Interactive Representations of Student Activity to Inform Teacher Collaborations: Results from a Formative Exploration

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Abstract: We describe a student activity visualization tool that we constructed to provide a context for ethnomethodological inquiry -- a design-based breach experiment (Crabtree et al, 2004) -- into how teachers might think and communicate about student thinking when they have tools that give them better access to student activity. We use the Learning to Notice framework (van Es & Sherin, 2008) to characterize the kinds of activity that occurred when teachers used the tools in a team meeting. Then, we show how theses uses suggest ways that research on and uses of student activity representations may need to be sensitive to how contexts of implementation shape the consumption and use of those representations.

Objective

Researchers in CSCL, educational data mining, games for learning, CSCW, and HCI more broadly are working to develop manual and automatic techniques for characterizing and classifying patterns, including patterns over time, in users' collaborative and individual interactions with computer-based media (Reimann, 2009). Suthers and colleagues are developing a methodology, and supporting tools, for analyzing logs of online activity in order to discover patterns in uses of on-screen representations that span multiple participants (Suthers et al., 2010; Medina & Suthers, 2008). Shute et al. (2009) describes how the play of educational games may be scrutinized to create psychometrically valid assessments of learning and understanding that may be embedded in-game. Bit by bit, CSCL and its cognate fields are developing the methodological tools to produce precisely the kind of accounts of student activity that could support breakthroughs in the responsiveness of instructional environments (Fullan et al., 2006). But very few efforts have been made to actually construct systems that would assist *teachers* in understanding their students' activity and learning in CSCL environments. Rare exceptions include Feng and Heffernan (2006)'s ASSISTment project, which explores how students' interactions with an intelligent tutoring system may be summarized in order to help teachers to know what students know and Summary Street, which provides teachers and students with feedback about the quality of students' text comprehension and summary writing (Wade-Stein & Kintsch, 2004).

Because of this, very little progress has been made toward figuring out how practitioners (teachers or students) will use computer-generated accounts of student activity (and what the challenges to doing so will be) once the difficult methodological challenges of constructing them have been sufficiently overcome. We do not believe that research into the application of representations of student activity and learning to improving teaching must wait until methods for generating valid and reliable accounts of activity and learning are established. Instead, we propose that CSCL should deepen its inquiry into how representations of students' activity may be used in schools even as it figures out how to create those representations. Indeed, research on how such accounts could be used, including the diverse ways in which different teachers might interpret different representations or in which different backgrounds or classroom contexts might shape their interpretation may be quite valuable in shaping the learning analytic program by helping researchers within it to focus their efforts on techniques that might have the largest impact on practice.

This paper describes the beginnings of an attempt to do just that. We describe a student activity visualization that we constructed to provide a context for ethnomethodological inquiry -- a design-based breach experiment (Crabtree et al, 2004) -- into how teachers might think and communicate about student thinking when they have tools that give them better access to student activity. We describe our results in two parts: first, we use the Learning to Notice framework (van Es & Sherin, 2008) to establish whether our tool provides enough stimulus to the existing context of work to make activity occur that is consistent with a leading theory of teacher learning. Then, we show how the uses of our tool in teachers' collaborative practice suggest ways that research on student activity analysis representation construction and uses of new representations in practice may need to be sensitive to how contexts of implementation shape the consumption and use of those representations.

Theoretical Framework

Teaching is a socially complex dynamic of data-rich interactions between teachers, students, and content, mediated by classroom materials. What teachers choose to focus on with respect to their

instruction, their classroom environment, and student understanding has a powerful influence on what they understand about their classrooms (Sherin & van Es, 2003). Teacher noticing is simultaneously a process of directing attention to certain features of instruction as well as a sense-making activity that connects what one notices to larger principles of action. Collaborative practices that improve teachers' capacity to notice student thinking in classroom activity can also develop common professional vision (Goodwin, 1992) amongst teams of teachers (an important ingredient in improving instruction in schools) as well as make teaching practices more public amongst faculties. In order to understand teacher noticing, Sherin & van Es have proposed a framework for Learning to Notice (2002). Within this framework, the skill of noticing consists of (van Es & Sherin, 2008):

