the subject of the lecture with a provocative question; 3) review some of the material presented during the current lecture; 4) engage both students and the instructor in the assessment of understanding for lecture material; and 5) expose and clarify subtle misconceptions. The remaining part of this section discusses some examples of clicker questions that focus on goals closely tied to both improved classroom dynamics and enhanced student learning.

Introduce the subject of the lecture with a provocative question

An effective strategy to mitigate the "Why do I need to know this?" attitude is introducing the lecture topic with a provocative question or a role-playing scenario (e.g., an interview for a job). As an example for this type of clicker question, the role of pore fluid pressure in structural geology is introduced by taking advantage of the current publicity associated with the common practice of "Hydrofracking." This practice is linked in the lecture to triggering of earthquakes along with a nod to "pop culture" via "A View to a Kill" (Figure 2 a and b).

The scenario created is that of a job interview. The students are given some time to discuss the topic and then polled using a clicker question slide. The initial result typically has a large distribution of selected answers (Figure 2 c) which creates the desired effect of uncertainty as to which is the correct answer. After presentation of the course material related to this question, the audience is re-polled with the identical question. The dramatic shift and tightening of the responses (Figure 2 d) is a strong confirmation

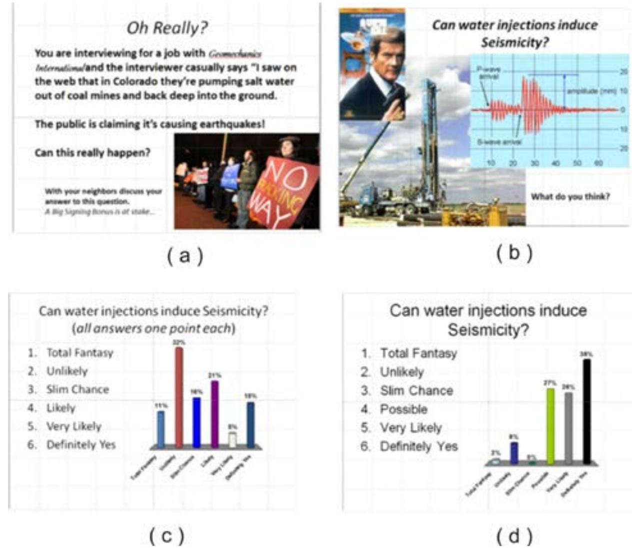


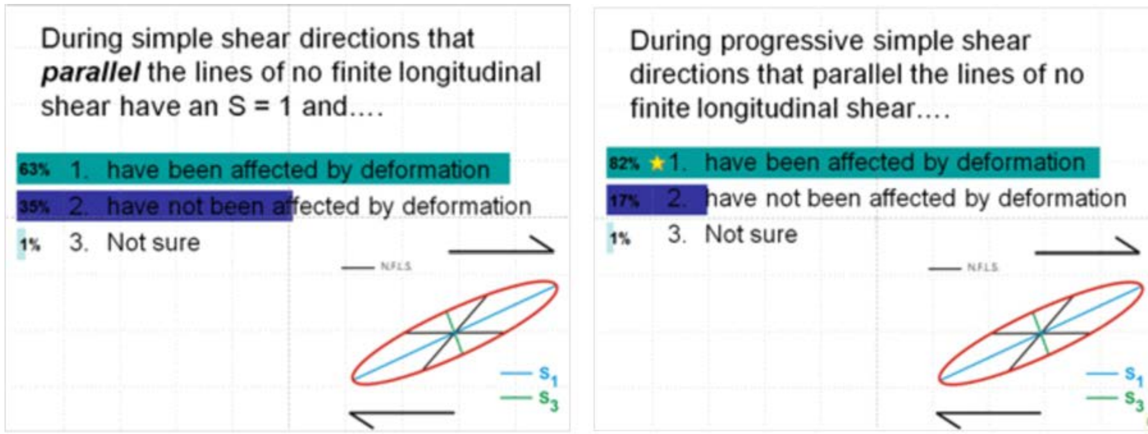
Figure 2. Sample slide used to introduce the subject of the lecture with a provocative question.

that students understand and can apply the presented concepts towards solving a problem.

