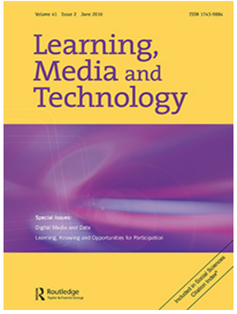

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Making students' mathematical explanations accessible to teachers through the use of digital recorders and iPads

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Analyzing students' mathematical explanations can be a powerful tool to enhance teachers' practice, but collecting these explanations can be cumbersome. Here, we describe our quest to find effective tools to make explanations accessible to elementary (K-6th) teachers. First, we describe how digital audio recordings enabled teachers to focus on the processes students used to solve problems and helped teachers to see patterns of development in students' thinking as well as to identify the prevalence of some misconceptions. In addition, we show how considering explanations from various classrooms provided an avenue for teachers to share their teaching practices. Second, we discuss a new tool that provides even better records of students' processing beyond the information gained from the digital recorders. We provide some preliminary data of our use of the *ShowMe*® screencast application on the *Apple*® *iPad* with students to illustrate the potential of this tool for teacher professional development.

Keywords: mathematical explanations; mobile learning; professional development

Introduction

With the recent emphasis on Data-Driven Decision-Making (D3M), educators are realizing the power of examining student work to promote teacher learning and instructional improvements. While this practice is not new, it has exploded because technological advances of the past two decades have made data easier to access, aggregate and share (Mandinach 2012). While many associate the term 'data' with students' performance on standardized multiple-choice tests, it can be interpreted much more broadly, to include various artifacts of students' performance. Among the most useful to gain insight into students' mathematical thinking are their explanations of problem-solving strategies. In order to become data, explanations have to be captured so they can be shared with others and analyzed. We sought efficient ways to do this as designers of a

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professional development program based on Cognitively Guided Instruction (CGI) (Carpenter, Fennema, and Franke 1996). In our previous experiences sharing CGI with teachers in economically disadvantaged districts, we faced resistance because the teachers did not believe *their* students could solve story problems independently. In this project, we set out to demonstrate the CGI framework by using examples from the teachers' own students so we embarked on our own D3M project to explore various approaches to capturing students' explanations of their solutions to story problems.

In this article, we highlight aspects of our inquiry process. We begin by discussing the theoretical underpinning of our professional development effort and our use of student artifacts in that effort. The following section will describe multiple ways researchers and teachers have previously captured students' mathematical understanding during problem-solving activities and how these techniques have led to greater understanding of students' mathematical thinking. It will then be followed by a description of how we integrated digital audio recordings of student explanations into our program. Teachers' reactions to students' work demonstrate the power of these tools to stimulate conversation and reflection on what students know and how they can grow. Afterwards, we provide a description of an iPad screencast-making application, *ShowMe*®, used to capture students' explanations along with an example of a transcribed student screencast to explore the great promise of this tool. We end by sharing future research possibilities on the use of the iPad screencast-making applications.

Background

The National Council of Teachers of Mathematics has emphasized, for over a decade, the importance of communication between teachers and students by indicating that 'observations and conversations in the classroom can provide insights into students' thinking' (NCTM 2000, 24) and that 'when students are challenged . . . to communicate the results of their thinking with others orally or in writing, they learn to be more clear and convincing' (60). The Common Core State Standards in Mathematics echo this emphasis on students' explanations in the Practice Standard: 'Construct viable arguments and critique the reasoning of others.' Specifically, the goal is for students to 'listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments'. This increased attention to students' constructing arguments and justifying their thinking requires teachers to learn to elicit and interpret students' explanations and CGI has demonstrated that when they do so, they are able to modify their instruction to advance students' thinking (Fennema et al. 1996).

Rather than using pre-established CGI materials for our professional development project, we generated our own materials (Kazemi and Hubbard 2008). We collected students' written work and audio explanations situated within the school district, and shared them with teachers at monthly after-school meetings. We did this to tailor the agenda to the needs of our group. We found that many of the published CGI videotapes of individual children and classrooms featured monolingual English-speaking students, who did not resemble the children in our teachers' classes. In addition, the contexts for some of the story problems were not culturally sensitive to our student population. Using our own local examples allowed us to track students for multiple years in order to follow their mathematical progress throughout the project. Our professional development had an underlying equity agenda. We hoped our examples, which included student representatives often with accents, would encourage teachers to create more culturally responsive and inclusive classrooms (Little 2006).

