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Elementary Students' Mathematical Explanations and Attention to Audience With Screencasts

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Abstract

Reasoning and constructing mathematical explanations for an audience have become increasingly important activities in elementary classrooms with the implementation of reform-oriented curriculum and standards. Mobile learning tools and applications, such as screencasts, allow students to generate multimedia presentations of their solution strategies. Nine elementary students were interviewed as they generated screencasts to solve mathematics problems on a mobile tablet. A rubric was used to analyze 45 student-generated screencasts to investigate the characteristics of their explanations. The majority of students constructed explanations that described the procedures of their direct modeling strategies. Students' determination to be understood by the viewer appears to be a viable prediction for this approach. Students also provided evidence of attending to the audience in other ways, such as assuming teacher personas and adjusting their explanations to improve clarity. (Keywords: audience effect, mathematical explanations, modeling strategies, screencasts)

With the implementation of reform-oriented curriculum and the Common Core State Standards (CCSS) in 43 states across the United States, what it means to actively engage in mathematics has changed in schools (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). Rather than a focus on computational fluency, increased attention is on students' constructing mathematical arguments or explanations and analyzing the reasoning of others. When students engage in these activities and communicate them to others, "they learn to clarify, refine, and consolidate their thinking" (National Council of Teachers of Mathematics, 1989).

Recently, the National Council of Teachers of Mathematics (NCTM) released *Principles to Action* (2014), in which it reaffirmed its commitment to improving mathematics education. In this document, the NCTM described six guiding principles, which highlight and update areas of best practices for mathematics education. One of those guiding principles, Tools and Technology, states, "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" (NCTM, 2014, p. 4). With advancements in technology, the use of tablets and mobile learning tools has increased in classrooms around the world to support learners and promote engagement (Hargis, Cavanaugh, Kamali, & Soto, 2014). In terms of mathematics, mobile learning tools have allowed researchers and educators to examine students' mathematical reasoning (Soto & Ambrose, 2014), and students can now communicate and represent their reasoning in ways not previously possible. Screencasts seem to be a particularly promising way to take advantage of mobile technology in classrooms.

Educause (2006) describes screencasts as "a screen capture of the actions on a user's computer screen, typically with accompanying audio." New mobile learning tools now allow users to generate

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screencasts with more accessible applications (apps). Screencasting is not new to education, as educators have created them to enhance their recorded lessons for students enrolled in distance learning courses or to provide feedback to students (Educause, 2006). Many readers may be familiar with the website Khan Academy, at which students can view screencast tutorials on a variety of topics. Generally, educators have used screencasts to "teach" different concepts to students (Yee & Hargis, 2010). The missions of many screencast developers have been to democratize learning and offer an open source of information for anyone to access. However, the majority of screencasts located on these websites duplicate the traditional top-down, behaviorist approach to teaching and learning, in which the teacher or expert is the keeper of knowledge and dispenses that knowledge to others. As a result, most screencasts do not substantially transform lessons; rather, they tend to be a mere substitution of a traditional form of teaching, for example, a lecture (Puentedura, 2013).

To align with the CCSS and the NCTM, students could use screencasts to communicate their understanding and processing to others. Because this technology captures student solutions in real time and in a format that contains their written work, gestures (with the use of the laser pointer), and verbalizations all in one, teachers gain a sense of not only a student's final answer, but also how that student was processing as he or she solved the mathematical problem. Students can also benefit from generating screencasts as they construct mathematical explanations while they solve problems and communicate their reasoning. These explanations are documented and could be viewed by the students themselves, a peer, their teacher, or others at a later time. This potential for an audience could encourage students to be purposeful in how they represent and communicate their thinking, as well as to reflect on their understanding.

Given the increased use of screencasts in the classroom, this investigation sought to investigate the mathematical explanations students construct when they generate screencasts. Also, as screencasts record students' verbalizations, notations, and gestures that can be reviewed by a variety of audiences at any given time, how students' expressed an awareness of a potential audience was also examined. The following research questions guided this investigation: What types of mathematical explanations do students construct when they generate screencasts to solve story problems? In what ways do students attend to the potential audience when generating mathematical screencasts?

Literature Review

One reason for encouraging students to construct mathematical explanations is for learning purposes. In the following section, students' learning when generating explanations for themselves and others will be discussed.