Clarifying subtle common misconceptions with clicker questions couplets

Clicker questions transform *reoccurring misconceptions* into an opportunity for the instructor to proactively address the topic and minimize potential confusion. The class can be polled by introducing the topic as a non-threatening opinion clicker question that includes the correct answer, the common misconception, and the option to indicate that you're not sure. At this point the instructor presents to the classroom only the results of the poll while *the correct answer remains a secret.* The need for immediate feedback, the ambiguity created by the polling results, and the suspense of not knowing which answer is correct, create a tension that heightens students' interest in the upcoming slides.

As exemplified in Figure 3, the sequence of events includes polling without the correct answer feedback (a), student discussions, re-polling the audience with the same question, and finally showing the correct answer (b).



(a) (b)

Figure 3. Understanding the concept of incremental progressive simple shear and the strain ellipse results in a significant portion of the students having the same misconception year to year as demonstrated by the larger portion of students selecting answer number "2" first time (a) as compared to second time (b) the slide is shown.

Student-Instructor assessment of understanding of lecture material

Clicker questions can be also designed to promote a more in-depth analysis of the material being presented. For example, in Figure 4 the first slide (a) introduces the concept of effective stress. In the second slide (b) the lecturer poses the problem to be addressed and then allows time for students to engage in discussion with their peers before answering the posed question. This slide is followed by a clicker slide (c) designed to assess if the desired understanding was achieved. Often for this type of clicker questions the instructor uses an "all of the above" option as a "negative" feedback intended to inhibit students' *robotic* answering of clicker questions.

The increase in number of correct answers (Figure 4 c) validates that the desired learning outcome was met – which, in the example, was the opportunity for students to utilize the *scientific method* to solve a problem rather than to memorize the correct answer.

Research Focus

Since 2006, the first time that clickers became part of the structural geology course, the instructor collected end-of-semester feedback and used it to improve the impact of clickers in the course. The major research focus of this study is to identify the trends in students' perception on the impact of this tool throughout its adoption. More specifically, the study will analyze students' perceptions on three major categories of clicker-related issues: 1) ease of use; 2) classroom engagement and support; and respectively 3) outside classroom engagement and support.

Research Methods and Instruments

To measure the impact of the clicker strategies on students' learning experience, an end-of-the-semester survey was administered using clickers. The questions used in this study were grouped in three main categories: ease of use, classroom engagement and outside classroom engagement. To reduce students' answer biases, the instructor implemented two major measures in deploying the survey. First, the survey was administered as an anonymous clicker section. That is, clicker's identification code used during the lectures to link student's name in the learning management system was not recorded. Second, a graduate student administered the survey while the instructor waited outside the classroom. Student participation in the survey was rewarded with clicker bonus points. As a limitation of this study, because of the anonymous character of the survey, the research was