Theoretical framework

We set out to develop a professional community as described by Louis, Marks, and Kruse (1996) containing the five elements of practice they consider essential to such communities. We hoped that teachers would develop *shared norms and values*, specifically that they would begin to share beliefs in their students' abilities to solve problems independently. We also hoped that they would begin to value students' strategies as resources for other children in their classrooms. We theorized that using students' work from the teachers' schools was necessary to develop these norms and values. A *collective focus on student learning* arose naturally from our close analysis of students' solution strategies, as did teachers' *collaboration* to make sense of what their students had done. Teachers engaged in *reflective dialog* as they shared possible ways of responding to students and anticipated multiple solution strategies that they might not have otherwise thought of by themselves (Jacobs et al. 2006). Louis et al. envisioned the final element, *deprivatizing practice*, as getting teachers to go into one another's classrooms through such activities as peer mentoring and role switching. We did not have the resources to make this happen so we depended on boundary objects to serve this role instead.

Star and Griesemer (1989) defined boundary objects as'objects which are both plastic enough to adapt to local needs and the constraints of several parties employing them, yet robust enough to maintain a common identity across sites' (393). In the case of professional development, students' written work is often used as a boundary object, meaning that it serves different purposes for different people in different settings. This work arises naturally as part of the on-going work in the classroom and then becomes an object of reflection and analysis in professional development. As noted by Stein and Coburn (2008) when boundary objects travel, they have to be interpreted when they cross into a new setting. Meanings embodied in the objects are always partial. The effectiveness of boundary objects depends in part on overlapping experiences between producers of the objects and others encountering the objects so that the objects retain as much of their original meaning as possible.

The challenge for professional developers interested in using boundary objects to deprivatize practice is to identify boundary objects that are as robust as possible while their production in the classroom remains a natural part of on-going activity there so that collecting these objects does not place additional burdens on teachers.

Previous research

Using students' work as a tool for teachers' learning has been done in a variety of ways. In Crespo's (2000) letter-writing exchange, preservice teachers wrote letters back and forth to fourth-grade students. These letters contained mathematical problems for both the preservice teacher and student to solve, their solutions to the problems, as well as personal information about their experiences with mathematics. Although writing has been shown to be a powerful activity to articulate and refine one's thinking, particularly for scientists (Ericsson, Krampe, and Tesch-Römer 1993), in Crespo's (2000) study, fourth graders did not always write out everything they understood or did when solving problems. Preservice teachers had to make inferences in order to interpret students' work. Crespo also pointed out that the preservice teachers tended to have negative responses to students' written work when students provided brief statements, had misspellings or immature handwriting, leading the preservice teachers to make erroneous assumptions about students' understanding. Even so, analysis of student thinking did lead the preservice teachers to shift away from focusing exclusively on answers to look at meaning making and in so doing their interpretations became more 'thoughtful and provisional' (178). In Crespo's study, the letters served as boundary objects, being generated through purposeful activity by children in their classrooms and then becoming objects of reflection in the methods classroom. When they were interpreted in the new setting, preservice teachers' stereotypes and biases led them to misinterpret the students' work, showing the limitation of static written work as boundary objects.

In other projects, additional resources have enhanced children's written work to provide more robust data for teachers to discuss. Kazemi and Franke (2004) detailed how teachers in their CGI-focused professional development program changed as they attended to children's thinking and strategies. In their initial workgroup meetings, Kazemi and Franke found that teachers often focused exclusively on students' written work and 'did not see it as important to engage their students in conversation about their strategies' (216). Although teachers were actively engaged in deciphering what their students wrote in their papers, many could not verify what the student had done as they were not present when the student completed the task or had not asked how the student solved the problem. After suggestions from the professional development facilitators, teachers realized that in order to get an accurate view of their students' mathematical understanding, they needed to communicate more with their students. Even though teachers realized that they needed to talk to students, Kazemi and Franke reported that some teachers admitted not knowing how to elicit students' explanations or not having time to talk to all students individually. However, some teachers did push themselves to communicate with their students and shared ideas about how to accomplish this, such as taking the time to talk to a few students a day or working with small groups of students as others worked independently. These teachers provided narrative accounts of their interactions with students during the professional development meetings. Given the fragility of human memories, we suspect that these narratives were not detailed and some of the important nuances of students' thinking were probably lost. Moreover, since they were second-hand accounts, the teachers' colleagues may not have found them compelling. Even so, written work coupled with students' verbal explanations provided those teachers who took the time to speak with their students a better window into the students' thinking than the written work without verbal explanations. As in Crespo's study the students' written work played the role of boundary object, having been generated in the classroom for the purpose of on-going academic activity. Teachers sought out more information from the children to enable them to 'translate' the boundary object for their colleagues after recognizing that the written work was not robust enough to speak for itself.

