**Clickers beyond the First Year Science Classroom**

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**Abstract***:*

This case study's primary objective is to describe the implementation of the electronic-response-system (clickers) in a small second year physics course at a large public university. The paper addresses the impact of the clicker-enhanced pedagogy on students' cognitive and affective outcomes, as well as students' attitudes toward using clickers. We also outline some challenges faced by the students and the instructors with regard to using this technology. The paper suggests a few possible ways of addressing these challenges leading to the successful implementation of the clicker-enhanced pedagogy beyond the first year university science classroom.

During the past decade, the use of electronic response systems (clickers) became very popular in undergraduate programs, both science and non-science alike (Duncan 2005; Hoffman & Goodwin 2006; Keller et al. 2007; Lasry 2008; Mayer et al. 2009; Milner-Bolotin 2004). There are many reasons why science instructors were so eager to incorporate clickers. First of all, during the past thirty years, physics educators developed reliable and easy-to-administer tests and surveys that allowed assessment of student learning (Hestenes, Wells, & Swackhamer, 1992; Perkins, Adams, Pollock, Finkelstein, & Wieman, 2004; Thornton & Sokoloff, 1998) and made the comparison of the learning gains across various educational institutions possible (Hake, 1998). These instruments helped new and seasoned instructors to evaluate their teaching effectiveness more objectively in terms of student cognitive and affective outcomes (Mazur, 1997a, 1997b). Consequently, a significant number of instructors became conscious that traditional teacher-centered approaches have limited effectiveness in science classes, especially considering the changing student demographics, increased undergraduate class sizes, and a renewed emphasis on developing critical thinking skills. Furthermore, science educators have made a considerable progress in identifying student learning difficulties and designing teaching methods to address them (Arons, 1997; Kalman, 2008). Most of these methods incorporate active learning and student-centered learning environments (Hake, 1998; Svinicki, 2000) that encourage student-student and student-instructor interactions. Many instructors who incorporate these teaching methods in large undergraduate science classes rely on clicker technology for instantaneous feedback on student learning. Finally, science educators produced an extensive volume of research-based materials that help instructors to get started in using interactive teaching methods, such as clickers. For example, many of the science book publishers include clicker question in the textbook packages, so a new instructor can start by incorporating ready-to-use clicker questions that come with the textbook. In addition there is a growing number of online databases dedicated to sharing effective clicker questions among the instructors (Harrison, 2005; Mazur, 1997b). However, while the effects of clicker-enhanced pedagogies in large undergraduate science classrooms have been studied extensively, little had been done to investigate clicker potential beyond the freshman year. The goal of this paper is to report on the implementation of the clicker-enhanced pedagogy in a small (25 students) second year physics course at a large public university.

**Clicker Implementation in a Second Year Physics Course**

In large universities, the second and third year physics courses are usually significantly smaller than the general first year introductory science courses: tens versus hundreds of students. Upper level physics course are designed specifically for physics or chemistry majors, with the goal of solidifying student knowledge gained in the first year and introducing them to the more advanced fields of physics such as electricity and magnetism, thermodynamics, quantum mechanics and the theory of relativity. These courses are cognitively more demanding than the first year courses, as they often require putting together multiple concepts and applying them to novel situations. In addition, upper level science courses demand a higher level of abstraction, attention to technical details and rigorous mathematical treatment. As a result, the conceptual side of the topic is often neglected, focusing mostly on mathematical representation of physics problems. For the instructor, despite the small class size, teaching a second year physics course poses a challenge as this is often the first "real" university-level physics course experienced by the students that is aimed at developing higher order critical thinking skills in a physics context (Bloom, 1956).

The "Modern Physics Course" described in this study fits perfectly within this description. The course was designed for the second year medical physics students (N=25) and covered some concepts of relativity and served as an introduction to the theory of quantum mechanics. It included four hours of classes a week and was taught by an instructor with the help of a Teaching Assistant. Due to the small class size and the availability of the HP tablet computers (Milner-Bolotin, Antimirova, & Zambito, 2008), the instructor had the flexibility to use computer simulations and online resources during the class at any time. As a result, the students were able to benefit from multiple resources. The students in this course have all previously used clickers (http://www.einstruction.com/) in their first year physics and chemistry courses and therefore not only had clickers in their possession, but were already familiar with the technology. Clickers were used on a daily basis with few rare exceptions of the classroom podium malfunction at which questions could not be projected on the board properly. On average four clicker questions were asked per class, and while most of them were multiple choice questions dedicated to the course material (Figure 1), a few were survey questions asking for the student anonymous feedback on the course and the use of technology. From the very beginning, the students were informed that five percent of their final mark will be based on their clicker participation: for every correctly answered question the students earned two points, for every attempted but incorrectly answered question, they earned one point.

