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Beyond Drill & Practice: Using Technology to Assess and Promote Reflection in Elementary Students' Mathematical Explanations

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Abstract. With increased access to mobile devices and more one-to-one initiatives implemented in classrooms around the U.S., teachers are seeking ways to integrate the technology into their instruction. Rather than incorporating the technology in ways that engage students in already learned material through games or repetitive drills, it can be used to engage students in more transformative activities and allow teachers to monitor students' thinking. Screencasting is one such activity. Screencasts, which are digital recordings of students' written work and verbal explanations, allow for greater access to documenting and assessing children's mathematical understanding. When students generate multiple screencasts of solution strategies and review their recordings, they have opportunities to reflect on their understanding and teachers can assess in-the-moment students' mathematical thinking. In this article, screencasting is described to illustrate the process of assessing student thinking and providing opportunities for reflection and revision.

Introduction

The implementation of the Common Core State Standards for Mathematics has ushered in a need to assess students' mathematical thinking in order to respond with appropriate instructional decisions (Council of Chief State School Officers [CCSSO], 2010). In order to meet the needs of all students, assessments must go beyond multiple choice and short answer responses in end of chapter exams and become integral aspects of the learning process. Such formative assessments include classroom discussions, interviews, portfolios, journals, and writing prompts. They provide teachers with data on how students make sense of mathematics and allow students to analyze and reflect on their thinking and learning (National Council of Teachers of Mathematics [NCTM], 2014).

The amount of data that can be collected and analyzed to interpret students' mathematical thinking can be overwhelming. Yet, technologies exist that can assist in the documentation and dissemination of children's thinking. The NCTM (2014) supports the use of technology in mathematics classrooms by stating, "an excellent mathematics program integrates the use of mathematical tools and technology as essential resources to help students learn and make sense of mathematical ideas, reason mathematically, and communicate their mathematical thinking" (p. 78). Surveys of teachers have indicated that the use of technology, specifically mobile devices, is on the rise with usage rates of about 40 to 44% (Takeuchi & Vaala, 2014). However, rather than implementing the technology in ways indicated by NCTM, Tekeucki and Vaala reported that the most common uses of tablets and handheld devices were to practice material already learned and to motivate or reward students. The use of technology must extend beyond procedural practice if students are to engage in 21st century skills, assess their own reasoning, and communicate their understanding in multiple ways.

Screencast technology could be used to transform the learning environment by allowing students to take ownership of their learning. Student-created dynamic artifacts can enable teachers to witness students' entire problem solving process. Educause (2006) has defined a screencast as "a screen capture of the actions on a user's computer screen, typically with accompanying audio" (Section: What is It, Para. 1). Once used solely by educators to teach or demonstrate activities on computer screens, screencasting has become a more ubiquitous task for students in classrooms (Yee & Hargis, 2010). Screencasts enable students to document their processing and reflect on their thinking as well as grant teachers access to students' understanding often missed when only written work samples are examined (Soto, 2015). This article describes how screencasting was used as a formative assessment tool during one-on-one interviews both to assess children's mathematical understanding and to promote reflection once students generated their screencasts. The goal of these interviews was to investigate the types of explanations and solution strategies students in the upper elementary grades generated when solving story problems with screencasts. In particular, the aim was to capture their mathematical thinking, rather than correct any problematic conceptions at that moment.

Setting and Procedures

The nine students that participated in this study were recruited from northern California and Florida through a flyer. Students were between the ages of 7 and 10, and they were transitioning into the third through the sixth grade. The interviews took place in late spring and early summer and I conducted them in students' homes, at local libraries, and parent's place of work. The four students from California were all enrolled in Spanish immersion programs where mathematics was taught in Spanish.

Documenting Students' Processes. Using an iPad and the application, *Explain Everything*, students generated screencasts and constructed mathematical explanations consisting of verbalizations, written notations, and gestures (as captured by their use of the pointer). During the one-on-one interviews, students were asked to create two screencasts, a practice version, where they shared their initial thoughts as they solved multiplication and division problems, and a polished version. After students completed their practice screencast, we (the student and myself) reviewed their screencasts. Then, they were given an opportunity to record a polished screencast, which allowed them to reflect on their initial thinking and make changes to their solution strategies if desired. This entire cycle took an average of 20 minutes to complete. As students created their screencasts, I stepped away to give them time and space to solve the problems. However, I stayed close enough to document anything that could not be captured on the screencast, such as students counting their fingers. These screencasts were generated in a one-on-one interview, extending the work by Richards (2012), who explored how students created these artifacts in a classroom setting by themselves and with other students.