- Identifying what is important in a teaching situation;
- Making connections between specific events and broader phenomena in teaching and learning.
- Using what one knows about the context to reason about a situation;

While the framework has been developed within the context of school-based video clubs (Sherin, 2000; Sherin & Han, 2004; van Es & Sherin, 2008), research on teacher noticing has also developed with other techniques such as digital photography and teacher journal writing (Sherin & van Es, 2003). Ultimately, as teachers develop their ability to notice, they are able to reframe their discussions about instructional matters in terms of student thinking (Sherin & Han, 2004). Cross-culturally, the capacity of groups of teachers with diverse perspectives to draw attention to, and make varying interpretations of, a broad range of classroom events is core fixture of Japanese Lesson Study (Lewis, 2000; Fernandez & Yoshida, 2004).

We propose that the learning to notice framework could be a benchmark that the CSCL community uses to gauge the utility of different representations that it constructs about students' learning activities. If an implementation of a new tool does not yield practice that satisfies the Learning to Notice criteria, then some measure of redesign may be necessary before more in-depth analyses of practice are warranted. If, on the other hand, the Learning to Notice criteria are satisfied, then the implementation should offer researchers to opportunity to examine deeply the ways in which the new tools are used to construct meaning about student learning.

To explore this claim, we use the Learning to Notice framework to characterize the kinds of activity that result from the introduction of a data visualization tool that depicts students' literate activities into teachers' work. Specifically, we will show how the activity that resulted from the visualization tool's implementation satisfied the Learning to Notice criteria, then illustrate how particularities of the resulting activity illustrate complexities in teachers' reasoning about student thinking that should guide ongoing design-based research into representational tools for teachers

Context

This design-based research is part of a larger effort to address literacy in the content areas at middle and high schools. The essence of the larger work is to build effective reading-to-learn environments for students and to use these environments to help us understand the reciprocal relationship between content area achievement and reading achievement.

This work took place in an urban suburb of a large Midwestern American city in a school containing K-8 students. The school attracts a diverse group of students from both disadvantaged and extremely affluent families. In particular, this paper will focus on one group of sixth grade teachers over the course of the first year of technical assistance involvement. After listening to a presentation on literacy in the content areas for the whole district, this team of teachers self-selected for participation in the project, and their principal agreed to set aside paid, protected time (free of other obligations) for the teachers to participate.

In this group of teachers, Ms. N. teaches mathematics, Mr. C. teaches reading and language arts and Ms. T. teaches social studies and science. They teach three blocks of classes every day, which reach all of the sixth grade students. Each class is taught every day except for science and social studies, which are taught on alternating days. Reading and Language Arts also alternated, although they often blurred together as one block. In addition, up to three researchers facilitated the meetings, Mr. B., Mr. S. and Mr. W. The group met every Friday morning for approximately one hour.

We focus on building reading-to-learn environments that rely on the three strategic approaches to reading support: summarizing, T-Charts and annotating text (Scherer et al., 2008). Summarizing allows students to capture the gist of a chosen text in writing as well as the major concepts and details supporting those concepts. T-charts, also known as double-entry journals, are two or three column charts (like the shape of a T) that provide a structure for students to monitor and document their understanding of texts (Atwell, 1990). Annotation is the process of marking up a text in order to perform content analysis as well as reveal the meaning behind various textual features (Liu, 1996). While these techniques can improve student understanding, no research has examined how the

representations that students produce through the application of these techniques can aid teacher insight into student thinking. The design based research described here was inspired by observations of teacher practice, which revealed that raw student annotation data was too voluminous and complex for teachers to use to drive instructional decision-making. Computer-based data visualization tools could help, but what should they look like? What kinds of teacher practices should they support? The absence of prior practice (both at our implementation site and in the research literature) offers no easy answers, and so we looked to a breach experiment, described in the next section, to find out.