To address the limitations of teachers' recall of interactions, some have collected student explanations by using technology and its capabilities to record students' activity while they solve problems and explain their solution strategies, particularly video recordings. The videos can be reviewed multiple times to provide a clearer understanding of what exactly the student did while solving the problem. Most of the research conducted on professional development programs using video recordings included either teachers' recordings of their own classrooms and lessons (Borko et al. 2008; Van Es and Sherin 2008), recordings of student one-on-one interviews (Jacobs, Lamb, and Philipp 2010; Soto and Ambrose 2011) or recordings of students as they work together in groups (Krebs 2005). Even though video clips provide additional information and advantages over written responses and non-recorded conversations between teachers and students, there still are some disadvantages. For one, teachers may not be running the camera during classroom recordings, which could give them limited control as to what is recorded. In addition, video recordings do not record everything or everyone and, at times, researchers and teachers may still have questions or trouble interpreting what students did (Krebs 2005). Also, video cameras are not typically found in classrooms so they can be intrusive and students may be nervous to be on film. Moreover, video recording requires extra effort due to the time required to set up and take down equipment, as well as requiring that the teacher obtain parents' permission to video record their children. Because video cameras are not native to the classroom environment, and the video produced serves no function for the students themselves, we question the extent to which video recordings can be considered boundary objects. Given the significant effort required to produce them, it is unlikely video can be collected on a regular basis so it can become data for the inquiry cycles suggested by D3M advocates (Hamilton et al. 2009).

For our professional development program, we used students' written work as a primary artifact, which Kazemi and Hubbard (2008) state is the most common classroom artifact used in professional development. Recognizing its limitations as a boundary object we sought to make this written work more robust so that teachers' interpretations of it would be more aligned with children's actual thinking processes. We used digital audio recorders to capture students' verbal explanations to provide additional information to help teachers interpret student work. We also felt that the authenticity of student voices would promote *shared values and norms* because many of the children had grown up in the schools and their teachers from previous years were in our professional development program. We recognized the audio recording had some of the same issues as video in terms of being boundary objects. Nevertheless, we saw it as a less intrusive, more natural vehicle for *deprivatizing practice.*

Here we discuss the ways in which audio recordings contributed to the development of our professional community as described by Louis, Marks, and Kruse (1996). Louis et al. noted that *shared norms and values* include teachers' relationships with their students. We theorize that hearing the voices of children from classroom enhanced their human qualities evoking teachers' emotions as they listened. In addition, the children had grown up in the school district, and many teachers in our group taught them and their siblings over the years. The many associations teachers had with these families often surfaced when they heard children's voices, which helped develop the *shared norms and values* in the group. Student voices combined with student work promoted *collective focus on student* learning because the multi-modal aspect of the artifacts helped teachers better understand how children were thinking. The teachers *collaborated* to make sense of the data. Because they *deprivatized their practice* through these artifacts, teachers felt better about their own imperfections because their examples depict real classrooms in all of their complexity. Participating in these communities of practice involved more than just attending sessions and taking materials from the sessions back into the classroom. Kazemi and Hubbard (2008) suggest that to be most effective, teachers' participation in professional development should be multidirectional. Their commitments to the professional development community motivate teachers to implement new activities and practices in their classrooms, and their classroom experiences provide fodder for conversations in the professional development.

In the spirit of D3M as we planned and implemented our professional development program, we collected data from our workshops, which we reviewed to continuously improve our work. The following describes how first the digital audio recordings were used in our CGI program. Data, including transcriptions of teacher meetings and evaluation forms, which asked them to share what they learned and valued as well as any questions that came up during the session, are then presented to provide evidence of the usefulness of this tool. Afterward, we present descriptions of how we began implementing screencasts to collect student data. The examples of student data analyzed in both sections relate to equal sharing problems with whole numbers in the problem but fractions in the solutions. These problems were particularly interesting to examine using these tools as there were often mismatches between students' written work and their verbal explanations. We conclude with our plans for future integration of these tools in our professional development programs.

Data sources

We offered our professional development in a small northern California school district where we served 95 teachers over a 5-year period. This district of five elementary schools (kindergarten through sixth grade) was located in a high poverty area on the outskirts of an urban area with a diverse student population. Forty-five percent of the students were designated as English Learners (ELs). During the first 2 years we offered our professional development, 20–24 kindergarten-through-second-grade teachers participated. In the final 3 years, we extended the professional development to include third-through-sixth-grade teachers and participation ranged from 24 to 45 teachers each year.

Collection of audio recordings in classrooms

As in Kazemi and Franke's (2004) work, we asked teachers to collect their students' written work on problems of our own design or that we selected out of the mathematics textbook used by the district. Once teachers received the problem, they signed up for a specified date and time when one of us, the facilitators, would visit their class to observe students solving the problem. During these visits, the teachers' roles were to pose the problem without providing explicit instruction on how to solve it, circulate around the room to answer students' questions, elicit students' solution strategies and provide support when needed. We, as professional development facilitators, watched as students solved problems and used digital audio recorders to capture their verbal explanations of their solution strategies. At times, these explanations were co-constructed between the student and facilitator as we used clarifying questions and prompts to help students clearly articulate their thinking. If students incorrectly solved the problem or had difficulty explaining their thinking, the facilitator provided suggestions and often returned to check their progress. These audio recordings lasted between 30 seconds to just over 2 minutes. We spoke with five to seven students in each classroom and kept a log of students' solution strategies to help us identify those explanations that were particularly interesting. Once students finished, teachers collected the students' written work for the next professional development meeting.

