Technology-Mediated Teacher Noticing: A Goal for Classroom Practice, Tool Design, and Professional Development

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Abstract: We introduce *technology-mediated teacher noticing* (TMTN): a vision for the design and use of technology-mediated tools that takes seriously the need for teachers to attend to, interpret, and respond to their students' thinking. This vision is situated at the intersection of research on teacher noticing, and on technology to support student thinking. We synthesize that work to highlight specific ways that technology-mediated classroom tools can focus and stabilize teachers' attention on valuable aspects of student thinking emphasized by current reform efforts. We then illustrate TMTN with classroom examples in which technology supported or obstructed teachers' attention to student thinking, and consider implications for research on technology in teacher practice, professional development, and the design of technological tools for K-12 classrooms.

Objectives

Educational technology has exploded over the past few decades, and many tools have been created to help students think deeply about disciplinary concepts. In many cases these tools have been shown to further student learning, conceptual understanding, efficacy and affect, and motivation. In short, if used productively within a broader classroom culture of inquiry these tools have the power to transform student learning.

Educators often argue that curricular materials are created for teachers as much as for students (e.g., Ball & Cohen, 1996). Yet this idea has not carried over to discussions of technological tools for classroom use. While some research has looked at how such tools can reveal and support student thinking in a given domain, the primary focus has been the students' experience. The teacher's contribution to student learning within such environments is often treated as an afterthought. More research is needed that explores teachers' role in facilitating student learning while using technologically mediated tools, especially in specific content domains; and more attention is needed in educational technology *design* to supporting teachers in noticing, attending, and responding to core disciplinary aspects of students' thinking.

Much work that explores teachers' use of technology (e.g. Mishra & Koehler, 2006) focuses on teachers' use, non-use, or competency with technology in general, or their beliefs about how and when to use technology. Other work explores how teachers design or modify curricula based on feedback from systems (e.g. Kali, McKenney, & Sagy, 2015). However, this focuses on evaluation—whether students answer correctly—and backgrounds the substance of student thinking, which can include productive ideas on which teachers can help students build. In contrast, we are interested in exploring how teachers can use technology-mediated tools to notice new and different aspects of their students' thinking in ways consistent with reform efforts and standards—for example, by supporting teachers' attention to reasoning about mechanism in science (NGSS, 2013), or pattern in mathematics (CCSS-M, 2010). In this paper, using classroom data for illustration, we argue that (i) designers and researchers of educational technology have not foregrounded supporting or studying the teachers' noticing of substance of student thinking as mediated by technological tools, but (ii) such *technology-mediated teacher noticing* (TMTN) should play a role in teacher professional development, research on classroom teaching, and the design of technological tools for classroom use.

Related work

In mathematics and science instruction, teacher noticing of the disciplinary substance of student thinking is critical for student learning (Schifter, 1998; Franke, Carpenter, Levi, Fennema, 2001; Carpenter, Fennema, Peterson, Chiang & Loef, 1989). Therefore, both teacher professional development and curricular design have aimed to support teacher noticing (Sherin & van Es, 2009). However, teacher noticing has yet to influence the design, study, and implementation of technological tools in the classroom. Here, we briefly review the literature on teacher noticing/teacher responsiveness, and on the design and use of technological tools to support student thinking. Then we investigate the intersection of these two literatures, to situate and inform our notion of technology-mediated teacher noticing.

Teacher noticing and responsiveness

A growing literature focuses on teachers' noticing of, attention to, and responses to the substance of student thinking (Sherin, Jacobs, & Philipp, 2011). In math and science, researchers and professional developers generally value noticing/attention that seeks to interpret rather than just evaluate students' ideas, and that attends to details of individual students' ideas rather than just general abstractions of "what the class was thinking." However, the seeds of productive disciplinary thinking that teachers can notice and nurture vary by discipline, e.g., productive intuitions about motion and causal reasoning in physical science; precursors to the concept of "variable;" and generalizing patterns from instances in algebra. Partly for this reason, both research and professional development focused on teacher noticing has generally been discipline- and even sub-discipline-specific (e.g., Star & Strickland, 2008). By contrast, work focused on teachers' use of technology explores teachers' general use of technology, not attending to the disciplinary context of its use (Voogt, Fisser, Pareja Roblin, Tondeur & van Braak, 2013).