Investigating Students' Thinking. After students generated their practice screencast, the student and I watched it together, so I could see how the student solved the problem and provide an opportunity to review what they just created. Once we watched the entire screencast, I asked specific questions to better understand student thinking and encourage reflection on the work (Figure 1). The questions gave feedback (to the students and myself) and the opportunity to slow down the problem solving process so that students could reflect on strategies and make changes as they saw fit. Here I share two examples from the one-on-one interviews to illustrate the process of assessing student thinking and providing opportunities for reflection and revision.

Reflection Questions
Can you tell me about...? *(Something specific about their solution strategy.)* *Note: Because the screencasts were recorded, I could rewind to specific locations that were unclear and ask clarifying questions to better understand the student's thinking.*
Is there another way you could have solved this problem?
What could you have drawn or written to help others understand your thinking or solution strategy?
What did you do well in your screencast?
After students generated their polished screencast, they answered these questions: How was your polished screencast similar to or different from your practice screencast?
Why did you change...? *(Something specific about their practice screencast.)*

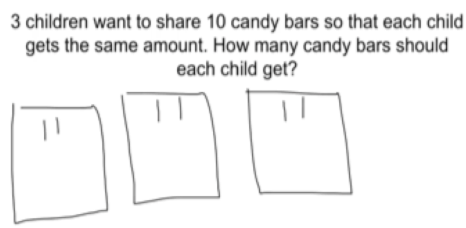
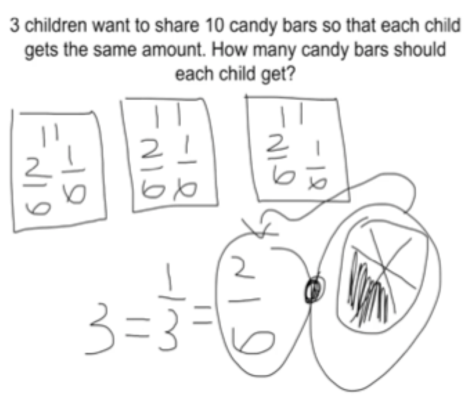
Figure 1. Reflection Questions for Reviewing Screencasts

Student Example – Katie

In the first example, Katie (9 years old and entering the fourth grade) created a solution for an equal sharing problem and, after watching her own practice screencast, expressed some confusion in her final solution. The problem she solved was "3 children want to share 10 candy bars so that each child gets the same amount. How many candy bars should each child get?"

Katie's screencast transcript is presented in Table 2. It contains what she said as she solved the problem, what she wrote on the screen, and the actions she took that may not have been captured on the screen. In solving the problem, Katie drew three rectangles, distributed six tallies by ones (so that each rectangle had two wholes) and then tried to determine how to coordinate the remaining fractional pieces with all the children.

Table 1. Katie's Practice Equal Sharing Screencast Transcript

Time	Verbalizations	Screenshot	Actions
0:00-0:50	Three children want to share 10 candy bars so that each child gets the same amount. How many candy bars should each child get? So I'm gonna make 3 people. 1, 2, 3. So that would be, 1, 2, 3, 4, 5, 6. So then, I don't have enough, cause that would be 7, 8, 9, and then I would have to have another person. So, let's see here.		In black pen, she drew three rectangles to represent the children and distributed one tally mark in each box, until she distributed three wholes. She then went back to the first rectangle and distributed a second tally mark (whole) to each rectangle.
0:51-2:41	So that would be, 3 is equal to 1/3 equal to 2/6, so let's see, that would be, 2 out of the 6, this one would be, would be 1, 2, 3, 4, 5, 6, so that would be 2 out of each, that would leave 4 left, that would be 6, 7, 8, 9. Then I would do, 2/6, 2/6, so then 2/6 and I have 1 left over. So, then I would, let's see here, since I have one left over I can do 1/6, 1/6, 1/6 so that would probably be enough candy bars for each child.		She wrote 3=1/3=2/6 on the bottom of the screen. She then drew a circle, divided it into sixths, and colored two-sixths. She circled her drawing and the 2/6, drew an arrow from the drawing pointing to the 2/6. Then she wrote 2/6 in each of the rectangles and added the 1/6.