Reviewing, selecting and sharing audio recordings

About a week prior to the professional development sessions, we met to decide which clips to share with the teachers. With 20 to 45 teachers participating in the professional development in any given year and recording 5 to 7 students' explanations in each class, determining which clips to share was rather time consuming. As we collected audio recordings, we noted those which we felt were promising examples to share with the teachers. We logged all of our examples and listened to several as we chose specific examples for the teachers to hear. The goals in selecting audio clips were to highlight children's solution strategy trajectories, share interesting invented strategies, add clarity to students' written work and analyze linguistic features of students' explanations, especially those of ELs. The use of the log helped expedite this process as we had a brief description of everyone's strategy that we could refer to.

Once we selected 10–15 audio recordings for the professional development meetings, we shared them in 2 ways. Our meetings began by asking teachers to sort through their students' written work and identify a few student examples they wished to share. When teachers shared their students' work, it was displayed by a document camera and teachers interpreted the work and discussed its instructional implications. If we had an audio recording to go along with that work, we played it for the group to hear. We also shared preselected audio recordings and asked the teachers to provide the student's written work. In both approaches to sharing student work, the student's work on paper was always analyzed first either in a whole group format or by small groups of teachers. Teachers had the time and opportunity to 'think like a kid' and determine the meaning of the student's inscriptions. Seeing the range of strategies for particular problems enabled them to think about the developmental trajectory of students' thinking and about relevant concepts.

Screencast technology

We did not initially set out to research screencasts. We believed that incorporating student voices was a powerful tool in our professional development program, and if the use of digital audio recordings were compelling, having an artifact with a temporal component that captured students' problem-solving and explanation together would be even better. One of the teachers in our program introduced us to the free app *ShowMe*® for the *Apple*® *iPad*. At the time of the writing of this paper, our use of the iPad was in its pilot stages, and we were interested in determining whether the use of the iPad could be a fruitful tool for gathering students' mathematical thinking to share in our professional development sessions.

ShowMe® is a free screencast app available on the iPad. A screencast is a 'screen capture of the actions on a user's computer screen, with accompanying audio' (Educause Learning Initiative 2006). Screencasts may be familiar to readers who have watched Khan Academy tutorials. The app developer's goal (LearnBat Inc. 2013) is to 'democratize learning', but many of the first screencasts available on their website were created by teachers or experts to 'teach' others a certain concept, reflecting a transmission perspective toward teaching and learning. However, we see great potential in a more bottom-up approach using this app. Because this app records everything that is written on the screen, students can capture their own solution strategies to share with their teachers and classmates. Student-produced screencasts could enhance teachers' assessments because they could clearly see exactly the order in which students wrote, drew, erased inscriptions as well as hear how students narrated their work.

Although there are various apps that have the same capability as *ShowMe*® (i.e., *Explain Everything*® and *Educreations*®), we first started using this particular app because it was free and simple. We found that first graders were able to manipulate the pen colors and erase errors without instruction. Once students completed their explanations and stopped recording, the app automatically replayed what was just recorded, so students could listen and see exactly what they wrote. We hypothesize that this feature could be a valuable way for students to reflect on their explanations and develop metacognitive strategies to monitor the quality of their explanation.

Collection of screencasts

We collected screencasts in conjunction with the audio recordings. Two facilitators of the professional development went into classrooms, one with a digital recorder and the other with the iPad. The person with the iPad set the app up in the back of the classroom and asked one to two students to solve the problem the teacher posed using the screencast app. These screencasts ranged in length from one to five minutes. Before asking students to share their solution strategies on the iPad, we gave students a quick introduction to the app, showed them how it worked and what it recorded. We explained that to make the most interesting or helpful screencasts, students needed to talk as they wrote. We collected the students' screencasts in different ways. One way was that we asked them to solve the problem posed by the teacher on the iPad and talk about what they were thinking and doing as they were problem-solving. This way of collecting students' work allows teachers to examine students' thinking as it unfolds affording insight into students' mathematical processing. Another way we collected screencasts involved a reflective method; students worked out their solution strategies on a piece of paper and then transferred their written work, drawing or representation onto the iPad and explained how they solved the problem. When students used this more reflective method, the screencasts were sometimes recorded as the students wrote their work on the iPad or after they transferred their work so their voices were only recorded. This second way of collecting the students' reflections most closely resembled data collection methods used with the digital recorders. We hypothesize that teachers could gain valuable and different kinds of information from their students depending on how they collected the explanations, having students talk either while problem-solving or afterwards.

