

# Understanding How Physics Faculty Use Peer Instruction

Chandra Turpen and Noah D. Finkelstein

*Department of Physics, University of Colorado, Boulder, Colorado 80309, USA*

**Abstract.** We investigate how the use of physics education research tools is spreading throughout faculty practice and examine efforts to sustain the use of these practices. We specifically focus on analyzing the local use of the innovation Peer Instruction. We present data based on observations of teaching practices of six physics faculty in large enrollment introductory physics courses at our institution. From these observations, we identify three dimensions that describe variations in faculty practices: the purpose of questions, participation with students, and norms of discussion.

**Keywords:** Educational Change, Peer Instruction, Personal Response Systems, Physics Faculty, Teaching Practices.

**PACS:** 01.40.-d, 01.40.Di, 01.40.Fk, 01.40.gb

## INTRODUCTION

Significant work has been conducted within the Physics Education Research (PER) community to better understand how physics professors come to adopt and adapt reform-based tools and curricula. Prior research has sought to understand both the beliefs and values that professors bring with them, and those beliefs which inform the design of curricular tools [1]. Dancy and Henderson specifically found that although most physics professors' beliefs and values are consistent with most PER-based reforms, professors' self-reported practices do not reflect these PER-consistent values due to systemic constraints surrounding the classroom environment [2]. Our work builds on this prior research by looking specifically at how physics professors make ongoing pedagogical decisions in a working classroom. Through observations of classroom practice in large-enrollment introductory physics classrooms, we seek to characterize similarities and differences among physics educators' actual practices and use of curricular tools. In this paper, we identify three primary dimensions along which we see significant variation in individual professors' implementation concerning one pedagogical tool, Peer Instruction [3]. We begin to describe these differences in practices, so that ultimately we may examine the impacts on student engagement and perception.

## METHODS

In this study, six introductory physics courses were observed using ethnographic observation techniques [4] and each of the observed class periods was audio-taped.

For each of the courses, at least twenty percent of all class periods were observed. Daily records of clicker question responses were collected, as well as other course documents such as syllabi, homework assignments, exams, and other web correspondence. In addition, the primary instructors for the courses were interviewed at the end of the course about their broader teaching practices and specifically about their use of clickers or personal response systems. The results presented in this paper primarily focus on the analyses of classroom observation data and course records. The identified dimensions of practice emerged from initially broad observations. Data from these observations and records were successively narrowed through an inductive analysis which led to the identification of characteristics and patterns across course sessions [4].

## BACKGROUND

All courses observed in this study were large enrollment introductory undergraduate physics courses with average lecture attendance ranging from 130 to 240 students. Five of the six courses studied used iClicker technology, a radio frequency classroom response system [5]. One of the courses used H-iTT technology, an infrared classroom response system [6]. In this paper, we will refer to both of these technologies as 'clickers.' Five of the six courses studied were courses required for science-based degree programs. The other was an elective course for non-science majors. In two courses where conceptual assessments were given, both courses achieved significant learning gains ranging from two to three times the national norm for non-interactive engagement courses [7].

The lead instructors for these courses varied from tenured professors to temporary instructors. Pseudonyms have been chosen to assure their anonymity. Two of the six instructors observed, Green and White, were novices with respect to the use of Peer Instruction and clickers in large-enrollment courses. Both also happened to be temporary instructors. Three of the instructors observed, Blue, Red, and Purple, were active members of the physics education research group at the University of Colorado at Boulder. Blue, in particular, has been nationally recognized for his excellence in teaching and has pioneered the use of Peer Instruction and clicker systems at our institution. It is also important to mention that Blue mentored Yellow as he learned to use clickers and Peer Instruction in his own large-enrollment introductory physics courses. Although all of these educators used the language of Peer Instruction, based on the work of Mazur [3], to describe their practice, none of them implemented Peer Instruction exactly as described by Mazur. The most notable variation between their practices and Mazur's description is that all faculty observed in this study did not have an explicit "silent" phase of the clicker question where the students came to an answer individually first. Importantly, we observe significant student discussion in all classes. In this way, the use of the term Peer Instruction by physics faculty and our use in this paper should be loosely interpreted.

### THREE DIMENSIONS OF PRACTICE

We describe three dimensions along which there exist significant variation within our local sample of six physics professors. It is important to note that there also exist significant similarities between these professors, but due to limited space these similarities will not be emphasized here. Each of the professors observed used clickers in the spirit of Peer Instruction as described by Mazur with significant peer discussion and carefully constructed conceptually-based clicker questions. The first dimension of practice identified, the purpose of clicker questions, directly relates to explicit recommendations by Mazur in *Peer Instruction*. We identify two additional dimensions for which no or few explicit recommendations are provided for in Mazur's book. These dimensions include the role of the professor during the clicker question response time and the role of discussion of question solutions.