Existing tools that focus on student thinking or on teachers' tracking of student progress

A number of tools exist that allow teachers to analyze their students' performance and reflect on curricular and instructional interventions (Rich & Hannafin, 2009). Dashboards and ambient displays provide visualizations of student progress on activities (Clarke & Dede, 2009; Phillips & Popovic, 2012), and help teachers determine where to direct help (Alavi & Dillenbourg, 2012; Börner, Kalz, & Specht, 2011; Slotta, Tissenbaum, & Lui, 2013). Some environments use data mining and analysis to lend insight into student competencies and needs (Gobert, Sao Pedro, Raziuddin, & Baker, 2013), or to guide teachers in assessing student knowledge (mCLASS; Amplify, n.d.). Other technology-mediated tools for classroom use offer supports to guide teachers' attention to student learning (Williams, Linn, Ammon & Gearhart, 2004), and provide data on student performance to inform the adaptation of curriculum (Matuk, Linn, & Eylon, 2015). Though useful for tracking student progress toward correct understandings, these tools do not focus on highlighting the disciplinary substance of individual students' thinking.

Other tools, designed with student users in mind, are intended to amplify reasoning and make thinking visible to peers and researchers. Interactive galleries and collaborative tools allow students to share and build upon one another's work (Scardamalia & Bereiter, 1994). Interactive mathematics environments and scientific modeling tools provide students with new representational systems and modes of interaction for expressing and exploring ideas (e.g. SimCalc; Geogebra; Boxer; NetLogo; a long tradition of research has modeled student reasoning with such tools; Williams, Linn, Ammon, & Gearhart, 2004; diSessa 2001; Papert, 1980; Simpson, Noss & Hoyles, 2005). However, the majority of such work has focused on *student* knowledge and interactions, rather than on teacher practice.

Our interest in *technology-mediated teacher noticing* contributes to this existing work a complementary view of what counts as "successful use" of such technologies by teachers. For most teacher-directed tools, success is marked by successful implementation or improved student performance on activities. For student-directed tools, it is deep engagement with discipline-specific content and practices. What we are interested in is active teacher engagement, within the context of planned classroom activity, to those disciplinary aspects of student thinking that are amplified and made available for observation through the use of technology-mediated tools.

Theoretical framework and driving questions

We argue there is untapped opportunity for technology to mediate teacher noticing in the classroom. Technology-mediated tools are increasingly a part of classroom practice, and can make student thinking visible by "...afford[ing] a view of the meaning-making process… a screen on which learners can express their thinking... the chance to glimpse the traces of their thought" (Noss & Hoyles, 1996, p. 6). Furthermore, the *types* of student thinking expressed in these media often reflect those that are emphasized by current educational reforms (Table 1) but that teachers often do not elicit and build upon. While technology is not a prerequisite for supporting these types of reasoning, research has shown that certain tools can foreground, stabilize, and highlight them.

Table 1: Examples of technology-mediated tools that emphasize disciplinary thinking in mathematics and science.

Aspect of Reasoning	Example & Related Research	Tools	Connection to Reform Efforts
Dynamicity	Students notice invariant relationships in a geometric construction and work to describe and explain it. (Jones, 2000; Mor et al., 2006)	Geogebra	CCSS-M "Look for and make use of structure"
Use of Linked Representations	Students coordinate information displayed across linked tables, graphs, algebraic expressions, and other representations to confirm/explore their understanding of a relationship. (Smith, diSessa, Roschelle, 1994; Hegedus & Kaput, 2003)	SimCalc, MiGen	NCTM "Select, apply, and translate among mathematical representations to solve problems"
Emphasis on Mechanism	*provided in Evidence & Analysis section below* (Blikstein & Wilensky, 2009; Sherin, 2001; Wilensky & Reisman, 2006)	NetLogo, Scratch	NGSS "Constructing explanations"
Exploration of Complex Systems	Students conduct investigations of varying systematicity within simulation environments (Hmelo-Silver, Liu, Gray & Jordan, 2014; Jackson, Stratford, Krajcik & Soloway, 1994; Sao Pedro, Gobert, & Betts, 2014)	WISE, PhET	NGSS "Planning and Carrying Out Investigations"

Attending to technology-mediated forms of teacher noticing yields many questions ripe for exploration. For instance, what are features of technology-mediated tools that draw teachers' attention to specific disciplinary aspects of student thinking important for a given domain of study? How can teachers learn to look for key student thinking practices, such as those outlined in the CCSS-M or NGSS, through the lens of technology-mediated student work? What are mechanisms that can be embedded in technology to allow aspects of student thinking, that otherwise might be hidden, to rise to the forefront?