Her approach was a non-anticipatory coordination between sharers and shares strategy (Empson & Levi, 2011), meaning she started solving the problem without a plan because she distributed six whole candy bars rather than nine. She then wrote on the bottom of the screen "3=1/3=2/6" and distributed two-sixths and then another one-sixth to each rectangle. Her explanation and reasoning after she distributed the initial six wholes were unclear and difficult to follow. Because of the uncertainty of her explanation after watching her screencast, it was important to ask her specific questions to gain more information and assess her processing and solution strategy.

Once Katie completed her practice screencast, we viewed it. Her solution strategy was difficult to understand and she disclosed that she was unsure of her final answer. Immediately after watching the screencast Katie said, "I don't know if that equaled ten candy bars, 'cause I was kind of mixed up of what I would do." I asked if she could describe step by step her problem solving process and she provided the following verbal explanation,

> First I wrote out the boxes and I knew that I had 10 so I would put 2 in each, but that would only be 6 and I had to do 7, 8, 9, 10. And if I was able to, that would be four children and then I would have to have another child. And well, I couldn't do that because it was supposed to be on the equation. So I wrote down two-sixths because that would be like two for each. That would be 6, 7, 8, 9, 10, 11, 12. Oh! I see what I did, it was 12 in each and then I added more, it would be the wrong equation. It was a good thing that I did practice but now I know what to do.

Not only did Katie provide a more detailed description of what she did, but also by talking through her problem solving process, she realized she made a mistake. She began by discussing how she distributed the first six wholes, then she referred to the problem and indicated that if she distributed the extra four whole candy bars evenly she would need another child, which was not specified in the problem. She also provided evidence to suggest that she considered the numerators of the fractions to be distinct counting numbers, "two-sixths because that would be like two for each."

Reviewing Screencasts and Reflecting on Work. In the process of verbally explaining to help me understand, it appeared that retelling her solution strategy helped Katie make sense of the problem. When she said that the two-sixths equaled 2, she recalculated and determined that if each child already had 2 wholes and they received an extra 2 sixths, which she understood to be 2 wholes, then she would have distributed 12 wholes, 4 wholes to each of three children, which was more than the 10 candy bars the problem stated. After this revelation, she said that she was glad she created a practice screencast and knew what to do to solve the problem for the polished screencast.

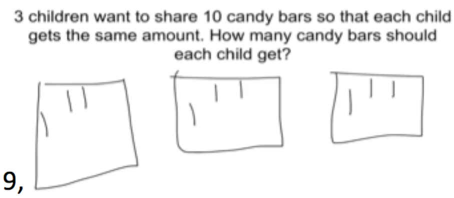
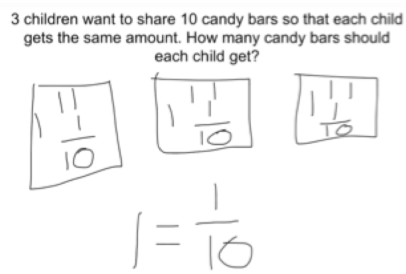
This highlights the importance of reviewing students' work with them and continually asking students to explain their solutions to slow down the problem solving process. Often students are asked to solve problems and move on, as with many drill and practice apps on tablets. The immediacy of being able to play back the screencasts enabled me to see how students solved the problems, discuss their solution strategies, and gather more evidence of their mathematical understanding.

For the students, the playback and interaction that followed gave them the opportunity to reflect on the problem and make changes for their polished screencast. Katie was unsure of her answer after generating her practice screencast, which she told me after we viewed it. She could have been unsure about her answer prior to replaying her screencast, although we do not know. However, after reviewing her work, she still was not satisfied with her answer, which gave the opportunity to revisit the problem, ask her more questions, and allowed her the time to talk through it and realize she had an error.