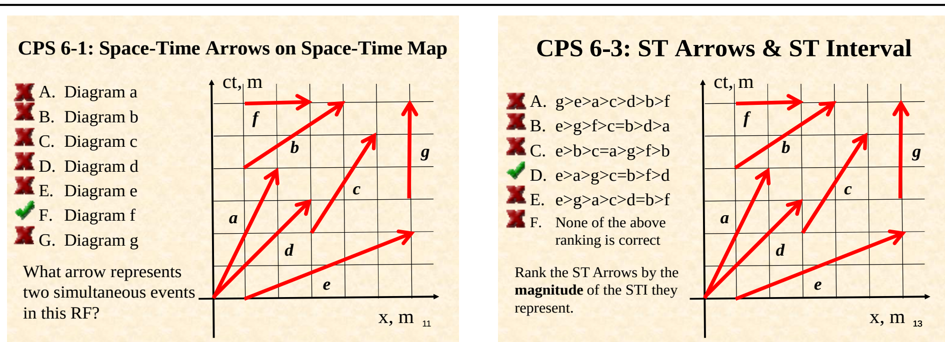


**Figure 1:** Examples of two multiple choice clicker question asking the students to interpret the Space-Time (ST) arrows on a Space-Time Diagram. Question CPS 6-1 is a lower level question that probes student understanding of the concept of a ST

The procedure for the administration of the clicker questions is displayed in Figure 2. We call it a Modified Peer Instruction (MPI), since it is based on the original Peer Instruction methods proposed by Eric Mazur(Mazur, 1997b). MPI method can be split into the following main stages: 1) The instructor poses a clicker question on the board, such as the one shown in the Figure 1. 2) The students are given a limited amount of time to think of the answer and submit it using clickers. At this stage the students are not allowed to discuss their answers with each other. 3) The summary of student responses is displayed without revealing the correct answer. 4) Two possible outcomes follow: either most of the students answered the question correctly and only a brief summary is needed to clarify the answer to the few who answered incorrectly; or the majority answered incorrectly and thus the question revealed difficulties in student understanding of the concept. 5) In the latter case, the instructor asks the students to discuss the question with their peers and vote again. 6) The revote is followed by a group discussion and detailed explanation as to the reasons behind the correct as well as the incorrect responses, to ensure that the students had a chance to construct a deep conceptual understanding.