Methods and Data Sources

We conducted a design-based breach experiment (Crabtree, 2004; Garfinkel, 1967) to illuminate the ways in which a team of teachers might use activity representation tools in their practice, and the personal perceptions, beliefs, and expectancies that shape those uses. Breach experiments are violations of the expectations that characterize normal social order, through the overt need they create for participants to restore that normal social order. This induces participants to explain how they think about normally tacit aspects of their lives, including expectations for others, and how the breach transforms or violates those expectations. The point is not to frustrate participants, but to violate their expectations enough that they must actively negotiate with their surroundings to restore normalcy. This is a valuable ethnomethodological tool because it may offer insights into participants' desires, perceptions, and dependencies that are so deep, and so tied to the participant's cultural milieau, that they difficult to interrogate through questioning and observation alone. They are, to use Garfinkel's language, "demonstrations designed as 'aids to a sluggish imagination'…produc[ing} reflections through which the strangeness of an obstinately familiar world can be detected." Crabtree (2004) argues that the introduction of novel technologies to participants' lives can function as breaching experiments, provoking practices and revealing participants' beliefs that could not otherwise be seen and making them available for design reasoning.

The purpose of this design-based breach experiment is to explore the ability of a re-representation of students' literate activity to support teacher noticing and thinking about students' literate thinking in content areas, as well as to use the differing ways in which different teachers react to what the new tools show (or what they see the tools as showing) about their students to illustrate (at least a corner of) the space of reactive possibility to novel representational tools in teachers' practice.

Breaching Tool: Markup

To do so, we created Markup, a prototype tool for students to annotate texts and for teachers to examine students' annotations. While annotation can be a powerful tool for student learning, it is difficult for teachers to use annotations to understand student thinking because the collected annotations (which we conceptualize as external representations of students' thinking) that result from a homework assignment typically contain thousands of data points spread across dozens to hundreds of pages. To assist teachers, Markup's teacher user interface provided three different tools for viewing student work; the most used and discussed representation was the interactive heatmap (see Figure 1). The heatmap was an interactive heatmap, inspired by Hill et al.'s (1992) Edit Wear and Read Wear. The heatmap, as depicted in Figure 1, is simply a complete original text with the text's background shaded to indicate the frequency with which the text there was annotated. Regions that were annotated frequently (number of students who annotated / number of students who did the assignment) glowed red (the more frequent, the bolder the red). A teacher-user could click anywhere on the text to see a table of what each student wrote about the clicked text; this is depicted in Figure 2.

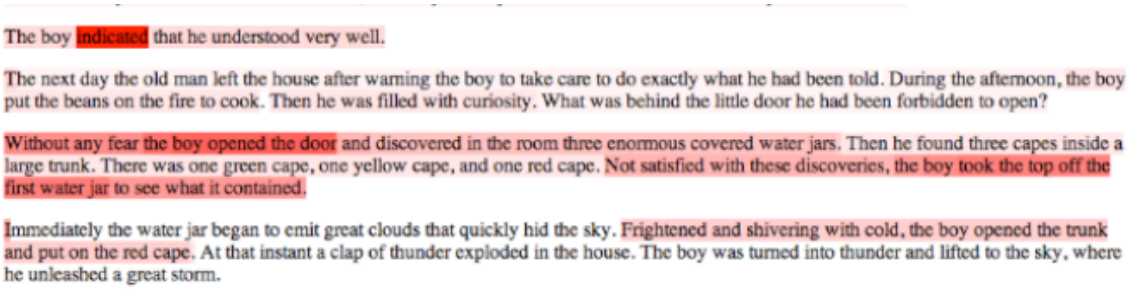
Teachers agreed to use Markup in their classes for about 6 weeks, during which time they reviewed students' annotations in Markup before school on every morning that followed an evening when students were assigned reading with annotation for homework. They also used the tools within a weekly team meeting to present, review, and discuss reading comprehension in each others' classes. We observed the ways in which teachers used the tools to exploratively analyze students' work and the ways that they used the tools to empirically ground discussion in their team meetings.