#### Purpose of the Clicker Questions

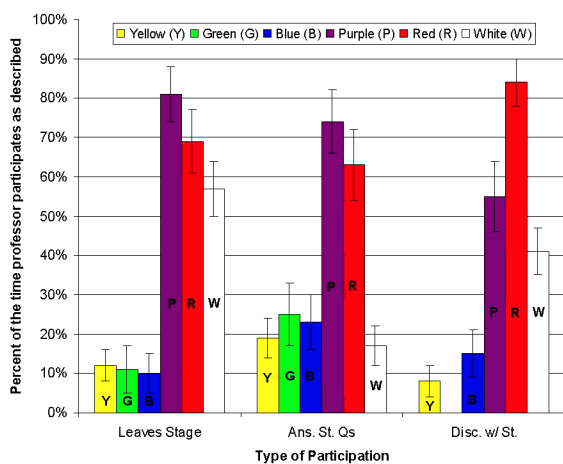
A preliminary, rough measure of the purpose of the clicker questions can be seen from the frequency of clicker questions used by the professor. In the courses

observed, there was great variation in the average number of clicker questions asked per hour of class, ranging from a maximum of 9.2 by White and a minimum of 3.2 by Green. The average number of clicker questions per hour for each professor along with the respective standard error on the mean was Green:  $3.2 \pm 0.1$ , Purple:  $5.0 \pm 0.3$ , Red:  $5.3 \pm 0.4$ , Yellow:  $5.9 \pm 0.5$ , Blue:  $6.5 \pm 0.4$ , White:  $9.2 \pm 0.6$ . It is interesting to note that the two professors at either extreme were the novice clicker users. From these data, there are indications that a clicker question in White's class may look different and have a different purpose compared to a question in Green's class. In addition to the challenging conceptual questions most closely resembling ConcepTests [3], our first pass analysis shows that some professors are occasionally using shorter questions to review or check for understanding. For these clicker questions students are given less time to answer the questions and less time is spent discussing the solution. These types of clicker questions were most frequently used by White, which we can see reflected in this course's unusually high frequency of clicker questions. Further classification of the characteristics of 'check for understanding' type clicker questions is currently being analyzed based on the distribution of students with correct and incorrect answers, the construction of the question itself, the average amount of time given to students to respond to clicker questions, and the amount of time spent discussing clicker question solutions.

Through our analysis and observations we have also identified another type of clicker question used by some of the professors, logistical questions. Logistical questions included questions where the students were asked when they would like the homework due or how difficult the midterm exam was. The purpose of these questions was usually to gather student opinions on how the course was going and possibly inform the structure or direction of the course. Yellow, Green and White almost never (<2% of the time) asked logistical questions, while Blue, Purple, and Red occasionally asked logistical questions (5-15% of the time). We also found that one of the professors observed, Red, was using clicker questions to give graded reading quizzes.

#### Role of the Professor during the Clicker Question Response Time

During the time interval where students were constructing an answer to a clicker question, what did the professors do? Based on our observations individual physics professors were spending this time differently. One significant difference was the extent to which the professor leaves the stage area of the lecture hall and walks around the classroom amongst the



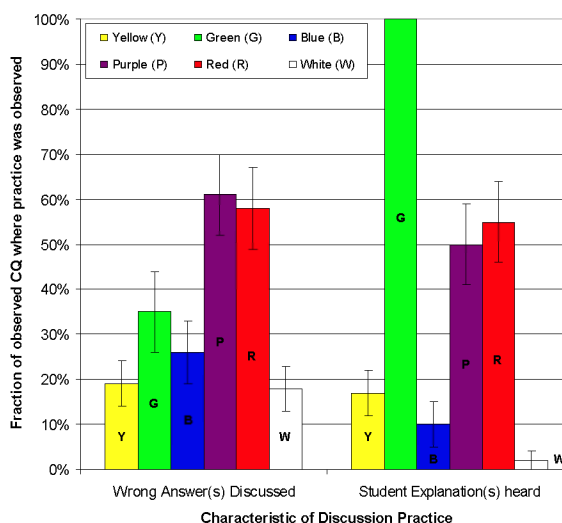
**FIGURE 1.** The percentage of observed clicker questions where the professor was observed to participate with the students during the response time by leaving the stage (column 1), answering student questions (column 2), or actively discussing with the students (column 3). The error bars shown are the standard error on the proportion.

students. The first column of data in Figure 1 shows the fraction of observed clicker questions where the professor left the stage area of the classroom. The professors also varied in how they spent their time interacting with the students during this clicker question response time. The fraction of the observed clicker questions where the professor answered students' questions or discussed with the students varied, as shown in columns two and three of Figure 1 respectively.