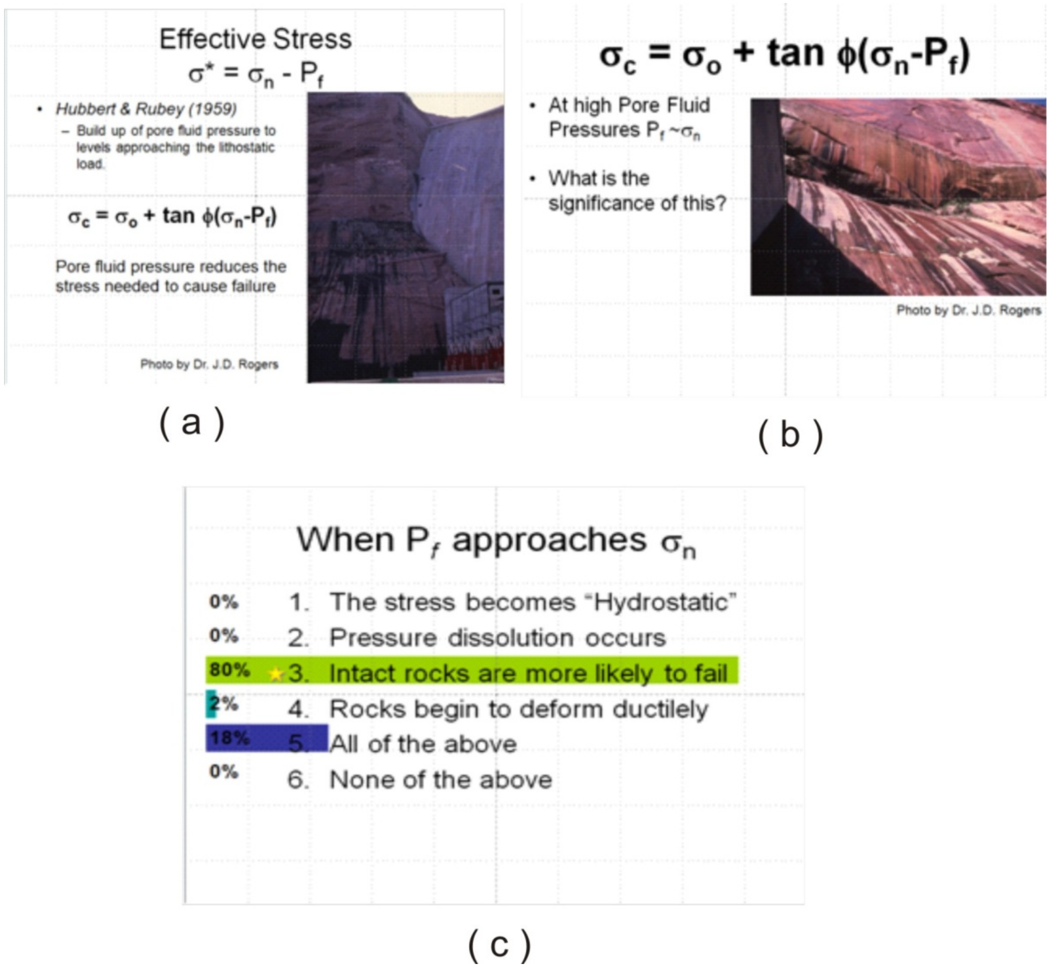


Figure 4. A series of three slides designed to promote more in-depth analysis of a concept by peer discussion.

limited to attitudinal and perception factors and the results could not be linked to students' actual classroom performance. In addition, because the survey was administered with clickers in classroom, the data collected was limited to quantitative, scale-type variables.

Survey Instrument

The main survey, initially deployed in the fall semester of 2006, included 19 questions that were kept as the core part of the upcoming surveys. However, more questions were added every year, producing the current format of the survey with 26 questions. The current format of the survey can be grouped in the following four main categories: a) ease and enjoyment of use, b) classroom engagement and support, c) outside classroom engagement and support, and respectively d) grading policy. The initial 19 core questions covered only the first three categories above mentioned. The grading-related issues emerged after the first two semesters of clicker use. Therefore, for this paper we will present only the research findings associated with the survey questions for the first three categories: ease of use, classroom engagement and out of classroom engagement. Students evaluated each item using a 5-point Likert Scale with 1 - Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree and 5-Strongly Agree.

Participants

Participation in the end-of-semester survey was limited by two major factors. First, the survey was typically administered in the classroom at the beginning of one of the last lectures in the course and therefore only students who attended that lecture had the opportunity to participate in the survey.

Second, the participation in the survey was voluntary, therefore some students that were present at the time of survey administration could decide not to participate for various reasons. Considering these conditions, the student participation in the survey throughout the duration of this study was 39 (71 %) for 2006, 58 (73 %) for 2007, 51 (63 %) for 2008, 71 (70 %) for 2009, 112 (73 %) for 2010 and respectively 134 (77 %) for 2011.

Research Design

To check for trends across the six semesters of successive implementation of clickers in the target course, we used one-way ANOVA followed by a post-hoc analysis to analyze data for each question part of each of the three major survey categories: ease of use, classroom engagement and out-of-classroom engagement. In addition, for each category we used paired t-Tests to compare the means across the six semesters for all questions of that category.