Verbalizations/Explanations in Learning

Ericsson and Simon (1998) distinguish between two methods of verbalizing thought processes. In one process, the think-aloud, individuals are instructed to verbalize their thoughts as they perform a task. In the second process, a more reflective form of verbalization, individuals provide explanations and descriptions of their thoughts once they completed a task. The verbalizations produced through the think-aloud process were described by Ericsson and Simon (1998) as disjointed speech segments that may contain speech errors. These types of verbalizations have been referred to by Chi (2000) as "a dump of the content of working memory" (p. 170). Since individuals are instructed to focus on the task and think out loud, these verbalizations most closely describe what individuals are actually thinking. Think-aloud protocols have been shown to assist students as they encode information and learn concepts they may not completely understand (Chi, Bassok, Lewis, Reimann, & Glaser, 1989).

On the other hand, when individuals are asked to provide explanations after they have completed a task, this process is more social and reflective in nature. Participants may be more deliberate in making their verbalizations clear and coherent, and in utilizing common referents, after they have completed tasks and have had time to reflect. Ericsson and Simon (1998) claim that although the postactivity, reflective explanations provide valuable information, these explanations are filtered and may not accurately describe the individual's thought process. Thus, these two forms of verbalizations, think-aloud and reflective explanations, offer different insights into an individual's processing.

Learning When Explaining to Others

Researchers investigating explanations, particularly during peer tutoring sessions, suggest that explaining to others can be as or more beneficial to one's learning than solely explaining to oneself (Chi, 1996). A consistent finding in tutor learning studies indicates that learning occurs in both the tutee and the tutor (Roscoe & Chi, 2007). Ploetzner, Dillenbourg, Praier, and Traum (1999) have suggested that preparing to teach others resulted in more learning in the tutor rather than explaining to others. However, others hypothesized that generating explanations for others, such as tutors do for their tutees, "helps tutors *metacognitively reflect* upon their own expertise and comprehension, and *constructively build* upon their prior knowledge by generating inferences, integrating ideas across topics and domains, and repairing errors" (Roscoe & Chi, 2007, p. 541).

It would appear that talking and generating an explanation for others, whether prompted or not, can increase learning (Chi, 1996). Roscoe and Chi (2004) have further claimed that explaining to live tutees, who respond to the tutor's questions and explanations, affects learning the most, rather than tutoring to an anticipated audience. In their study, when tutors were asked either to teach a lesson face-to-face or to videotape themselves explaining, those tutors in the face-to-face condition performed better on posttests than those in the videotaped session. However, only the scores on the definition posttest were statistically significant when pretest differences were controlled. The posttest scores on the short-answer, deeper learning sections were not significantly different. It would appear then that either an actual audience or the potential for an audience could be beneficial for the explainer's deep, conceptual learning.

Specifically in mathematics, explaining to others has also been beneficial in learning. Rittle-Johnson, Saylor, and Swygert (2008) investigated whether children as young as 4 and 5 years of age benefited from generating explanations of patterns to others. Students who explained their solutions to their mothers learned more, as assessed through problem-solving posttests, than those who simply repeated the answer or explained to themselves. This study suggests that even if the audience does not provide feedback, students still benefit from explaining to others.

Mathematical Explanations and Representations

In the context of mathematics, verbalizations may not suffice in gaining a full understanding of the concepts being studied or accurately communicating one's knowledge to others. Schleppegrell (2010) stated, "A key challenge is that mathematics incorporates a symbolic language that developed out of natural language and also uses visual display to construct complex meanings" (p. 74). Not only are verbalizations important, but so are nonverbal aspects of mathematics when analyzing students' explanations. In the context of this study, the word "explanations" encompassed verbalizations, mathematical symbols, drawings, and gestures produced to convey the student's thinking.

As communication and justifications continue to take more prominent roles in mathematics classrooms, what is judged to be a mathematical explanation is important to consider. Carpenter, Franke, and Levi (2003) indicate that

> Students who learn to articulate and justify their own mathematical ideas, reason through their own and others' mathematical explanations, and provide a rationale for their answers develop a deep understanding that is critical to their future success in mathematics and related fields. (p. 6)

By generating explanations, students are better able to process the mathematics they are learning. However, to have the most impact, mathematical explanations should have certain characteristics. As discussed by Kazemi and Stipek (2001), mathematical explanations should contain not only details as to how the problem was solved, but also justifications as to why the problem was solved in a particular way. Not only can mathematical explanations be communicated verbally, but as Kazemi and Stipek (2001) and Schleppegrell (2010) described, students can also represent their thinking in various ways such as with mathematical symbols, drawings, and charts to express their mathematical understanding. Finally, "doing mathematics" is more than solving problems one way and moving on. Rather, norms should be established that allow students opportunities to reflect and generate multiple solution strategies and representations, which can be communicated through students' mathematical explanations.