Because we focus here on teachers' use of the tool in collaboration with each other (and not the work teachers did on their own), data for this paper are drawn from field notes and recordings from the team meetings. The specific data here come from two different team meetings, though many more were recorded and analyzed. These conversations were typical. As participant observers, we gathered observation notes, meeting agendas, and teacher-generated artifacts as well; this heightened our sensitivity to context of the research (Marshall & Rossman, 2006). These data provide thick qualitative descriptions of the teachers' individual and collaborative work. Using the Learning to Notice framework, the data were coded, often fitting into more than one of the Learning to Notice framework categories. The coded data also provided us with counterexamples. Analytic memos were written to

test our conjectures and counterexamples during the analysis process (Maxwell, 1996). These memos were also an opportunity for discovery, orienting and developing new categories of analysis (Strauss, 1987). Two researchers discussed the data in order to increase reliability of the coding, multiple coding and counterexamples.

Results

In the results, we will use excerpts of teacher conversations during team meetings – selected for their illustrativeness – to illustrate how resulting teacher practice corresponded to the dimensions identified by the Learning to Notice framework. These examples indicate that our design-based breach led to new teacher practices. Moreover, these new activities correspond to those that in other interventions have tended to improve teaching outcomes. That is, the results illustrate how new tools may support a richer teacher focus on student thinking. In our discussion, we discuss how the particulars of *how* teachers did so suggest implications for further research into representational tools for teachers.



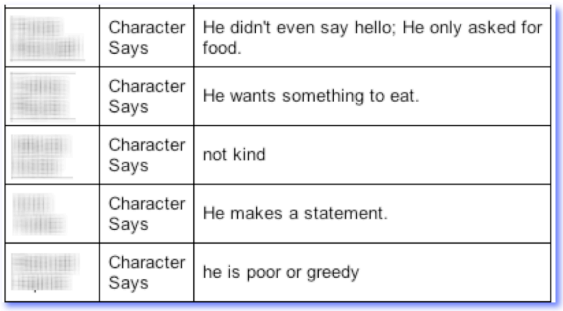
The boy indicated that he understood very well.

The next day the old man left the house after warning the boy to take care to do exactly what he had been told. During the afternoon, the boy put the beans on the fire to cook. Then he was filled with curiosity. What was behind the little door he had been forbidden to open?

Without any fear the boy opened the door and discovered in the room three enormous covered water jars. Then he found three capes inside a large trunk. There was one green cape, one yellow cape, and one red cape. Not satisfied with these discoveries, the boy took the top off the first water jar to see what it contained.

Immediately the water jar began to emit great clouds that quickly hid the sky. Frightened and shivering with cold, the boy opened the trunk and put on the red cape. At that instant a clap of thunder exploded in the house. The boy was turned into thunder and lifted to the sky, where he unleashed a great storm.

Figure 1. The heatmap



[illegible]	Character Says	He didn't even say hello; He only asked for food.
[illegible]	Character Says	He wants something to eat.
[illegible]	Character Says	not kind
[illegible]	Character Says	He makes a statement.
[illegible]	Character Says	he is poor or greedy

Figure 2. Pop-over aggregating students' interpretations of a text passage clicked by the teacher.

Identifying what is important in a teaching situation

Analyzing the transcripts of the group of teachers talking about the student work represented in the heatmap, we notice that the teachers are drawn to the features highlighted in the heatmap. That is, a common point the teachers call out concerns the extent to which students did or did not highlight the text. For example, Mr. C, the literature teacher, stated, "I am already really concerned that, like – why didn't – why did so few of them even do questions? I mean, that was the whole – that was the instruction. I mean, is – how many do you think this is?" He is referring to the disappointing amount of students as a whole class that actually did their homework. It is not surprising that teachers' attention would be drawn to this fact since this is the clearest function of the heatmap. As we note in our discussion, however, the fact that the heatmap encourages this way of looking at student activity may actually distract from the overall aim of improving teachers' understandings of student thinking.