Generating Multiple Screencasts of the Same Problem. For Katie's polished screencast, she quickly began solving the problem in a similar manner as her practice screencast (see Table 3, next page). She drew three rectangles and distributed nine tally marks by ones. When she reached nine she explained that if she distributed the last tally mark, there would be two children without a fourth candy bar, making it unfair. This was a change from her previous screencast where she only distributed two wholes to each child.

This time, the left over whole was divided, but rather than dividing it into thirds and giving each child one-third of the final candy bar, she indicated she would give each child one-tenth. This indicated to me that although Katie knew each child could not receive another whole candy bar, she may not have known what to call the fractional piece or was unsure how large that piece would be. Like the previous problem, she did not specify how much each child would receive, just that they would get the same amount and she believed it equaled the ten candy bars that were shared.

Table 2. Katie's Polished Equal Sharing Screencast Transcript

Time	Verbalizations	Screenshot	Actions
0:00-0:34	Three children want to share 10 candy bars so that each child gets the same amount. How many candy bars should each child get? So I'm gonna write out 3 little kids, 1, 2, 3. I'm gonna put 1, 2, 3, 4, 5, 6, 7, 8, 9, if I did another 1 for a different child, that would leave 2 kids out.		Used the black pen and drew three rectangles. Then distributed tally marks by ones to each group.
0:35-1:07	So, since I have one left, I could break that up into, 1/10, cause there's 10 in each. So I do 1/10, 1 out of 10, 1 out of 10, so that would be 3, that would be 9 plus 1 for each would equal 10. So each child will get the same amount.		She wrote ``1=1/10'' at the bottom of the screen. Then wrote 1/10 in each of the rectangles.

Students did not always produce correct answers after our discussions or creating their two screencasts. However, there were times when students did correct their solution strategies after reviewing a practice screencast.

Student Example – Olivia

In the following example, Olivia (9 years old and entering fifth grade) incorrectly solved a partitive division problem in which 92 balloons were placed into 4 bunches. For her answer she multiplied the two numbers and indicated each bunch would have 368 balloons (Figure 1). After viewing her screencast, Olivia quietly said, "Oh, ok." When I prompted her to explain why she responded this way, she said, "No, I think I got it wrong? Because it says how many balloons are in each bunch and they [sic] can't be that much balloons in each bunch." She found the product of the two numbers with ease but realized that her calculations resulted in a solution that was too large for the context of the problem. I asked her if there was another way she could solve the problem and she indicated she could try dividing.

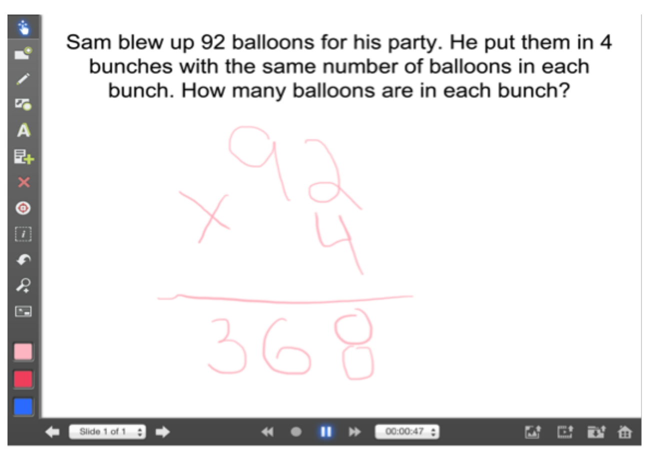
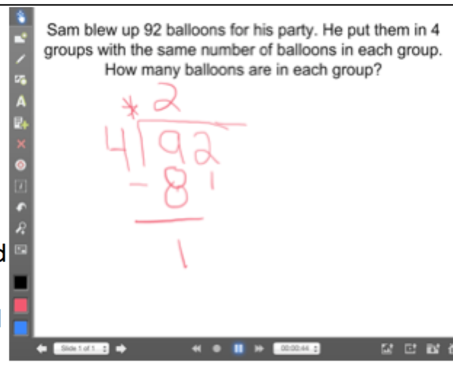
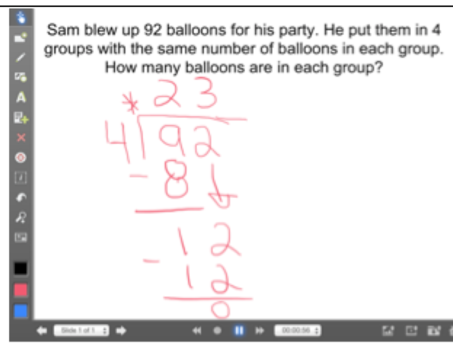
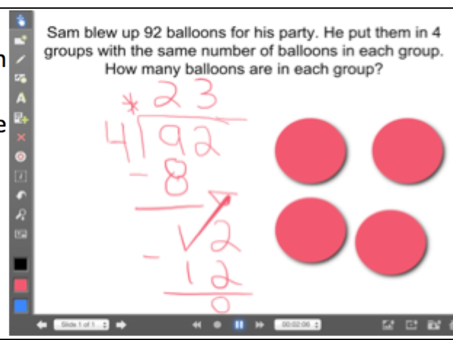


