

Complex Interactions Between Formative Assessment, Technology, And Classroom Practices

Edward Price

Physics Department, California State University, San Marcos, CA 92096

Abstract. Interactive engagement (IE) methods provide instructors with evidence of student thinking that can guide instructional decisions across a range of timescales: facilitating an activity, determining the flow of activities, or modifying the curriculum. Thus, from the instructor's perspective, IE activities can function as formative assessments. As a practical matter, the ability to utilize this potential depends on how the activities are implemented. This paper describes different tools for small group problem solving, including whiteboards, Tablet PCs, digital cameras, and photo-sharing websites. These tools provide the instructor with varying levels of access to student work during and after class, and therefore provide a range of support for formative assessment. Furthermore, the tools differ in physical size, ease of use, and the roles for students and instructor. These differences lead to complex, often surprising interactions with classroom practices.

Keywords: Formative assessment, educational technology, activity theory

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INTRODUCTION

This paper discusses formative assessment in relation to interactive engagement activities in physics. Understanding the implementation of such activities requires considering the tools available, classroom norms, and the roles of students and instructor. I will present examples showing how these features interact in complex ways and can lead to surprising outcomes.

Formative Assessment

Formative assessment (FA) is widely discussed in the broader education community, but is less prominent in physics education and physics education research. Black and Wiliam describe FA as "activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged [1]." Based on a literature review, Black and Wiliam find that "formative assessment can lead to significant learning gains." FA is often informal and ongoing. In contrast, summative assessment is intended to measure the results of learning.

Evidence of student thinking and feedback (from instructor or peers) are key aspects of FA. To be effective, feedback must inform actions by the instructor or students. During FA, the instructor draws on her pedagogical content knowledge to recognize and respond to students' thinking. An important goal in FA is for students to develop the ability to self-assess. Students' affective response to feedback can influence its effectiveness, with feedback emphasizing

learning goals having greater learning gains than feedback focused on self-esteem [2].

With its emphasis on evidence of student thinking and feedback, FA is closely aligned with Hake's description of "interactive engagement [IE] of students in heads-on/hands-on activities which yield immediate feedback through discussion with peers and/or instructors [3]." Indeed, IE activities, including in class activities such as Peer Instruction, Interactive Lecture Demonstrations, group work, or tutorials, can take on a FA function. For instance, using clickers for in-class questions provides a mechanism for learning about student thinking (by instructor and students). Students' responses can then become the basis for discussion (with instructor or peers) providing the opportunity for students to revise their thinking. The following sections further explore features of this example and how it can serve as a FA activity.

Tools

To better understand the use of in-class questions with clickers, it is useful to distinguish between technology (or, more broadly, tools) and pedagogy [4-6]. Tools play a mediating role in action and shape the likelihood of possible actions. The concept of affordances helps when thinking about tools. Following Norman, I use affordances in the sense of 'perceived affordances' as "the perceived and actual properties of the thing... that determine just how the thing could possibly be used [7]." For instance, a computer-based motion sensor affords the collection and graphing of data, making it easy to create and

investigate graphical representations of motion. Tools also impose constraints. For instance, many clicker remotes only allow one of five responses.

As a tool, clickers allow fast, easy, and private sharing of student responses from all students. Clickers formalize participation through the act of pushing a button and having one's response included in a chart. The chart of student responses provides a referent for discussion, and data is saved for review, grading, or research. With familiarity, the technology fades into the background and becomes automatic.

Thus, clickers can help facilitate FA by collecting and displaying evidence of student thinking and providing an opportunity for discussion and revision of thinking. The extent to which this happens depends on how the clickers are used; common pedagogies include reading quizzes, conceptual questions, Peer Instruction [8], question sequences [9], and question driven instruction [4]. Furthermore, though I distinguish tools and pedagogy, they are linked and interact in complex ways.

Norms

The tools and pedagogical activity (e.g., clickers and Peer Instruction) alone do not determine the opportunity for FA. Classroom norms are important as well. Examples of norms include "students should make sense of ideas," and "students are responsible for generating and evaluating ideas." Instructor practices, such as grading policies and how discussions are conducted, affect student behaviors and so contribute to norms [10,11]. These norms have implications for feedback and its impact on student thinking, and hence implications for the activity as FA. For instance, encouraging student-student discussion supports a norm that students are responsible for generating and evaluating ideas.