The heatmap enabled the teachers to focus on individual students as well. While this also led to some observations of how much or how little annotation was done, the teachers also identified places in the text that were not annotated by individual students. For example, Mr. C observed about a student's annotation that "It is interesting, a ton in the beginning and then only a couple at the end… But the middle of the story does kind of get left out." Since the teachers had annotated their respective texts before assigning them to their students, they had an inclination of important places in the text.

The pop-up window depicting what questions or comments students made about their annotations also provided details that teachers called out. For example, when reading a question from one student, the science teacher says,

> **Ms. T**: Look at this. *[She reads what the text says:]* "Some stars are much larger than the sun" *She then reads a student's annotation.* "Dose that mean they are hotter? (sic.)"

It's such a simple question but it really is important.

Here the teacher is calling out the question this student writes regarding a statement from the textbook. The student is connecting size of a star with heat. This is an important relationship within the scientific domain the students were studying; the tool supported the teacher noticing students' reasoning about it.

Making connections between specific events and broader principles of teaching and learning

We found limited evidence of teachers explicitly linking specific instances of annotations to broader principles of teaching and learning. Nonetheless, several examples illustrated how teachers' *implicit* values shaped practice with Markup. One example worth noting refers to an exchange among the teachers about a student's question from the text:

> **Ms**. **T**: For example… [the text] says, "The sun is about 100 times greater than that of earth." They are trying to say how big the sun is and other stars and Daniel's [a pseudonym] comment is, "What about gas to keep the plane going if the plane were actually going that far?" … I mean he is thinking about this analogy.
>
> **Mr. C**: He's seeing outside the box.
>
> **Ms. T**: No. That's not even what I mean. I just mean he's actually like reading the words and understanding the words and this is maybe even what I'm talking about when I'm saying that sometimes it's so hard for me to say, "Well, a student doesn't understand this just by reading what they wrote," because there are so many ways –
>
> **Ms. N**: To access their knowledge?
>
> **Ms. T**: A student could have copied directly the definition for parallax from the text and I wouldn't say that I thought they necessarily understood it. I know so much more from Daniel saying, "What about gas to keep the plane going?" than I do from someone copying word for word the definition for parallax.

This excerpt demonstrates one teacher's reasoning about the particular student's response and how his response demonstrates understanding. Ms. T acknowledges that the student is trying to connect the size of the sun with an analogy from his own life. She is identifying the student's learning as a process of negotiation and interpretation (Cobb, 1994), including implications not intended by the author. She is not trying to determine whether the student's response is right or wrong (as Mr. C generally tended to), but rather whether the response reveals the kind of engaged attentiveness (an important broader teaching principle; see Pianta & Allen, 2008) to the text that the teacher is hoping for.

Using what one knows about the context to reason about a situation

Teachers' conversations about students' work also addressed student understanding. Ms. T stated that "It is harder to tell what they do not understand than what they do understand, because…I guess you can kind of say you are giving the benefit of the doubt, unless – like, I would want to see how they talk about it…" Here the teacher makes two important points. First, even with the new tools, she has a difficult time inferring what students do not understand about the text. Second, even when she infers that there is student understanding, she would prefer to check the understanding through another means, such as discussion. This presents an interesting problem: it is possible that annotation, which has previously been shown to *aid* text comprehension, may, alone, produce representations that cannot be easily used to *assess* comprehension. This suggests that one possible source of design guidance on designing representational tools for teachers, studies of existing assessment practices, may be of limited value to CSCL researchers in this area, because they do not encompass uses of data that can inform teachers (such as evidence of student engagement) but do not comply with psychometrically reliable models of assessment.

The extent to which the tool reveals or does not reveal student understanding was echoed later in the teachers' conversation. In a conversation with Mr. C, Ms. T said,

> "I just think …the ways that they…show that they understand it, like, you do not know exactly what those will be. Like I have to wait and see, how did they word something, or like what – how did they respond to it? And just because they, like, copied the definition directly from the book about light year [I might not know]"

Here the teacher is referring to the feature that allows students to write a definition of a word. While a student may be able to write the definition (definition was a kind of annotation; teachers sometimes directed students to annotate new vocabulary thusly) on the computer, it does not mean that they will be able to use the word in an appropriate way. The teacher is also reporting on the difficulty of articulating in advance what evidence of understanding will look like, and that instead a Stewart-like "know it when I see it" approach is needed. Mr. C responded by suggesting that Ms. T alter the task she

has given students to require them to use the language in a sentence, rather than simply defining it. His suggestion illustrates the important role that the instructional context can have on the utility of any data visualization.