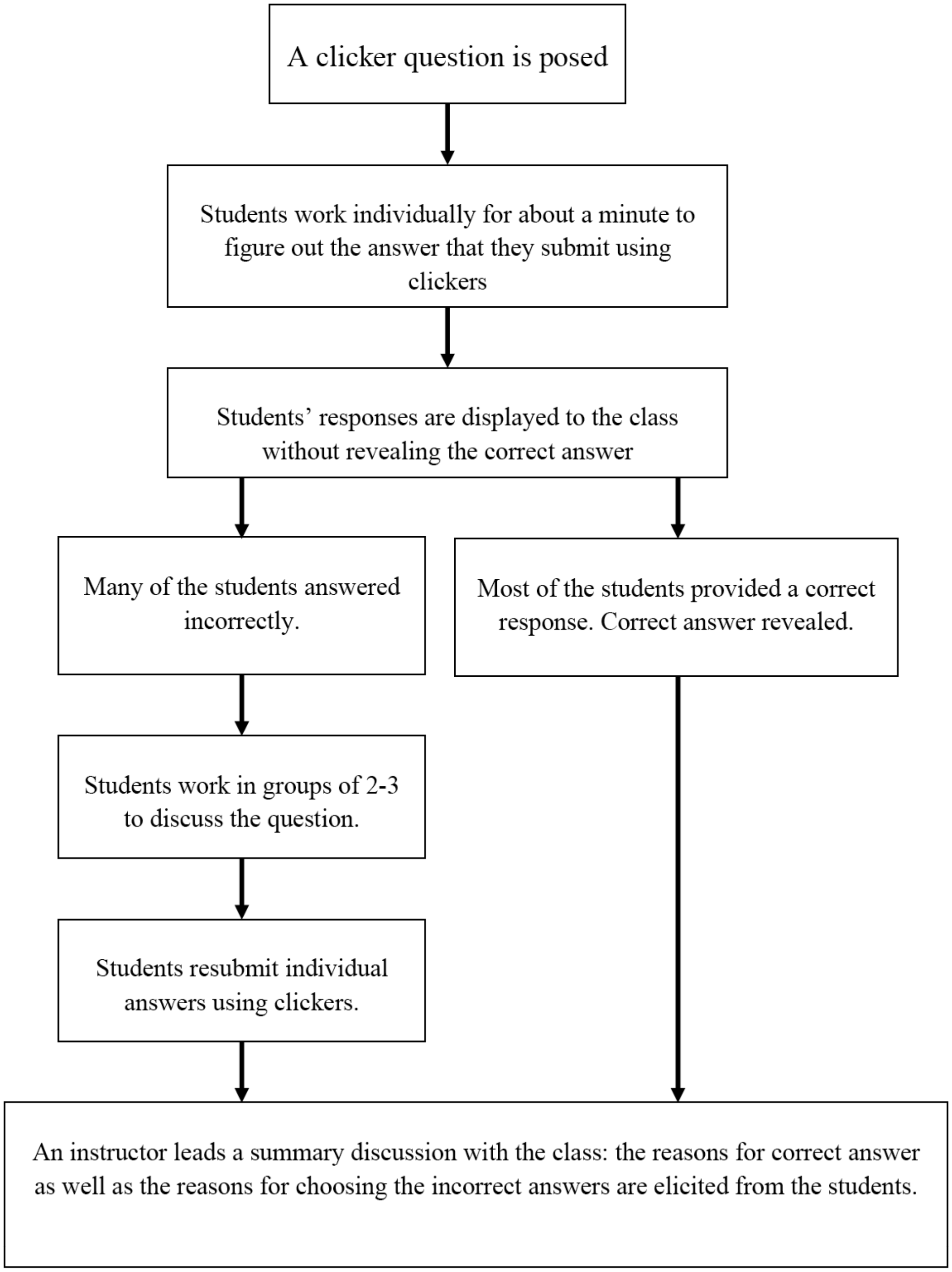


Figure 2: A flow chart representing Modified Peer Instruction pedagogy.

Commonly, after the students vote for the second time, most of them understand the question and the physics concept behind it. Moreover, during the peer discussion stage, the instructor circulates among the students, asks leading questions, notices student difficulties and helps the students to clarify the concept. If a question is particularly interesting, the instructor uses student responses as a basis for the further discussion and clarification of the concept. It is worth mentioning that when the students vote for the second time, their initial responses are overwritten. This way the majority of the students have reasonably high clicker participation marks, which are perceived by the students as formative, rather than the summative assessment that contributes to their positive performance in the course.

**Results:**

To assess students' attitudes toward clickers and their effectiveness as perceived by the students in the upper level physics courses, the researchers asked a specific clicker-related question on the anonymous course survey. The question stated, "Would you recommend using clickers beyond the first year courses?" Out of 17 students who responded, 12 students (70%) said that they would recommend the use of clickers since they find them helpful, 3 students (18%) said that they were neutral (clickers make no difference), and 2 students (12%) said that the clickers were a waste of time and they would not recommend their usage. Since the sample was relatively small, the researchers decided to conduct interviews with student volunteers asking them to describe the impact of different technological tools on their learning. The interviews were administered by the research assistant (A.P.) and the results were not revealed to the course instructor till the course was over. During the interviews, the students were asked to reflect on different technology uses in the science classes as well as on the effectiveness of the clickers. Here are some of the excerpts from these interviews:

Student 1: “Use of technology makes the lectures fun, like the use of clickers. It is a motivation to attend the class, discuss the topic, and get feedback”.

Student 2: “Use clickers for every class: the more the better”.

Student 3: “Yes, use clickers in every single class”.

Student 4: “Clickers should be used beyond the first year because they help to prepare for midterms, provide feedback for the teacher and the students, are interactive, and provide an easy way for the students to get good marks”

Student 5: “The clickers are easy and convenient to use”.

Student 6: “Clicker technology is a tool to learn more and to understand the concepts”.