Results and Interpretation

The analysis of results follows the three main categories of questions used in the exit clicker survey: ease of use, classroom engagement and outside classroom engagement. For the first three semesters covered in this study, we generated the dataset from the frequency tables. Therefore, for each of the three main categories above-mentioned, the data analysis follows individual survey questions rather than perception scales.

Ease and enjoyment of use

To analyze students' perceptions related to the ease and enjoyment of clicker use, we analyzed the following three major questions:

Q1. I find the clickers easy to use,
Q2. I enjoyed using the clickers in this class, and
Q3. The clicker questions were too easy.

For each of these three questions, a "1" will represent the lowest level and a "5" will represent the highest level for ease or enjoyment of use. The one-way ANOVA with one between-group factor, semester of implementation, indicated no statistical significance for the first questions (clickers are easy to use) but indicated a significant impact of semester of implementation for the second and third question as shown in Table 1. Figure 5 summarizes the means for these three questions during the period analyzed in this study.

Table 1. Analysis of Variance for Enjoyment of Use and Difficulty of Clicker.

Source	**df**	**F**	**η2**	**p**
Between subjects				
Q2. I enjoyed using clickers in this class	5	11.56**	.12	.99
error	437	(508)		
Q3. The clicker questions were too easy	5	3.11*	.04	.88
error	432	(443)		

Note: Values enclosed in parentheses represent mean square errors. **p < .001; *p<.01

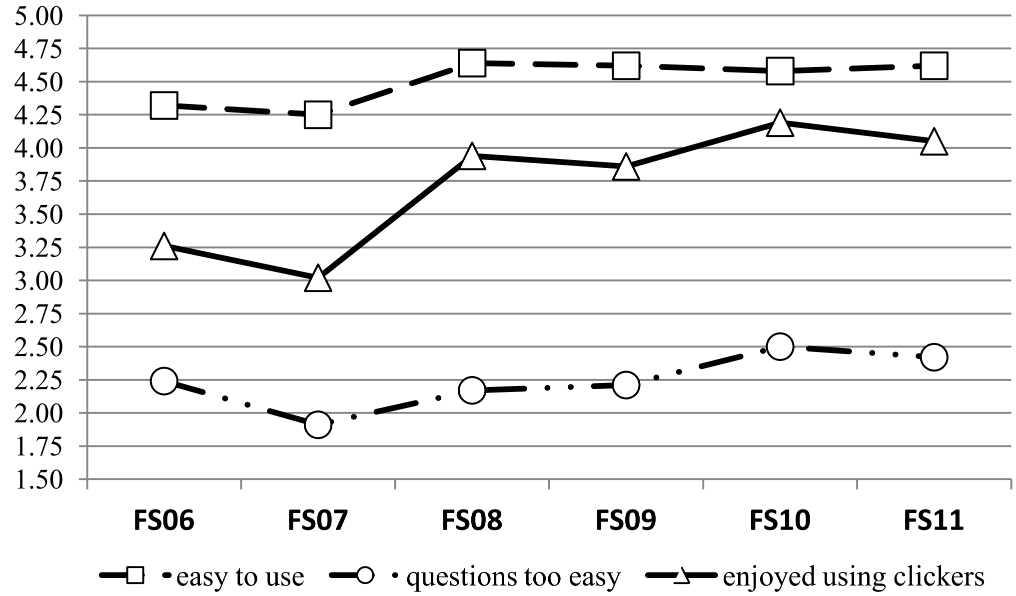


Figure 5. Means for the three questions related to the ease and enjoyment of clicker use.

While the means for the three perception questions related to *ease* and *enjoyment* of clicker use follow a similar pattern, the latter is the only one that showed a clear increase from the initial to the last implementation phases of clickers. The rather flat shape of the perception of use of the technology tool itself, the clicker, can be explained by the careful implementation of this technology at the organizational level. As mentioned in the beginning of this paper, the IT department was carefully implementing this technology from the readiness of the classrooms to the seamlessness of the clicker registration for students.

