Comparing Educational Tools Using Activity Theory: Clickers and Flashcards

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Abstract. Physics educators and researchers have recently begun to distinguish between pedagogical approaches and the educational technologies that are used to implement them. For instance, peer instruction has been shown to be equally effective, in terms of student learning outcomes, when implemented with clickers or flashcards. Therefore, technological tools (clickers and flashcards) can be viewed as means to mediate pedagogical techniques (peer instruction or traditional instruction). In this paper, we use activity theory to examine peer instruction, with particular attention to the role of tools. This perspective helps clarify clickers' and flashcards' differences, similarities, impacts in the classroom, and utility to education researchers. Our analysis can suggest improvements and new uses. Finally, we propose activity theory as a useful approach in understanding and improving the use of technology in the physics classroom.

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INTRODUCTION

Physics educators and education researchers have developed and used a number of innovative educational technologies. Several researchers have conducted comparative studies of different technologies, including simulated versus physical experiments [1], animated versus static questions [2], tablet PC versus paper lab notebooks [3], and class response systems (hereafter referred to as clickers) versus flashcards [4]. Activity theory (AT) [5-8] provides a structured framework for making such comparisons. Though AT is a broad framework, we illustrate its usefulness in physics education by comparing clickers and flashcards as tools for Peer Instruction [9].

OVERVIEW OF ACTIVITY THEORY

AT provides a framework for understanding human activity and provides an explicit focus on tools. AT is therefore useful for analyzing the role of technology in education. According to Kaptelinin and Nardi:
"In activity theory, people *act* with *technology; technologies are both designed and used in the context of people with intentions and desires. People act as* subjects *in the world, constructing and instantiating their intentions and desires as* objects*. Activity theory casts the relationship between people and tools as one of* mediation*; tools mediate between people and the world* [8, p10, emphasis in the original]."

What exactly is an activity? Activity "is understood as a purposeful interaction of the subject with the world [8, p31]." Activities are the unit of analysis in AT, and provide the minimal meaningful context for goal-oriented actions. The purpose of activity is to transform an *object* into an *outcome*. The relationship between the subject and the object is mediated by *artifacts,* which shape the subject's range of possible interactions with the world. In this paper we focus on one class of artifacts – technological tools[#].

As an example, imagine a person carrying out actions such as drawing a building, buying wood and nails, and cutting a board. What activity is this person engaged in? In other words, what is the *minimal* context required to understand these actions? Perhaps the person is building a garage. If we consider some of the person's other actions, such as buying a car and changing its oil, "building a garage" is not sufficient context to understand this action. The minimal context

[#]Other classes of mediating artifacts, such as language, are often included in AT, but are not considered here.

required to understand this larger collection of actions might be an activity such as obtaining transportation. Thus, the collection of actions we wish to understand determines the scope of the activity under consideration. Returning to the activity of "building a garage," the object might be plans, nails, and a pile of wood, which, through the activity of building the garage, is transformed into a building (the outcome). The mediating role of tools becomes clear if you imagine how the activity of building the garage would be different with a nail gun, with a hammer, or without any kind of hammer.

To give an example from a physics classroom, students may be subjects engaged in Peer Instruction (the activity). Their object is understanding of the relevant physics concept and the (hoped for) outcome is improved understanding of those concepts. In this example, mediating tools might include clickers or flashcards, as well as a projector and screen.

The subject-object relationship is not sufficient to describe human activity, however. AT locates the subject within a community of people sharing the same object. The subject's actions are shaped by participation in the community. In the Peer Instruction example, the community includes the students and instructor. *Rules* prescribe how the subject and community should go about the activity. Rules may be explicit (such as a grading policy) or implicit (such as a classroom norm that no one else talks when the instructor is speaking). During the activity, a *division of labor* describes the actual roles of the participants. For instance, in Peer Instruction, the instructor poses the question and the students discuss and answer it. Thus, an activity system is constituted by a subject acting in a community in relation to an object; the interactions between subject, object, and community are mediated by tools, rules, and a division of labor. These relationships are often represented schematically as in Figure 1.