Because our primary role in this project was as professional developers rather than researchers, our main objective was to design and implement the program. Because we were interested in perfecting our craft, we also engaged in inquiry about our work as time allowed. We did not set out to study teacher discussions during our meetings; however, once we realized that these conversations were quite powerful for the teachers, we made attempts to capture the activities of the group through audio recordings and written evaluations. We use these for illustrative purposes here to demonstrate the potential of our approach.

Findings

Example from after-school meeting

At an after-school meeting in February 2012, with a group of 20 third- through-sixth-grade teachers, we shared some audio clips of students solving an equal sharing problem. The problem stated, 'There are six children and they are sharing nine licorice sticks. How much licorice should each child get so that it is fair?' In the meeting, the second author asked the students' teachers to share the written work and played the audio recordings. The second example that was shared during this meeting was from a third-grade student Jason.[1] (Figure 1)

Prior to listening to Jason's explanation, the second author asked the teachers how they thought Jason solved the problem based on his written work. The following transcript excerpt was what the teachers discussed.

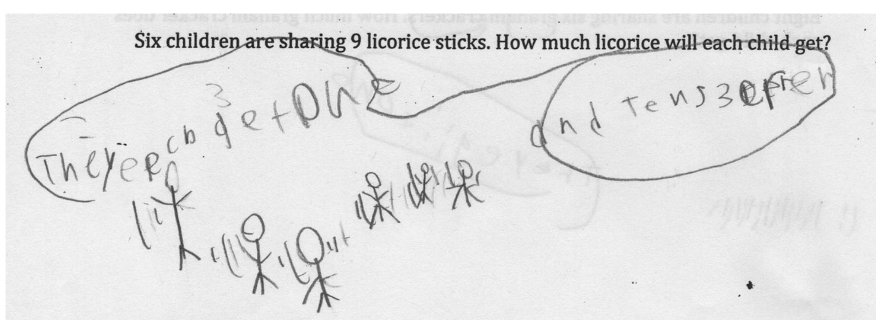


Figure 1. Third grader Jason's written work, six children sharing nine licorice sticks.

Voices:	Oh, I don't know.
Second Author (A2):	Do I need to make that bigger?
Voices:	I don't think that is going to help. I can't understand it. Ten's? Three's?
Voices (to Jason's teacher):	Can you translate it?
Jason's teacher:	They each get one . . .
Voices:	Oh!
Jason's teacher:	And, then ten . . .
Ellen (Teacher Participant):	Then three'er.
A2:	Three'er? Well, let's listen and see what he said. What do you think he has in his drawing? What do you think these are?
All:	One and a half.

After this discussion, the teachers listened to Jason's explanation. He began by saying, 'I was thinking for a long time, because they couldn't divide it equally so I was thinking that they each get one and there's three extra ones.' He was then prompted to describe what he should do with the left overs. He went on to say, 'Cut them in half. So then we give it to, one half, two half, three half, four half, five half, six half. So they each get one and a half.'

As the audio clip finished you could hear a low 'Whoa' come from the teachers. One teacher, Ellen, said, 'you would never have gotten what he said from looking at what he did' (as she pointed to Jason's paper being displayed on the document camera and others agreed in the background). She also returned to his written work and began reinterpreting it, 'I guess those are halves, those little pieces.' Just as in Crespo's (2000) study with preservice teachers who quickly judged their pen-pals based on misspellings or messiness, this teacher was quick to dismiss this student's thinking because she may have found the work to be messy and assumed his 'sticks' were tens. The written work on its own was not robust enough to enable the teachers to interpret it. Moreover, the child's teacher could not explain the child's notation. However, because the audio recording of his explanation was shared, the teachers were able to get a better sense of how Jason went about dividing the licorice pieces and how he was paying attention to the sizes of the pieces. Without the extra information from the audio recording, they would not have known that he understood the numerator to be a counting number and the denominator to be a measure of the size of the units being counted ('one half, two half', etc.). Without the written work they would not know that he made individual marks for each half rather than showing a whole licorice stick cut in two pieces, showing that he was using what Empson and Levi (2011) called an additive coordination strategy. He coordinated the number of children (6) and the number of licorice sticks (3) and realized that cutting his extra sticks in two would work. The work also demonstrated that while Jason could name and verbalize fractions, he was not using fraction symbols in his written work so this could be an aspect of fraction work his teacher could support. Together the audio recording and the written work provided the teachers with greater access to Jason's thought processes than either artifact in isolation could have and gave the teachers an opportunity to engage in what Louis, Marks, and Kruse (1996) described as *reflective dialog* in which they considered the developmental level of his strategy (what does he know?) and discussed how to further support his development (how can he grow?).