From Figure 1 we see that Yellow, Green, and Blue are almost never leaving the stage (less than 15% of the time). On the other hand, we see that Purple, Red and White are usually leaving the stage (more than 50% of the time). We also note that the professors who usually left the stage were more likely to answer student questions or actively discuss with the students than the professors who almost never left the stage.

### Role of Discussion Concerning the Clicker Question Solution

After the students had finished responding to the clicker question, how was the explanation phase of Peer Instruction conducted? We have identified two characteristics of this discussion that vary across professors: whether incorrect clicker question answers were addressed and whether students participated in the explanation of the clicker question solution. The first column of data in Figure 2 shows the fraction of observed clicker questions where incorrect answers were discussed during the description of the solution. The second column of data in Figure 2 shows the



**FIGURE 2.** The percentage of observed clicker questions where the wrong answers were discussed and student explanations were heard. The error bars shown are the standard error on the proportion.

fraction of the observed clicker questions where student explanation(s) of the clicker question solution were heard during the whole class discussion. From Figure 2 we can see that Purple and Red are usually discussing incorrect clicker question answers and that they are doing so more frequently than the rest of the educators observed.

It is also interesting to note that although Green and Blue are discussing incorrect options about the same fraction of the time, in Green's class these explanations of the incorrect options are coming from the students while in Blue's class the explanations of the incorrect options are coming from the professor's explanation of common student challenges. In Purple and Red's courses, the discussion of incorrect answer options was commonly coming from both the students and the professor. The second column of data in Figure 2 also shows that Green is always using student explanations when explaining the clicker question solution. Purple and Red are usually using student explanations in the construction of the clicker question solution, while Yellow, Blue, and White are rarely (less than 20% of the time) using student explanations.

The number of students explanations usually heard in class for a given question also fluctuated. When students were asked to contribute explanations of the clicker question solution, Yellow on average heard from  $2.2 \pm 0.2$  students, Green:  $1.4 \pm 0.1$ , Blue:  $1.3 \pm 0.3$ , Purple:  $2.3 \pm 0.5$ , and Red:  $2.4 \pm 0.4$ . White was not included in this analysis since student explanations were only used once. We see that Blue and Green are primarily hearing from only one student concerning the correct answer, when student explanations are used,

while Yellow, Purple and Red are usually hearing from at least two. We can infer that in the classrooms of Yellow, Purple, and Red there is more emphasis on discussing the incorrect answers and associated student reasoning.

## DISCUSSION AND CONCLUSIONS

Despite all six instructors implementing the ‘same’ activity, Peer Instruction, we observe that there are influential decisions that these faculty members make that distinguish their practices. Some of these specific decisions have not been previously discussed in the research literature. We seek to identify categories of practice in order, ultimately, to distinguish which aspects of Peer Instruction are flexible and can be effectively implemented in a multitude of ways and which aspects of Peer Instruction are essential for the effective use of the educational tool. In the present work we have identified three categories which differentiate faculty practice: the purpose or type of questions, participation of faculty in the student response time, and discussion norms surrounding the description of the question solution.

From these categorizations and observations of faculty in class, we found that instructors new to using clickers were more likely to reflect the extremes of the dimensions described. For example, Green always heard student explanations for the questions solutions, while White almost never did. This ‘all or nothing’ observation of novice faculty practice may be indicative of the fact that novice users do not have highly developed heuristics for deciding when to use certain practices.

We found the similarities between the practices of Blue and Yellow particularly notable, considering Blue was a mentoring instructor for Yellow when Yellow was beginning to learn to use clickers and Peer Instruction. The aspects of practice described here begin to capture some of the similarities in these instructors based on their time spent teaching together. Additionally, we observe very similar practices for two of the PER faculty, Red and Purple. Despite teaching in two different types of environments (one a non-science majors course and one a required course for engineers), their teaching practices surrounding Peer Instruction are almost indistinguishable.

It is also interesting to note that there is diversity of practice even within the subset of physics education research faculty members. While we do find Red and Purple to be quite similar on all dimensions described, Blue’s practices vary. This description of practices surrounding Peer Instruction is surely not complete, and is made clear by the fact that Blue’s excellent teaching practices do not stand out as unique along the

dimensions described. Perhaps more subtle features of practice were not captured by these initial descriptive measures. For instance, we hypothesize that based on years of teaching experience and familiarity with the PER literature, Blue already understands common student difficulties. For this reason, Blue may not necessarily need to solicit student explanations to understand what students are thinking; whereas Yellow, White and Green do not have this background knowledge. In this way their practices would mean something different. Finally, these varying practices may be directed towards achieving different goals, all of which may be realized through Peer Instruction in the generic sense. Unpacking the variation in classroom practices and how these practices shape classroom culture and ultimately student engagement and learning are the subjects of current studies.

## ACKNOWLEDGMENTS

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