Only two out of ten interviewed students mentioned that the clickers are ineffective in small classes compared to the large ones. One out of the ten interviewed students stated that clickers are not necessary in upper level physics courses, while nine out of ten students responded that they would recommend the use of clickers beyond the first year. During the interview, the students were prompted to reflect on what they like and dislike about the use of clickers in the upper level science classes. Their responses are summarized in Table 1. Notice, that some opinions were recurring among the students.

| **What the students liked about the use of clickers (number of respondents out of 10)** | | **What the students disliked about the use of clickers (number of respondents out of 10)** | |
|---|---|---|---|
| Immediate feedback from the teacher | 7 | Loosing marks for missing classes (attendance/participation) | 5 |
| Practice for midterms | 2 | Technical problems with technology | 3 |
| Interactivity (not just reading or writing but engaging) | 3 | Clickers discourage you if you got a wrong answer | 1 |
| Reinforcing student attendance by giving marks for participation. | 4 | Clicker questions are too fast, not enough time to think of the answer | 1 |
| Direct simple conceptual problems are helpful. | 1 | Clickers take away time from the lecture | 1 |

Table 1: Summary of student opinions about the use of clickers in the second year Modern Physics course

In summary, the majority of the students found clickers to be helpful for learning physics beyond the first year physics courses. However, despite the small class size, a few second year students came with the expectation of “direct lecturing” and information transfer they have experienced in some of their large first year courses. The students believed that the instructor is supposed to provide them with all the information they have to learn (memorize), and active class participation should not be required. Nevertheless, the majority of the students were positive about active class participation and the dynamic learning environment. Many of them enjoyed using clickers in their first year science courses; therefore, using clickers in the second year was a natural extension. It is not surprising that the main advantage of using clickers, from the students' perspective, is an immediate feedback and an opportunity to clarify physics concepts. The biggest complain about the use of clickers was the fact that class attendance was rewarded, so the students who would skip the class otherwise, were "forced" to attend it. However, the class participation mark based on the clicker input (5% of the total grade) did not lower the grade for any one of the students. On contrary, it only improved the students' final mark. It is important to mention that active class participation via group problem solving, in-class discussions and other activities often clashes with students' expectations that the most effective mode of learning is reading the textbook or following the lecture notes posted online which can be done at home. The importance of in-class discussion on student learning cannot be overemphasized for both lower level and upper level physics courses (M.K.Smith et al., 2009).

From the instructor's perspective, the use of clickers provided necessary feedback on students' progress and helped the instructor to focus on difficult concepts as well as provide the students with ample opportunities for meaningful interactions with each other and with the instructor.

**Addressing the challenges**

There are several reasons why science instructors are still reluctant to use clickers beyond the freshman year. First of all, there is still a prevalent view among the instructors that their main goal of the upper level courses is to "cover the material" and using clickers or any other interactive engagement methods reduces the amount of time available for direct lecturing. As more research evidence is collected supporting the claim that the effectiveness of the interactive engagement methods reaches beyond the first year, science educators will be able to use it to convince science instructors to use interactive engagement in upper level courses. Another reason is the fact that creating effective clicker questions is challenging and time consuming (Betty, Gerace, Leomard, & Dufrense, 2006). In case of the introductory courses, science education researchers have made a significant progress in understanding student difficulties and creating appropriate teaching methods, including effective clicker questions. This situation is currently not applicable for t the upper level courses. The work in this area had just began and thus the instructors who are determined to use clickers in upper level courses will be required to design a significant number of these questions themselves. This will require a few iterations and will be best accomplished when science educators work on it as a community. Moreover, in order to evaluate the effectiveness of interactive engagement methods such as clicker-enhanced pedagogy, a more uniform learning assessment tools specific to upper level courses should be constructed. Only when science educators designed reliable instruments, such as Force Concept Inventory, Force and Motion Conceptual Evaluation, (Hestenes et al., 1992; Thornton & Sokoloff, 1998) to measure student learning in introductory physics courses, it became clear that traditional teaching methods were ineffective for the majority of the students. It can be predicted that the same will happen when similar instruments for upper level science courses become available and widely used.

We are convinced that clicker-enhanced pedagogy has a potential to become an effective educational tool that will help science instructors in facilitating meaningful science learning beyond the first year. We invite the instructors who want to use clickers in upper level courses to combine efforts in designing effective clicker questions, sharing their experiences and creating a community of practice aimed at promoting interactive engagement in science courses at all levels.

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