Another observation is the relatively high levels of perceived difficulty of clicker questions, with all of the means for the third question (the clicker questions were too easy), placed toward the lower end, totally disagree, of the evaluation scale used in this study (see Figure 5). The paired t-Test analysis of means across the six semesters showed that perceived questions easiness (Q3) was significantly lower than the enjoyment of clicker use (Q2), $t(5) = -11.14$, $p < .01$, but not significantly lower than the ease of clicker use (Q1).

The low level of perceived easiness of clicker questions indicates that even if the enjoyment of clicker use was high, students did not perceive the clicker questions deployed during the lectures as trivial. For the two questions that indicated a statistically significant effect for the semester, we conducted post-hoc analyses using Tukey HSD (honestly significant differences) test.

Enjoyment of use. Tukey HSD indicated two independent homogeneous subsets for this question as shown in Figure 6. Students enjoyed using clickers *significantly less* in 2007 when compared to the 2009 to 2011 period. In addition, students enrolled in 2006 enjoyed using clickers *significantly less* than students enrolled in 2008, 2010 and 2011. We found no significant difference between students' enjoyment of clicker use in 2006, 2007 and respectively 2009.

Perceived easiness of clicker questions. Tukey HDS indicated that students enrolled in 2007 perceived clicker questions as being *significantly more difficult* than students enrolled in 2010 and respectively 2011. There was no statistically significant difference between perceived difficulties of clicker questions for 2006, 2008, 2009 and 2011 (see Figure 7).

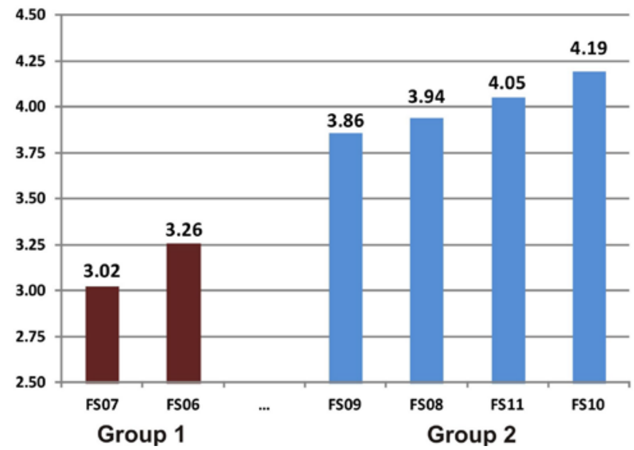


Figure 6. Tukey HSD homogeneous subgroups for enjoyment of clicker use (1-low enjoyment to 5-high enjoyment).

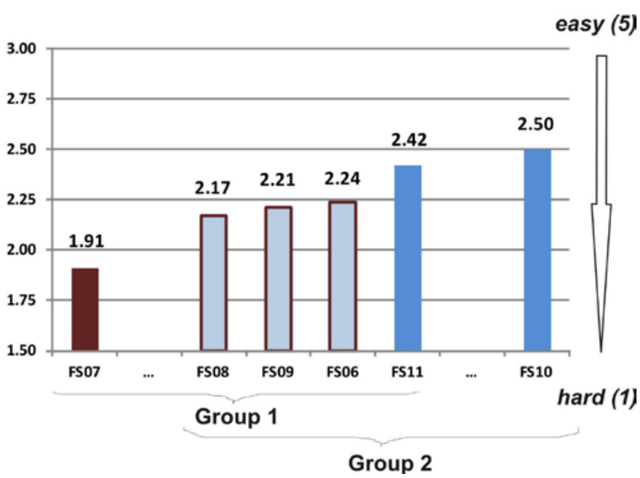


Figure 7. Tukey HSD homogeneous subgroups for perceived easiness of clicker questions.

Classroom engagement and support

To analyze students' perceptions related to the classroom engagement and support of clickers we analyzed two major groups of questions as follows.

Two classroom engagement questions:
Q4. The clicker questions helped me become a more active learner during lecture
Q5. I found the clicker questions useful in enhancing my interaction in the lecture, and

Two classroom support questions:
Q6. The clicker questions helped me pay closer attention during lecture
Q7. The clicker questions help me gauge whether I am following the course materials during class.