PRIOR RESULTS

A recent study [4] compared the learning gains between two concurrent semester-long mechanics classes. Both groups were taught using Peer Instruction by the same instructor. However, in responding to in-class ConcepTests, students used clickers in the first group and flashcards in the second group. The two treatments were found to be equivalent in terms of student learning: both groups had sizable learning gains, and no significant difference was found between the clicker and the flashcard groups. However, the study also noted a number differences between clickers and flashcards with respect to teaching, including, "the ability to archive student responses, the appeal of technology, and institutional expense." The paper thus concludes, "The pedagogy is not the technology by itself."

AN ACTIVITY THEORY LOOK AT CLICKERS AND FLASHCARDS

In this paper, we adopt an AT approach to understanding Peer Instruction, comparing how the activity is constituted with clickers or flashcards. We first consider the student's perspective and then the instructor's perspective on the activity, in an effort to interpret the results from reference 4 described above.

Student Perspective

Taking the student as the subject, Peer Instruction can be represented as in Figure 1. Here, the student participates in a community consisting of other students and the instructor. The activity is motivated by the student's effort to understand physics concepts. Both clickers and flashcards allow students to respond to questions and the instructor to observe the distribution of responses. With either clickers or flashcards, the most important rules are the PI protocol. The rules may also include a class norm that participation is important. Labor is divided between the instructor, who poses the question and determines the flow of the course, and the students, who consider the question, respond, and discuss. In sum, the activity has the same essential features with either tool, suggesting that similar outcomes should result. This is consistent with the student learning outcomes found in reference 4.

Despite their essential similarities, there are important differences between clickers and flashcards. Clickers quickly and accurately collect students' responses, automate public sharing of the results, and preserve a record for grading or future reference. The clicker software usually allows the instructor to preview the results as students respond, compare responses before and after discussion, automatically

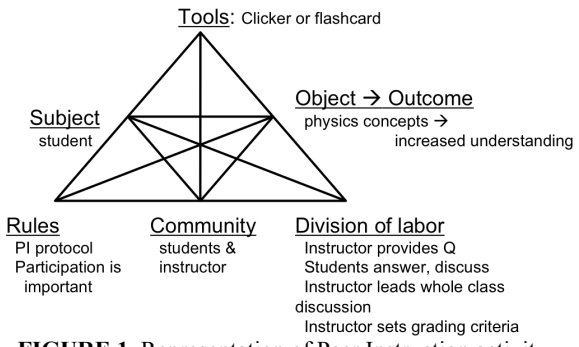

FIGURE 1. Representation of Peer Instruction activity.

time questions, and choose a student to call on. Furthermore, the act of answering with a clicker is private (not visible to other students or the instructor during class), while an individual student's response is visible with flashcards.

AT suggests that, given the differences in the tools' affordances*, we may find differences in other aspects of the Peer Instruction activity depending on the tool used. For instance, with clickers the instructor can easily give points for participation. This may reinforce the norm that participation is important. The instructor may also award points based on whether students' answers are correct, which may support a norm that the answer is more important than the solution. This could affect the way students approach and discuss the question, which may undermine the instructor's goals [11]. As a second example, differences in the process of answering – clicking a button versus holding up a card – may impact class norms regarding participation is a low-risk activity. This could affect students' willingness to commit to a response they think might be wrong. Other differences between clickers and flashcards, described in the previous paragraph, may also have consequences for the activity.

This analysis is not meant to enumerate consequences that will flow deterministically from the choice of tool. Rather, the value of this analysis is that it provides a structured means of analyzing an existing situation, or exploring possible impacts different tools may have on the activity. This type of analysis can guide instructors, researchers, and curriculum designers to ensure that the activity meets their goals by choosing or modifying the tools, rules, or division of labor. For instance, an instructor concerned with students' comfort in participating might provide all-white flashcards rather than color-coded ones.

Instructor Perspective

For the instructor, Peer Instruction takes place within the larger context of teaching physics class. The information obtained during Peer Instruction can help the instructor structure or modify the course to yield improved student learning outcomes. The instructor is engaged in this activity over multiple timescales - from day to day or from semester to semester. Figure 2 represents this activity from the instructor's perspective. Both clickers and flashcards allow the instructor to carry out the Peer Instruction protocol during class and thereby obtain information on student thinking. However, the clickers' ability to preserve a record of student responses enables new possible actions by the instructor. Of course, other tools such as exams, homework, and discussions with students are also important in this activity.