Evidence and analysis

Here we present two vignettes that exemplify productive and unproductive instances of TMTN, to illustrate its relevance for research, professional development, and technology design. The first episode comes from a whole-group discussion in a fifth grade science class in an urban rim public school. The school serves a diversity of students with respect to socioeconomic background, ethnicity, and special education status, and the school's demographics were roughly represented in the classroom from which these vignettes come. The classroom teacher had attended a teacher certification program that was explicitly focused on noticing and responding to student thinking. Students had worked in small groups to create animations and simulations of evaporation. They were now sharing and critiquing their work. In the excerpt below, the classroom teacher encourages students to describe specific computational rules they used in their simulation, and what those rules represent about evaporation as a scientific phenomenon. He connects those rules and interpretations to conversations he observed among student groups earlier during the activity.

Teacher What do we think guys? What do we think about this, this simulation, this representation of it? Sheree?

Sheree I think it represents when the sun evaporates the water, um the clouds they start to make new ones because of the water vapor.

Edgar I think it represents because the water droplets are going up, and then the clouds are getting bigger and bigger because all the water's up, then when it gets full it [gestures down].

Teacher Ok, and that's the next step if this simulation were to keep going it would probably show that.

Miles I think it's just like the water droplets are going up, and then it's just gonna get bigger and bigger and then it's gonna like start getting ready to-

Alan	I think they're trying to represent that the water vapor forms new clouds, like more clouds.
Teacher	I'm even seeing something, I'm trying to remember if this came up in this class or the other class, like, when there's evaporation, and it goes into the air, does it form its own new clouds, or does it add on to the clouds that are already here? So it seems, from what we see here it seems to be adding on to clouds that are already there. That idea was kind of floating around in this room too.

In this excerpt, available functions within the simulation environment such as changing the size of an object or cloning an object focused both teachers' and students' attention on describing potential mechanisms within the represented scientific system (clouds "get bigger" when "full" with water, versus water vapor "forming" clouds by "making more"). These functions lent a shared language to the activity, and allowed the teacher to highlight and connect different student ideas about mechanism.

Our second episode features a small group of students working with the same teacher and tool, this time earlier during the unit to build their simulation of evaporation. However, this time the constraints of the tool blunted conversations about mechanism, focusing the teachers' attention on *what was possible to represent* in the simulation rather than students' ideas about evaporation.

Ryan	Then when it [water droplet] hits it [cloud], the clouds are gonna like get bigger.
Teacher	Oh wait sorry, say that again Ryan?
Ryan	When it hits is, um, it's gonna get bigger
Teacher	When it hits the cloud, the cloud should get bigger?
Ryan	Yea. I don't know if we can do that
Teacher	Yea, that might be, so let's think what's uh
Luis	No, like when it gets like when it touches the cloud the water droplets like go away.
Teacher	So they should disappear?
Luis	[Nods]
Teacher	So what commands, or sorry what rules do we have to give to this water droplet to have it disappear the way you want it to?

In this case, the teacher's preoccupation with which commands were available to use in the software impeded his noticing and drawing out students' conceptual ideas (clouds "containing" water and droplets being "absorbed" or going away).

We emphasize here that what the teacher is attending to is manifested in the moment and through the technological media. In the first case, the media help make evident the persistence and development of student ideas over time. In the second, noticing of student thinking is obstructed, in favor of attention to practical constraints within the software. In both cases, the teacher must interpret student thinking as mediated by the available tools, and choose what aspects of that thinking to elaborate and act upon.

Scholarly significance

The work started in this paper helps shed light on the ways technologically-mediated tools can foreground or background student thinking. Moving forward, we will continue to explore cases that help us understand what features of these tools help expose student ideas to teachers and help teachers make sense of these ideas. Ultimately this insight will help inform the development of professional development, classroom tools, and research methods that can support teaching practice in technology-rich spaces.

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