For each of these questions, a "1" will represent the lowest level and a "5" will represent the highest level of engagement and support. The one-way ANOVA with one between-group factor, semester of implementation, indicated a significant effect of the semester of implementation for all four questions, as shown in Table 2.

Figure 8 summarizes the means for these four questions during the period analyzed in this study. As seen in Figure 8, the shapes of the curves representing the four classroom engagement questions are quite similar. For the last two years, also, the mean values for all four questions are quite close, a clear statement for the increased quality of clicker use as this technology-driven tool got into a more mature stage of implementation. The pair t-Test analysis confirms this observation by not showing any statistically significant differences between the mean values of the four clicker classroom engagement and support questions across.

Since the two major categories of questions indicated a statistically significant effect for the semester, we conducted post-hoc analyses using Tukey HSD test.

Perceived clicker-related classroom engagement. For the perceived help of clickers to *stimulate active learning,* Tukey HSD indicated that students enrolled in the course between 2008 and 2011 found clickers more effective in helping them to become active learners than students enrolled in 2006. In addition, students enrolled in the course between 2009 and 2011 found clickers *more effective* in helping them to become active learners when compared with students enrolled in both 2006 and 2007 semesters.

Table 2. Analysis of Variance for Classroom Engagement and Support.

Source	df	F	η2	p
Between subjects				
Q4. … helped me become a more active learner	5	11.14**	.12	.99
error	428	(354)		
Q5. … useful in enhancing my interaction	5	7.46**	.08	.99
error	435	(406)		
Q6. …helped me pay closer attention	5	5.20**	.06	.98
error	408	(402)		
Q7. …help me gauge whether I am following the course	5	13.78**	.14	.99
error	430	(374)		

Note: Values enclosed in parentheses represent mean square errors. **$p < .001$

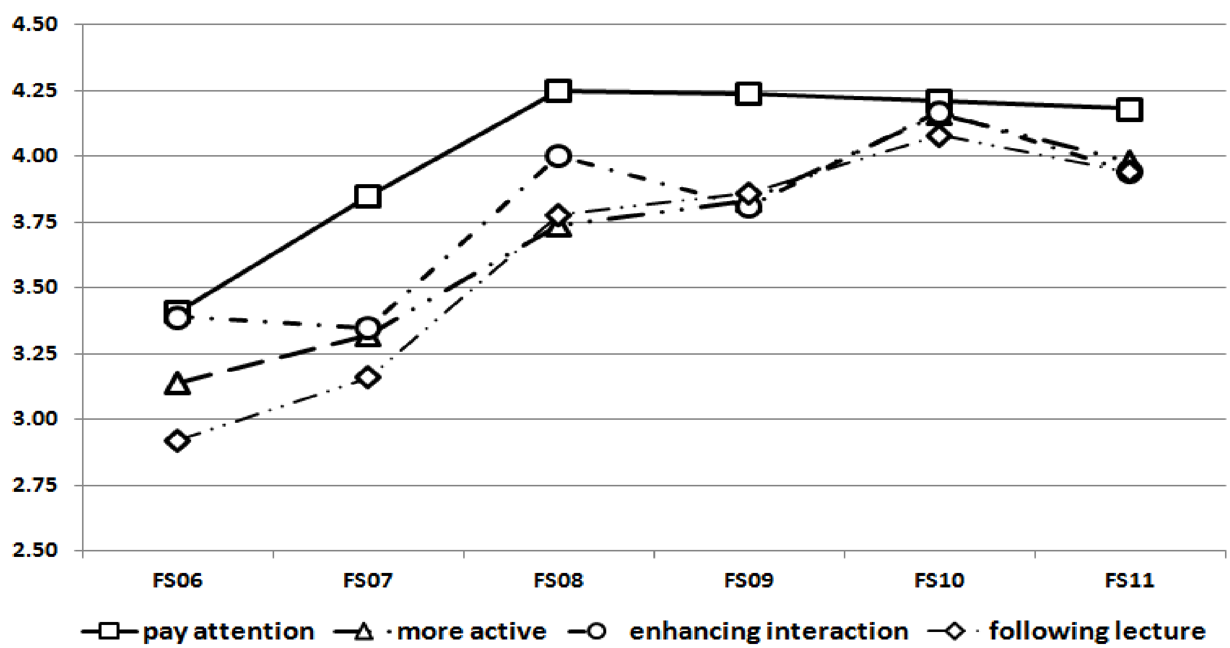


Figure 8. Means for the four questions related to clicker classroom engagement and support.