While teaching, the instructor continually makes decisions about how to conduct the course: when to cover or skip a topic, what homework to assign, whether to review a concept, how to approach teaching a topic. The set of guidelines on how to make these decisions (perhaps implicit), constitute the rules by which the instructor engages in this activity. The things the instructor does to improve the course constitute the division of labor. The particular actions the instructor engages in are largely dependent on his or her assessment of student understanding. Clearly, accurate and timely information on student understanding should result in more effective actions. Both clickers and flashcards provide this type of feedback during class, which allows the instructor to adjust instruction accordingly. But, the record generated with clickers facilitates decision-making after class is over. For instance, if on reviewing student responses after class, an instructor finds that students need more practice on a topic, he or she may decide to assign additional homework. The record is even more useful when considering changes to future courses, allowing the instructor to adopt a data-driven approach to questions such as: Should a topic be approached differently? Did students understand the concept in the time spent? Is a concept question worth including?

We note that it is *possible* for an instructor to make a record of students' responses with flashcards. However, this would certainly be more time consuming and less accurate than the record provided by clickers. Again, we do not present tools as deterministic. Rather, the ease with which clickers record evidence of student thinking makes it easier for an instructor to make data-driven decisions outside of class. Furthermore, because it is easier to reflect on the results with clickers, they may increase the likelihood of change in an instructor's views about teaching, learning, and the effectiveness of instructional modes.

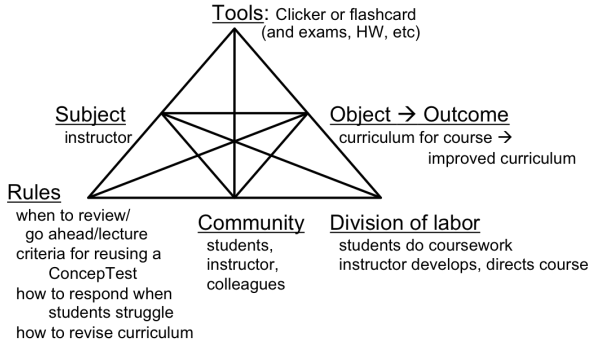

FIGURE 2. Teaching a course with Peer Instruction

* Following Norman, we use affordances in the sense of "perceived affordances" to mean "the perceived and actual properties of the thing… that determine just how the thing could possibly be used [10]."

Research Community Perspective

Peer instruction also plays a role in physics education research as a means of data collection [12]. Thus, we can perform an AT analysis at a yet larger scale: the activity of physics education researchers investigating student learning through Peer Instruction. This analysis suggests that the affordances of the clickers, as a tool, combined with constraints on time and funding (which lead to rules such as "conduct cost effective research") make investigations featuring student responses to in-class questions more likely than lines of investigation involving, *e.g.*, student interviews.

DISCUSSION

AT provides a structured framework for understanding a null result between clickers and flashcards with respect to student learning outcomes [4]. Moreover, it also helps us catalog possible differences in other aspects of the classroom, such as norms governing behavior, which may not be accessed by pre/post evaluation. An AT analysis can thus point to unintended outcomes associated with the adoption of new tools, and guide efforts to sustain/create desired features of classroom practice.

AT also provides a means of considering the multiple layers of context in which an activity resides. In this example, Peer Instruction appears in over-lapping activities, from student learning to curriculum improvement to research on student learning. The choice of tool may affect those activities in different ways. At the level of student learning, both tools may effectively support the activity (Peer Instruction), but clickers may better facilitate curriculum improvement. This is consistent with observations of a difference between clickers and flashcards from a teaching perspective [4]. Finally, clickers make feasible a form of classroom research that flashcards cannot.

The fact that AT provides a structured, comprehensive framework that includes tools, the social nature of activity, and the interactions between these aspects, suggests that it would be very useful in analyzing any situation where one educational tool replaces another, eg, tablet PCs replacing paper lab notebooks [3]. Lastly, while we have focused on using AT to compare technological tools, it is a powerful framework for analyzing other instructional settings of interest to PER. For instance, AT may help the PER community tackle problems such as understanding students' frustration in an innovative curriculum, effective curriculum development, and the difficulties of secondary implementations.

CONCLUSION

In this paper we used AT to compare Peer Instruction implemented with flashcards or clickers. We find that AT helps clarify the differences and similarities between clickers and flashcards. It also provides a way to explore effects in activities beyond the immediate student participation in Peer Instruction. Finally, we expect that AT can be a useful approach for a broad range of issues in physics education research.

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