The Classroom's Complexity

The preceding discussion indicates the complexity of the classroom. Activity theory (AT) provides a useful framework for considering such situations [12-15]. AT locates a subject (such as a physics student) within a community of people (other students, the instructor) sharing the same object (learning a physics concept). The subject's actions are shaped by participation in the community and mediating tools. Rules and norms (implicit and explicit) prescribe how to go about the activity, answering the question "How do things work here?" Roles, or a division of labor, describe who does what. These elements of the activity system all interact in a complex way.

In Peer Instruction, mediating tools might include clickers or flashcards, as well as a projector and screen. 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). Roughly, the *division of labor* is for the instructor to pose the question and the students discuss and answer it. To give a more specific example, the division of labor indicates who (instructor or students) definitively identifies the correct answer. The instructor would likely have this role if students were graded for correct responses (a rule). Of course, grading for correctness is only feasible with clickers (a tool).

APPLICATIONS

The preceding discussion explored formative assessment, the technology-pedagogy distinction, tools, norms, and activity theory. This section applies those ideas to the introduction of new tools to a stable classroom setting.

Setting And Background

At CSU San Marcos we offer calculus-based intro physics courses for students in the biological sciences [16]. These classes meet twice weekly for a total of six hours. Working in groups, students respond to prompts and record their work on 2'x 3' whiteboards. They then explain their responses to their peers in a whole class discussion. The instructor facilitates these discussions, but students are expected to lead, evaluate the solutions, and make corrections as needed. The instructor lectures for a total of about 75 minutes per week, mainly to help organize the ideas encountered in the group activities. Though students receive summary notes for each block of activities, there is no formal textbook for the course. Students' work on in-class activities thus constitutes an important resource.

The in-class activities in this course are formative assessment opportunities. The whiteboards and small group and whole class discussions provide evidence of student thinking that is available to peers and instructor. Students give and receive peer feedback in small groups and whole class discussions, and the instructor also provides feedback while facilitating group work and whole class discussions. This feedback can lead to changes in students' thinking as they work together in their small groups to prepare a response, and as they present to the whole class.

The whiteboards are an invaluable tool in these courses. They provide an inexpensive workspace where students can quickly create written explanations, graphs, diagrams, and equations. With whiteboards, however, materials created during class

are normally lost or unavailable once class is over. This volatility is a serious shortcoming in courses with so much emphasis on student-generated work. To address this, we introduced Tablet PCs and Ubiquitous Presenter (UP) as an alternative to whiteboards. With a Tablet PC, students can use a stylus to “write” on the screen, making it ideal for quickly creating visual or symbolic material in an informal setting. UP is a Tablet PC-based system developed at the University of California, San Diego [17]. With UP, students access workspace through a web interface and use ink or text to create a response. In this way, a Tablet PC essentially becomes a digital whiteboard connected to the instructor via the web. At any time, students can send their work to the instructor, who can preview, project, and annotate submissions from any of the groups in the class. Furthermore, the instructor can create and write on blank slides, thereby using the system to lecture. Finally, all student submissions, instructor slides, and added ink are automatically archived stroke by stroke and can be reviewed via the web interface.

To investigate the impact of these new tools, we conducted a case study where students in two course sections used either whiteboards or Tablet PCs. Both sections spent equal time with each tool. Data sources included classroom observations, instructor reflective notes, student interviews and surveys, students’ in-class work, and server access logs.

Projecting Student Work During Whole Class Discussions

Projecting students’ work during whole class discussions was highly effective. The projected display was approximately 7’x 5’ while the whiteboards were 3’x 2’. Students were also able to modify their work during whole class discussions by writing on the instructor’s tablet. Figure 1 shows students’ responses to an end of semester survey. The majority of students responded that it was easier to see other students’ presentations and during their own presentations to refer to and modify their work. In terms of FA, this is significant in a course where students are expected to provide feedback to peers.

Initially, however, the whole class discussions were less productive. With UP, the instructor tablet controls what is projected and only the instructor tablet can be used to annotate solutions. In this course, the instructor usually sits in the back of the classroom while the students present (to support a student-driven discussion). During pilot testing for this study, the instructor sat in the back with his tablet, selected the students’ slide, and asked that group to present their work. When an issue arose that required modifying the

solution, the instructor made the changes. In essence, the instructor was now correcting the group’s work in front of the whole class. This led to a shift away from a student-driven discussion.