Opening the classroom door

In addition to providing more information about children's thinking, bringing students' voices into the professional development setting also 'opened the classroom door' to break down the isolation that teachers often feel (Little et al. 2003). In our sessions, hearing one another's students as well as the hum of activity in their classrooms gave teachers a peek into one another's classrooms and *deprivatized their practice* (Louis, Marks, and Kruse 1996). This was evident after our first session sharing audio recordings (November 2009) when we listened to children's activity during a Counting Collections task (Schwerdtfeger and Chan 2007). Twenty-two kindergarten-through-second-grade teachers listened as kindergarteners counted by ones saying, 'twenty-nine, twenty-ten, twenty-eleven'; first graders discussed how they grouped items by tens; and second graders hesitantly counted hundreds of pennies by tens. Teachers' responses to hearing the recordings were extremely positive. In their anonymous evaluation forms, teachers commented on how they valued 'seeing/hearing examples of student work', 'analyzing recordings=' and 'listening to how they [students] counted'. It is one thing to talk about what students are doing and quite another to actually hear, from the students themselves, what and how they are thinking.

Not only did the audio recordings help illuminate how students were thinking but we hypothesize they could be a catalyst in the development of collective efficacy among the teachers. In her evaluation form, one teacher commented on how she learned 'that some of the things I see my first graders doing, are the same in other first grades, i.e., 20 ten, 30 ten'. Not only were best practices shared, but also some of the things teachers struggled with were discussed in a constructive, safe environment. Other teachers on the same evaluation form mentioned how they valued 'hearing how others handle the same sticking points', and they learned that 'most teachers/students are experiencing the results I am seeing'. As they heard children from a variety of classrooms with the same counting conceptions, they began to see that the trajectory of children's thinking in developing an understanding of our numeration system was similar across students and that when children counted 'incorrectly' it was not because of a failure on the teachers' parts; rather it was natural to the evolution of children's development in coordinating the different units associated with the base-ten system (hundreds, tens, ones, etc.).

Limitations

It is clear that the audio recordings enhanced the students' written work by filling in some of the gaps so teachers could better understand the students' thinking; however, the recordings would not fit with a strict interpretation of 'boundary object'. The teacher and students did not use the audio recording during the lesson so the recordings were not part of the on-going classroom activity. Moreover, listening to the audio recordings to identify audio clips to share proved to be time consuming. While this could be reduced by having teachers collect and analyze their own audio recordings, we did not want to add an extra burden to teachers and thus decided to collect the recordings in the manner described above. Also, we wanted to highlight particular aspects of children's development and so felt it important to have examples that illustrated those aspects. Even with the time-consuming nature of collecting and analyzing the audio recordings, we felt it was a worthwhile activity that others should consider in order to gain more insight into students' mathematical thinking.

Another inconvenience that sometimes occurred was that teachers may have wanted to share a student's written work that they found interesting, but we had not recorded that particular child's verbal explanation. One way that we tried to adjust for these situations was that because we logged all of the audio recordings, we often had another child's verbal explanation that was comparable to the student work the teacher wished to display. Although we could not be sure that the student (whose work was displayed) thought or understood the problem in exactly the same way the other student explained, it could however help provide additional insight into children's mathematical thinking in general. This then leads to another limitation of digital recordings: because the recordings were retrospective explanations of what the student said or he/she did when solving the problem, it is not possible to know for sure if the verbal explanation of *what they say* they did accurately described *what they actually* did. While we felt that the addition of the audio recordings enhanced our professional development, we worried that it would not become part of any D3M processes done on a regular basis due to the somewhat artificial nature of collecting audio data.

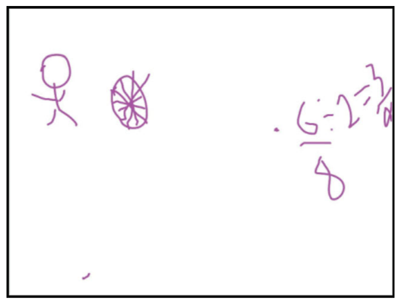
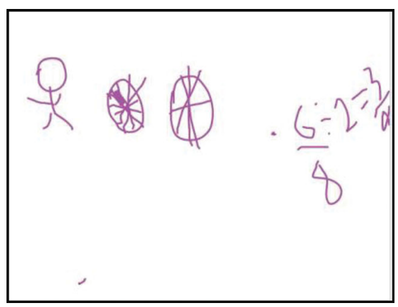
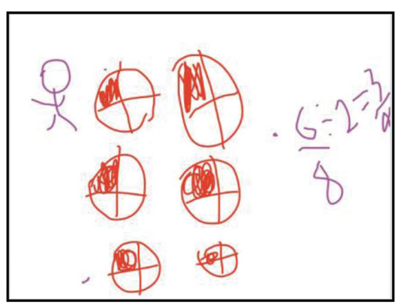
Example of a student-generated screencast