For the perceived help of clickers *to enhance interaction* during the lectures, Tukey HSD indicated a different trend. That is, students enrolled in the course in 2008, 2010 and 2011 were considering clickers more instrumental in supporting interaction than students enrolled in 2006 and 2007. However, no significant differences were found between the perceptions of students enrolled in the course in 2009 when compared with any of the other five semesters covered in this study.

Perceived clicker-related classroom support. For the perceived help of clicker to *increase attention* during the lectures, Tukey HSD indicated that students enrolled in the course between 2008 and 2011 found clickers more helpful than those enrolled in 2006. However, no significant differences were found between the perceptions of students enrolled in the course in 2007 when compared with any of the other five semesters covered in this study.

For the perceived role of clickers to enhance the ability to follow the materials during the lectures, Tukey HSD showed two independent groups, with students enrolled between 2008 and 2011 perceiving a higher value for this type of support than students enrolled in 2006 and 2007.

<u>Outside classroom clicker engagement and support</u>

To analyze students' perceptions related to the ability of clickers to enhance the engagement and support outside the classroom we used the following three major questions:

8) The clicker questions helped me to assess if I understood the material being covered
9) The clicker questions helped me to remember the material covered in the lecture
10) The clicker questions motivated me to prepare for lecture before coming to class

For each of these questions, a "1" will represent the lowest level and a "5" will represent the highest level of outside classroom support or engagement. The one-way ANOVA with one between-group factor, semester of implementation, indicated a significant effect of the semester of implementation for all three questions, as shown in Table 3.

Figure 9 summarizes the means for the above three questions during the six semesters analyzed in this study. It can be seen that students' perceptions related to ability to assess their own understanding of course materials (Q8) and respectively to remember materials covered in lectures (Q9) followed quite similar patterns and showed mean values above the middle of the evaluation scale. However, perceived motivation to prepare for lectures before coming to the class (Q10) showed mean values lower than the middle of the evaluation scale.

In addition, the paired t-Test analyses indicated that students' perception of clicker-related motivation (Q10) is statistically significant lower than:

a) Perceived ability to assess understanding (Q8, $t(5) = -14.10$, $p < .001$), and
b) Perceived ability to remember (Q9, $t(5) = -31.11$, $p < .001$) materials presented in lectures across the six semesters analyzed in this study.

Since all questions related to outside classroom support and motivation indicated a statistically significant effect for the semester, we conducted post-hoc analyses using Tukey HSD test.

Perceived clicker-related outside classroom support. For the perceived help of clicker to assess understanding of materials being covered, Tukey HSD indicated that students enrolled in the course between 2008 and 2011 perceived clickers as being more helpful than for students enrolled in 2007. However, only students enrolled in 2010 perceived clickers as being significantly more helpful to assess understanding than students enrolled in 2006.

Table 3. Analysis of Variance for Outside Classroom Engagement and Support.

Source	df	F	η2	p
Between subjects				
Q8. … helped me to assess if I understood the material being covered	5	12.04**	.12	.99
error	429	(344)		
Q9. …helped me to remember materials covered in lectures	5	14.24**	.14	.99
error	426	(346)		
Q10. … motivated me to prepare for lecture before coming to class	5	8.78**	.09	.99
error	432	(611)		