Another way that reasoning about context can occur is in using the insight into student thinking offered by a tool to make decisions about altering the context, such as by changing instructional plans based upon what one has seen. An instance of this occurred when Mr. C made note of students annotating in ways that were contrary to his thinking. This provided a tension in his mind between students not annotating "correctly" either because they were not annotating what he felt they should or because he was gaining evidence of multiple perspectives from the students. This provided new awareness – and instructional ramifications -- for the English teacher. As he told the other teachers, "if I discussed this story today I'm going to be going in more open minded that there are a lot more opinions out there than I thought there were."

Single Example: Learning to Notice

In some cases, an extended comment or discussion exhibited the multiple dimensions of the Learning to Notice framework. For example:

> **Mr. C**: …Dominic was done with it, got his ten done and stopped, didn't even get half way through the story. Whether he read it or not he was done. That is Dominic.
> **Ms. N**: That's so him.
> **Mr. C**: And that's his big issue, it's about as quick as I can get it done. The rule was ten, he did ten. So, it's hard to assess him. When you look at him, what he did in the beginning was – it was okay. He used a lot of the same words over, but he didn't do a horrible job, but that's him, half way. Get it done, walk away.

Here, within the context of Mr. C attempting to relate his instructional goals to what the student actually did, Mr. C is identifying what one student has done in the class and how the extent of the student's work is not enough to fulfill the full purpose of the assignment or to allow him to assess the student's understanding. This exchange corresponds to all three elements of the Learning to Notice framework because Mr. C called out a notable element of a student performance, characterized it in terms of a known problematic phenomenon (not completing an assignment), and related it to that student's historical tendencies. The conversation continued:

> **Ms. T**: I'm sorry, what about that thing he wrote for rap?
> **Ms. N**: He was really intense about that.
> **Ms. T**: He wrote the longest rap and it is awesome. It's so sophisticated.
> **Ms. N**: But it's the first time I've seen him like –
> **Mr. C**: Engage.

Here, Ms. T argued with Mr. C and Ms. N's historical characterization of Dominic by presenting a different background to the students' performance on the Markup. While Dominic's annotation may have been typical of his behavior in reading, his level of engagement had seen peaks (corresponding to an assignment that aligned with the student's interest in rap) as well. While this conversation does not necessarily address instructional strategies to address Dominic's engagement, Ms. T's gentle critique does allow the teachers to acknowledge the many sides students bring to their learning situations, including the ways in which well-constructed assignments can motivate students to excel. It is also noteworthy to mention that this snippet of discussion is not very deep with respect to the instructional topic. However, it is possible to view the collaborative actions among teachers through the Learning to Notice framework both to provide future support to the learners as well as to aid in the design process of future instructional tools by suggesting conversational contexts and protocols (e.g., presenting counterexamples that explain students' successes contextually) in which they might be employed.

Significance

This study demonstrates how design-based breach experiments can fill an information gap that exists when trying to design tools to support learning in an absence of current practice. This is acutely the case for researchers designing data analysis tools for teachers to use to understand student thinking through detailed analyses of student activity. With the exception of early mathematics and reading, such practices are exceedingly rare in schools and have been only lightly researched. We demonstrate how a breach experiment may be used to understand some of the practical problems of understanding students' literate activity through analysis of external representations produced during that activity. In addition, we showed how the Learning to Notice framework provides designers of collaborative learning tools a window into how teachers attend to student learning through examination of student activity. Looking at and discussing student work is an important learning activity for teachers and the learning is embedded in the collaborative activity (Koschmann, 1996). By providing a reference frame