Figure 2. Screenshot of Olivia's Practice Screencast

In her polished version, Olivia solved the problem using the traditional division algorithm (Table 4, next page). Once she finished creating her screencast, she said, "That makes more sense." When I asked her why it made more sense, she indicated, "Because it's not that much? [in each group]."

Table 3. Olivia's Polished Screencast Transcript

Time	Verbalizations	Screenshot	Action
0:00-0:45	So Sam blew up 92 balloons for his party. He put them in 4 groups with the same number of balloons in each group. How many balloons are in each group? So then I will try to divide to get the answer. So, 4 divided by 92 will get me the answer. So 4 times what will get me to 9? Um, 4 times 2 will get you 8, so that's close. Then that would get 1.		Using the red pen, she wrote a traditional division problem, 92 divided by 4. Wrote the two above the nine; wrote an eight below the nine and subtracted; wrote a one as the remainder.
0:45-0:57	Bring down the 2 will give me 12, 4 times 3 will give you 12. So then there's zero left.		Drew an arrow for how she "brought down" 2 next to 1, wrote 3 above the 2 in the 92(dividend), multiplied the 3 and 4 (the divisor) to produce 12, and wrote under the prior 12, subtracted and wrote a zero as the remainder.
0:58-2:17	Then in the 4 groups there are 23 in each group. In each group so Sam and the 4 groups has 23 and that is the answer. That makes more sense.		Using the Shape tool, she made four red circles. She then used the laser pointer and made a circle motion in each circle as she indicated that they each would contain 23 balloons.

Conclusion

The two examples, with Katie and Olivia, illustrate how allowing students to view their screencasts could be beneficial in helping students reflect on their thinking. This reflection may not result in a correct answer, however it provides students the opportunity to revise their work and make mistakes. This ability to revise their screencasts could be an incentive for students and it may encourage them to take risks and try a new solution strategy.

Encouraging students to generate multiple screencasts for one problem also enables teachers to compare the screencasts to identify changes the students made and patterns of misconceptions. In Katie's case, she distributed more wholes in her polished screencast so that each child received three whole candy bars, however, she continued to incorrectly name the fraction of a candy bar each child would receive. In classrooms, screencasts could be used in multiple ways to assess students' mathematical thinking. Students could rotate days they generate screencasts, groups of students could co-construct explanations and presentations, or perhaps resource teachers or volunteers could work one-on-one with students as they record their screencasts. Although screencasts are complex data, they provide valuable information that could help guide instruction.

By reviewing students' in-the-moment processing, posing questions embedded in the students' work, and allowing students to generate multiple screencasts, students' mathematical understanding can be accessed in greater depth than previously without the technology. Not only can screencasts provide teachers with possible opportunities to assess their students' in-the-moment processing, but students too could learn valuable self-assessment skills. As indicated by the NCTM's (2013) position statement on the use of formative assessment in mathematics classrooms, students must take an active role in their learning by assessing their understanding.

Technology extends beyond mere drill and practice in mathematics classrooms. With screencasts, teachers can assess the problem solving process as it happens and support students in building metacognitive skills.

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