Given the limitations of the audio recordings, we continued to be on the lookout for other approaches to share students' explanations. Later, we share data from our initial efforts to use the *ShowMe*® app with students. At our after-school meetings, we tried to share at least one to two screencasts. Although we have not used student-produced screencasts extensively in the professional development program, we share an example here so that readers get a sense of the type of information that could be examined by teachers. Table 1 is an example of a transcribed screencast gathered in the Spring of 2012 from a fourth grader. In this example, the student solved the following problem: *There are eight children sharing six small cakes. How much cake should each child get so that it is fair?*

This student's solution is interesting in many ways. First, he wrote out the correct answer very quickly after he heard the problem and he readily reduced the fraction to lowest terms. However, when he gave his answer he said that each child will get 'six eight' rather than six-eighths. Without the audio component of the screencast, one might think that the student understood this fraction and was using what Empson and Levi (2011) called 'multiplicative coordination', the most advanced strategy for a problem of this kind. With the audio, one learns that he viewed the two numbers as distinct counting numbers. When asked what the 6/8 stood for, he provided a rote memorized, procedural answer, the number of items being shared go 'on top' and the number of people sharing the items go 'on the bottom'. When asked to show how he would divide the cakes, he was unsure whether to cut the cakes into six or eight slices. When he tried for six slices, he drew six lines, which actually cut the cakes into twelfths. Fortunately, the screencast captured all of the student's work, so, even though the student erased the circles that he divided into twelfths, this work was recorded revealing his struggles drawing fractions. If we only had his final written work, we would not know that partitioning the circle into sixths was a challenge for this child. Even toward the end of the episode when he colored in one-fourth of each cake, this student was focused on the number of pieces each child received rather than the size of the slices and his statements make it clear that he did not know how to interpret the '8' that he put in the denominator. Coupling his written work with his utterances provides viewers with much greater insight than either feature would in isolation and provides an opportunity for *collective focus on student learning* as all the data are conveniently aggregated. A group of teachers analyzing this screencast might come to the conclusion that bypassing the more labor-intensive drawing strategies that children naturally develop to solve equal sharing problems lead to limited understanding. Without documentation of his drawings and his utterances, teachers might not be convinced that he needs more experience drawing fractions to better understand the meaning of the numerator and denominator.

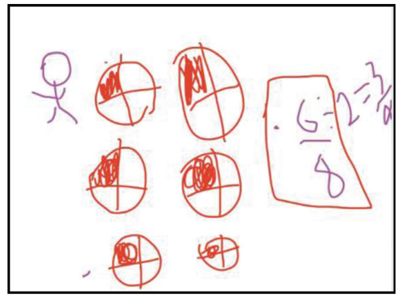
We can imagine that the production and viewing of screencasts could become part of the on-going activity in the classroom and offer some important advantages. First, students producing screencasts could replay them providing them the opportunity to hear their own explanations so they could reflect on their work. Second, the teacher could play some screencasts for the whole class to view. This would provide all students the opportunity to hear classmates' uninterrupted explanations. They could then engage in the practice advocated in the Common Core State Standards in Mathematics of critiquing students' arguments. We hypothesize that screencasts would help students focus on the substance of classmates' work because they would only be

Table 1. A fourth grader's screencast transcript of eight children sharing six cakes.

Time	What was said	What was written
:19	**Student (S)**: Well, the answer is, six *eight*. But you can draw it out too. **Interviewer (I)**: Can you tell me about that six eight, how did you know it was six eight so fast? **S**: Because you put how many things they want to eat on the top, and you put this on the bottom. *(pointed to the eight on the paper where the problem was written)* *(He then described how he knew 3/4 was equivalent to 6/8.)*	
1:50	*(He drew a person and one circle.)* **S**: How many slices? I'll do six . . . *(after a short pause)* I don't know how many slices to do. With eight or six slices . . . I'll try six slices. One, two, three, four, five, six. *(He drew six lines across the circle.)* Whoa, yeah, let's do six first.	
2:55	**S**: So one kid gets one. *(He filled in one slice in the circle.)* And then he gets another piece of the cake. *(He then drew another circle and began to cut it into "six" slices. After drawing four lines he says . . .)* These cakes are deformed. *(He erased the two circles and started again.)*	
3:35	S: So I'll draw . . . four slices. (*Drew a circle and divided it into fourths.)* One gets a piece. Then he gets another piece of the cake. Then he gets another piece. *(He continued to draw circles, divided them into fourths, and colored in a fourth.)* And look it, one, two, three, four, five, six!	

(*Continued*)

Table 1. (*Continued*.)

Time	What was said	What was written
4:14	**I**: Ok, so how big are those slices? **S**: Uh . . . One . . . One . . . One fourth! **I**: One fourth, ok. So do they get six pieces that are one fourth? Or, what does this mean here, the 6/8? **S**: That they each get six slices and that's how many kids there are. I don't know what that eight stands for. **I**: You don't know what that eight stands for? **S**: No. I just put how many kids there were.	

focusing on the notations and explanation rather than on the person generating the work. Finally, the replay option would allow further scrutiny of the explanation by the teacher and/or students. Already one teacher participant stated that she appreciated how screencasts captured students' actions so she could see exactly how they solved the problem rather than relying on others' interpretations of the students' solution strategy. If screencasts could be used in the way described, they would serve as true boundary objects that could be transported to professional development and used for D3M.