Note: Values enclosed in parentheses represent mean square errors. **$p < .001$

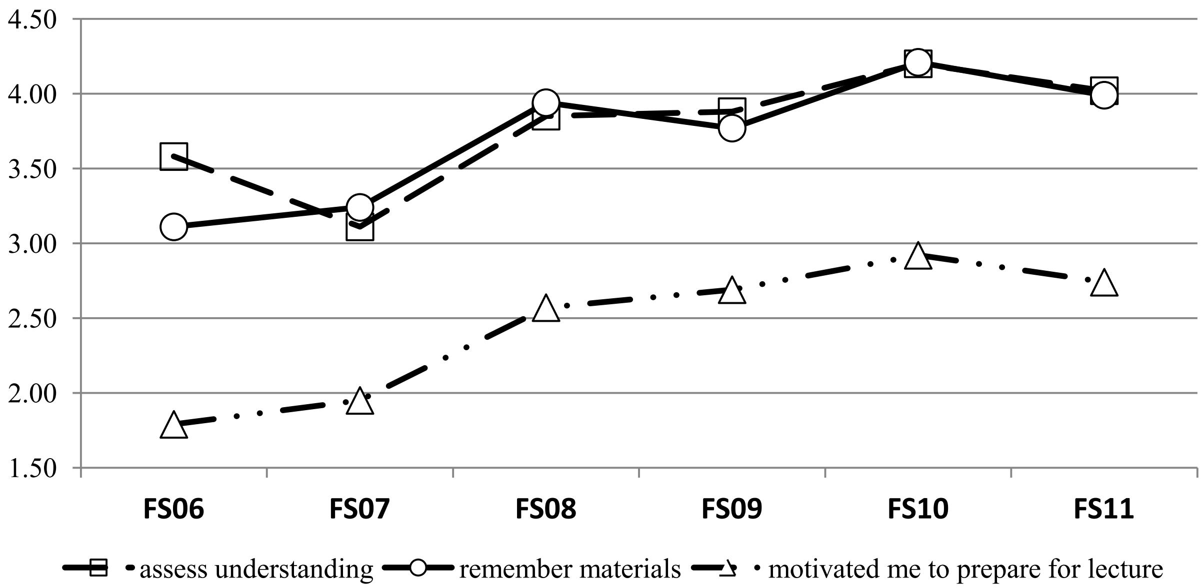


Figure 9. Means for the three questions related to outside classroom clicker engagement and support.

For the perceived help to remember materials covered in the lecture, Tukey HSD indicated two independent homogeneous subsets with students enrolled between 2008 and 2011 perceiving clickers as significantly more helpful for remembering the materials covered in the lecture than students enrolled in 2006 and 2007. Figure 8 presents the two homogeneous groups resulted from this analysis.

Perceived clicker-related outside classroom motivation. For this question Tukey HSD indicated again two independent homogeneous subsets similar with the second support question analyzed before.

Conclusions & Future Research

This analysis of an early adoption of clickers at both instructor's and university levels shows that it took students on average two semesters to significantly shift their perception and view clickers as supporting both activities inside and outside the classroom. This can be explained both by the novelty of this tool for students and the instructor's adjustment to the potential of the instructional strategies associated with clickers. However, because the adoption of this tool at the course level closely mapped its adoption at the organizational level, students' perception of clickers' ease of use was high from the beginning of clickers use in the course. This finding proves again that a well-crafted strategy to introduce innovative technology tools at the organizational level will reduce students' resistance to the tool itself at the course level.

Finally, the instructor's clear focus on using clickers as a tool to increase and support active learning during lectures was clearly reflected in students' perception of this classroom tool's support for active learning. That is, the four questions that measured students' perception on classroom engagement and support showed a similar trend throughout the six semesters analyzed in this study. In addition, the means for the four questions targeting clicker classroom engagement and support were very high in the last three semesters when this tool reached a more mature level of implementation.

Due to the focus on anonymity of students' answers, one major weakness of this study was the inability to associate students' answers to this survey and their course performance. As the implementation of clickers is moving toward more mature stages, we plan to change the future administration of this survey to an online format that will allow students to provide some qualitative feedback and decide if they want to reveal their identity. This format of the survey will also allow the researchers to: a) focus on testing if some of the questions categories presented in this study can generate reliable and valid scales to measure students' perceptions associated with the use of clickers, and b) link students' perceptions to course performance measures. Over the long-term, we would like to test if these scales can be used to measure students' perceptions associated with other active learning strategies and tools in the same course as well as the implementation of new, innovative instructional tools in other classroom settings.

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