for identifying teacher practices that are associated with improved teaching, Learning to Notice allows CSCL researchers to identify whether an important class of teacher activity results from the implementation of a new tool, and then to study and potentially problematize that activity. As we showed, it is possible for individual teachers to practice in ways that satisfy the Learning to Notice criteria without thinking deeply about student thinking. For example, the Markup heatmap directed teachers' attention to how (in)frequently students annotated any given passage of text. But while this is an important feature, it challenges designers to highlight features that qualitatively differentiate student work and expose student thinking. Mr. C's past practice (i.e., before this intervention) tended to be strongly top-down; he directed classroom conversations based upon his interests (early field notes noted the lack of opportunities for students to talk about their ideas in his classroom) and he often judged students' activity, as depicted in the heatmap, based upon how well it concurred with his own. The heatmap supported this behavior by enabling him to make quick work of checking whether students annotated the "right" things. If used solely on his own, Mr. C's work with the tool may not, thus, have been much of a learning experience for him. The tool made it easy for him to continue his past practices and relative lack of focus on student thinking. However, with critique from his peer teachers, he recognized that other interpretations of the data were possible. By making activity in Mr. C's class transparent to his peers, Markup enabled a collaboration that expanded Mr. C's thinking about his students' activity.

Cases like these indicate ways that CSCL researchers could examine the problems of practice that occur when teachers try to use data analysis tools to inform their teaching. Specifically, by examining differential interpretations by different participants of common representations, researchers may understand not only the possible approaches to meaning making with new tools, but also the ways in which collaborative practices may bridge different interpretations to enrich teacher thinking. Such cases can aid design work by suggesting ways in which designed representations could either foreground details in student activity that are likely to have controversial interpretations (thus increasing the likelihood that teachers' conversations will include discussions of multiple points of view) or directly suggest multiple meanings – gathered through exhaustive study of how different teachers make sense of analogous cases -- for displayed data, tutoring teachers in how to make sense of classroom activity.

More generally, this work suggests visualization tools, even relatively simple ones like the Markup tool, can facilitate teacher learning and discussion through de-privatizing their practice. Extensive research has shown both the degree to which the teaching profession is isolated and the power of collaborative teams and communities of teachers to support learning. Prior research has suggested that a focus on a long-term instructional goal, such as literacy strategies, can aid in building collegial relationships among teachers (Wardrip, 2009). Our results show how even uncomplicated representations of student activity can support teacher analysis of student thinking, reaffirming our opening claim that research on responsive practices to new representations of learning activities need not wait until more complex analysis are ready for deployment.

In closing, it is important to note how these results highlight a limitation of the Learning to Notice framework with respect to studying collaborative learning. While the Learning to Notice framework highlights both individual and group-level change in perspective taking and noticing, it does not highlight tensions or dissonant views, including claims about appropriate instructional responses, that often occur in groups of teachers with varying experiences, beliefs and expertise. In future work, this theoretical framework may need to be modified in order to support deeper analyses of collaborative learning. CSCL has a pivotal role to play in guiding, and being enriched by, that theory construction.

References

Atwell, N. (1990). *Coming to know: Writing to learn in the intermediate grades*. Portsmouth, NH: Heinemann.

Crabtree, A., Benford, S., Greenhalgh, C., Tennent, P., Chalmers, M. & Brown, B. (2004). Supporting ethnographic studies of ubiquitous computing in the wild. *ACM Symposium on Designing Interactive Systems*, State College, PA, 60-69.

Cobb, P. (1994). Where is the mind? Constructivist and sociocultural perspectives on mathematical development. *Educational Researcher*, 23 (7), pp. 13-20.

Feng, M., Heffernan, N.T. & Koedinger, K.R. (2006) Addressing the testing challenges with a web-based e-assessment system that tutors as it assesses. *Paper presented at WWW 2006,* May 23–26, Edinburgh, Scotland.

Fernandez, C. & Yoshida, M. (2004) Lesson Study: A Japanese approach to improving mathematics teaching and learning. NJ: Erlbaum.

Fullan, M., Hill, P. & Crevola, C. (2006). *Breakthrough*. Thousand Oaks, CA: Corwin Press.