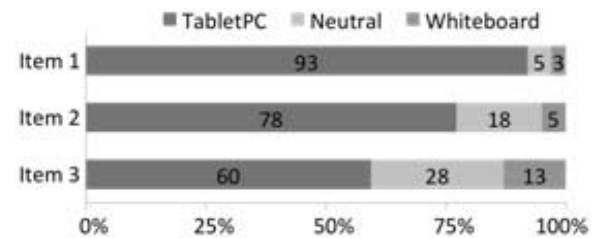


FIGURE 1. Students’ responses to an end of semester survey. Items were: (1) Which mode was most useful, in general, for viewing other students’ presentations? (2) Which tool best facilitated referring to your solution while presenting to the class? (3) Which tool best facilitated modifying your solution while presenting to the class?

After reviewing the incident, the instructor developed a new procedure: he would leave his Tablet PC at the front of the room, hand the pen to the students, and encourage them to annotate their work. This solution worked well, as indicated by Figure 1 and comments in the instructor’s reflective notes. The instructor created a new norm, mediated by a tool (the pen), which reorganized the roles and placed the students in control of the presentation.

Why was this solution not implemented originally? First, there was a lack of physical continuity; in contrast, with whiteboards, students carry their board to front and present. Second, only the instructor’s Tablet PC can make annotations to the presented work. This is because UP was designed for lecturing, where one person (instructor) controls the presentation. This is a way that tools shape what we do... tools carry the intent of the designer. Third, it was natural for the instructor to hold onto ‘his’ tablet (a rule or norm).

Small Group Collaboration

The Tablet PCs were physically smaller than the whiteboards they replaced, and this impacted the group work. Based on student survey responses, interviews, classroom observations, and instructor reflective notes, with the Tablet PCs collaboration became more difficult, and it became more difficult for the instructor to monitor the groups. There were implications for the whole class discussions, including more instances of a single student explaining the groups’ work to the whole class and groups presenting work that needed substantial correction during whole class discussion. These changes clearly diminish the opportunity for FA in these activities.

Archiving Student Work

An important feature of the UP system is the automatic creation of a web-based archive of students' work. As reported elsewhere, students described this resource as valuable and heavily accessed the materials to review for quizzes and to do homework [18]. Notably, students viewed considerable numbers of student-generated pages (as distinct from slides created by the instructor while lecturing, which were also available for viewing). This is consistent with the importance of student work in this course.

Whiteboards, Again, With Photos

In subsequent semesters, we began taking digital photographs of students' whiteboards and uploading the images to the photo-sharing website Flickr.com [19]. This preserved student work while also maintaining the collaborative space provided by whiteboards. Students' use of and views on the photo archive were similar to those of previous students using Tablet PCs.

The introduction of this practice led to interesting and unexpected consequences. Before photos and Flickr were used, only whiteboards presented during whole class discussions were edited. Even though the instructor commented on the other students' work, there was little motivation to edit the whiteboards since they would be erased when the class moved on to a new topic. During the semester when photos were being taken, students began to edit whiteboards in class so that the photo captured a correct solution. In this way, photographing the whiteboards motivated a final round of instructor feedback and student revision.

This outcome was reorganized by the tools (specifically the timing and mechanism of capturing the image) but originated from the students, motivated by their role in the class (being responsible for creating and understanding solutions to in-class problems). This final round of feedback and revision provides a valuable opportunity to support FA.

CONCLUSIONS

FA and IE share an emphasis on feedback in response to evidence of student thinking. Complex classroom activities, including those with a formative assessment role, require a rich description like that provided by activity theory. By considering the roles of instructor and students, rules and classroom norms, and tools, we can better understand and create the conditions for FA and hence promote learning.

The approach described here has several broader applications. First, it can help fill in pre-post

assessment studies with a process-oriented description of the classroom. Second, the sensitivity of the classroom environment to the introduction of different tools has implications for dissemination of curricula. Finally, explicit attention to tools and the social context in which they are used can aid in the design and improvement of tools for the classroom.

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