Limitations of the **iPad** *and* **ShowMe®**

As with all technology, there are some limitations to using the iPad and the *ShowMe®* app. First, iPads are quite expensive; so having a classroom set with one iPad for every child may be out of the question for many teachers. Researchers who investigated the use of iPads in elementary classrooms revealed that young students (fourth graders) were capable of learning and did well when they shared iPads between two and four classmates (Culén and Gasparini 2011); so it would be possible for teachers to work with 6 to 10 iPads in their classrooms. Another interesting alternative could be to introduce the apps to the students and have them (if their family had one) work on the iPad at home. Some students we worked with told us that their parents had iPads at home, and wanted to know the name of the app used to record their explanations. We later learned that they had downloaded the app and were using it with their siblings. As the price of tablet technology comes down, we expect that they will become more common in classrooms and in homes.

Another limitation is that screencasts would be rather time consuming for teachers to view if all their students generated one during an activity or lesson. This could be alleviated by, as was suggested by teacher participants in Kazemi and Franke's (2004) article, selecting a few students a day, week, etc. and having them record their solution strategies on an iPad, either one owned by the teacher or one owned by the school. Also, maybe developing some sort of guidelines for the creation of the screencasts could reduce the amount of time teachers would have to spend reviewing them.

As with all technology, the iPad is not a silver bullet that will capture everything students are thinking. Take for example the screencast transcript provided above. After trying to divide the cake into six slices, the student then decided to try dividing it into four slices. However, it was unclear why he decided to try cutting it into four as opposed to some other number of slices. To get a full understanding of students' thinking, it is important for teachers to continue asking questions and in so doing facilitate sense-making.

We hypothesize that screencasts could replace student written work as the preferred *boundary object* transferring between classrooms and professional development settings for two reasons. First, as demonstrated above, by combining voice with written work, screencasts are much more robust than written work alone. Teachers do not have to make as much inference about a child's understanding because the child fills in some of the information missing from the inscriptions with their verbal explanation. Second, teachers would not have to set up special equipment and intrude on the classroom space with exotic technology to collect data to share with colleagues. We can imagine teachers having a database of screencasts to share, providing them with a host of options to demonstrate what is happening in their classrooms.

Conclusion

With digital gadgets and mobile teaching tools making their way into the classrooms, it is important to remember that these items are tools. In the context of this article, they were tools used to help teachers learn about their students' mathematical thinking, make sense of students' explanations and *deprivatize their practice* (Louis, Marks, and Kruse 1996) in our professional development program. We examined in depth the explanations of two students solving equal sharing problems. With the use of audio recorders, teachers in our professional development were able to better interpret a student's written work and realized that his thinking was more mature than his primitive drawing might suggest. These recordings also opened the doors of teachers' classrooms providing us with plentiful and detailed student explanations and authentic examples of teachers' practice. With the iPad, we were also able to capture a student's explanation of what at first glance appeared to be a sophisticated strategy, which, upon further questioning and examination, became clear was a rote procedure that the child did not understand well. These examples highlight the type of data that could be collected and used with the technology to help teachers gain a better understanding of children's development of fractional understanding as they engage in the inquiry cycle being promoted by D3M advocates. Although digital audio recorders provide additional data lost when only written work is examined, it is limiting. Since screencasts capture the entire problem-solving process, these data could better help teachers identify what students know, what misconceptions they may have, when their thinking goes astray and allow them to target and individualize their instruction. These boundary objects, as well as serving as formative assessment methods, also contribute to the development of the five elements essential in establishing a professional community (Louis, Marks, and Kruse 1996).

Because digital recorders are relatively inexpensive, they could be quickly integrated into the classroom. Even though iPads or other mobile learning tools in the classroom may be rare in many locations, they are continuing to grow in popularity and as newer, less-expensive options begin to enter the market, they are making their appearances in classrooms all around the world. Future research could look into how teachers are implementing mobile technology in their classroom and whether or not screencasts achieve the status of preferred boundary objects we hypothesize. In terms of students and the use of mobile technology particularly screencasts, future research could investigate potential learning that could come about by generating screencasts. With capturing students' mathematical thinking, there are differing ways to collect student explanations, either during execution of a solution strategy or retrospectively, after the problem has been solved, and future research could highlight the affordances of each way of collecting these explanations. Our use of screencasts was just beginning at the time of writing and we look forward to continued research into the affordances that were actualized with the use of screencasts as both a classroom (Soto 2014) and professional development tool.

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Note

1. All names are pseudonyms.

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