Goodwin C. (1994). Professional vision. *American Anthropologist.* 96, 606-33

Hill, W., Hollan, J., Wroblewski, D., & McCandless, T. (1992). Edit wear and read wear. Proceedings of the SIGCHI conference on Human factors in computing systems , 3-9. 201

Koschmann, T. (1996). Paradigm shifts and instructional technology. In T. Koschmann (Ed.), *CSCL: Theory and practice of an emerging paradigm* (pp. 1-23). Mahwah, NJ: Lawrence Erlbaum.

Lewis, C. (2000) Lesson Study: The Core of Japanese Professional Development. Paper presented at the special interest group on research in mathematics in education at American Educational Research Assocation Meeting, New Orleans, LA.

Liu, K. (1996). Annotation as an index to critical writing. *Urban Education*, 41: 192-207

Marshall, C., & Rossman, G.B. (2006). *Designing qualitative research.* (4th ed.) Thousand Oaks, CA: SAGE Publications.

Maxwell, J.A. (1996) *Qualitative research design: An integrated approach*. Thousand Oaks, CA: SAGE.

Medina, R., Suthers, D. & Vatrapu, R. (2008). Inscriptions becoming representations. *Proceedings of the 9th international conference on Computer Supported Collaborative Learning*, Volume 1.

Pianta, R.C. & Allen, J.P. (2008). Building capacity for positive youth development in secondary school classrooms: Changing teachers' interactions with student. In M. Shinn & h. Yoshikawa (Eds.) *Toward positive youth development: Transforming schools and community programs.* New York, NY: Oxford University Press.

Reimann, P. (2009) Time is precious: Variable- and event-centred approaches to process analysis in CSCL research. *International Journal of Computer Supported Collaborative Learning*, 4 (3), 239-257.

Scherer, J., Gomez, K., Herman, P., Gomez, L., White, J., & Williams, A. (2008). Literacy infusion in a high school environmental science curriculum. In K. Bruna & K. Gomez (Eds.), *Talking science, writing science: The work of language in multicultural classrooms.* Mahwah, NJ: Erlbaum.

Shapiro, R.B. & Wardrip, P.S. (2010) Understanding formative instruction by design. In: *Proceedings of Ninth International Conference of the Learning Sciences (ICLS 2010)*, Poster Session, Chicago, IL, pp. 316-317

Sherin, M. G. (2000). Viewing teaching on videotape. *Educational Leadership*, 57(8), 36-38.

Sherin, M. G. & van Es, E. A. (2003). A new lens on teaching: Learning to Notice. *Mathematics Teaching in the Middle School*, 9(2), 92-95

Sherin, M. G., & Han, S. (2004). Teacher learning in the context of a video club. *Teaching and Teacher Education*, 20,163-183

Shute, V. J., Ventura, M., Bauer, M. I., & Zapata-Rivera, D. (2009). Melding the power of serious games and embedded assessment to monitor and foster learning: Flow and grow. In U. Ritterfeld, M. Cody, & P. Vorderer (Eds.), *Serious games: Mechanisms and effects* (pp. 295-321). Mahwah, NJ: Routledge.

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning.In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge: Cambridge University Press.

Strauss, A.L. (1987). *Qualitative analysis for social scientists*. Cambridge: Cambridge University Press

Suthers, D.D., Dwyer, N., Medina, R. & Vatrapu, R. (2010). A framework for conceptualizing, representing and analyzing distributed interaction. *International Journal of Computer-Supported Collaborative Learning*, 5(1), 5-42.

van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education*, 10(4), 571-596.

van Es, E. A. & Sherin, M. G. (2008). Mathematics teachers "Learning to Notice" in the context of a video club. *Teaching and Teacher Education*, 24, 244-276

Wade-Stein, D., and Kintsch, E. (2004). Summary street: Interactive computer support for writing. *Cognition and Instruction*, (22), 333-362.

Wardrip, P. S. (2009). *The role of literacy work circles in developing professional community*. Paper presented at the annual meeting of American Educational Research Association (AERA), San Diego, California, April 13–17.