NCTM (2000) defines mathematical representations as the process of generating concepts or relationships, to the final product. It is through creating representations that students organize, record, and communicate their mathematical understanding. These representations can take the form of concrete manipulatives, diagrams, charts, symbols, and written language. Technology has facilitated the way some mathematical concepts are experienced, communicated, and represented. In one example, students' use of virtual manipulatives led to increased conceptual understanding of fractions (Reimer & Moyer, 2005). In terms of screencast technology, students not only communicate their thinking and reasoning but also to take ownership of their learning by deciding when and how to share their work and to make revisions (McLeod, Lin, & Vasinda, 2012).

In this investigation, elementary students' screencasts were examined for the types of explanations they constructed. Also examined were the ways students attended to the potential audience as they constructed their mathematical explanations, as this could be a possible venue for increased mathematical learning.

Methods

Student participants were recruited through convenience sampling from a small rural town in northern California and a large metropolitan city in northern Florida. Since this investigation was descriptive in nature, it is not intended to generalize to the larger population. To recruit student participants, a flier containing information about the study was distributed to parents in the community. Students were interviewed in their home, at their parent's place of work, or at a public library.

Participants

In total, nine students participated in the study, four from California and five from Florida. Students' were between the ages of 7 and 10 years, and they ranged from third to sixth grade. Six participants were girls and three were boys. Three were Latina, one was African American, one was Asian American, and four were White. One out of the nine students was diagnosed with autism. All four students from California were enrolled in Spanish immersion programs where mathematics was taught in Spanish. These students were given the option to have the interview conducted in Spanish, which one student initially selected. The story problems were presented to her in Spanish; however, she later decided to solve the problems in English.

Research Design

The research design for this study took the form of one-on-one clinical interviews with the interviewer and student (Ginsburg, 1997). Prior to the first interview, all students participated in a 30-minute, one-on-one app training session to familiarize themselves with the options available on the app. Each option had a small icon along the left hand side of the app, and one by one, the interviewer described the function of each option. After each explanation, the interviewer requested that the student complete a task to practice using the option (Table 1). Once they completed the app training, students were given a sample multiplication problem to solve, and were to generate a screencast and practice using the options they learned. While generating this screencast, students were encouraged to talk and explain their thinking as they solved the problem. Students did not see an example of a screencast that might have influenced their work.

Table 1. Explain Everything App Options and Student Tasks During App Training Session

App Option	Student Tasks
Pen	Student will adjust the width of the pen tip, change the pen color, and use the stylus to write something, such as their name, on the screen.
Eraser	Student will erase part of something they wrote on the screen.
Shape	Student will select a shape (circle, square, arrow, line, or star), place the stylus on the screen to create the shape, and drag the stylus across the screen to enlarge or shrink the shape.
Duplicate	Once the student has created the shape, she will make two or more copies of the shape.
Text	Student will type a sentence on the screen. Once the text appears on the screen, the student will move the text by dragging it to another location.
Pointer	Student will select a pointer (an arrow, a laser, or hand) and drag it across the screen.
Record	After completing the above tasks, student will record a solution to a multiplication story problem (8×7) and incorporate some of the options she learned.

After the app training session, each student participated in a one-on-one hour-long clinical interview. During this session, students generated screencasts on an Apple iPad using the Explain Everything screencast app and solved story problems that were typed and saved ahead of time on the screens. The story problems students solved included multiplication, partitive division, and equal sharing problems. The multiplication and partitive division problems students solved were used in a previous professional development project, while the equal sharing problems came from Empson and Levi (2011). Smaller number choices were selected for students entering the third and fourth grade and larger number choices were selected for students entering the fifth and sixth grade. However, if a student struggled with a particular set of numbers, the number choices were adjusted. If a student quickly solved a problem, larger numbers were given.

Students participated in one of two versions of the interview session; two students from Florida participated in both versions. In the first version of the interviews, students solved a multiplication, a partitive division, and an equal sharing problem, and generated two screencasts (a practice and a polished version) for only the equal sharing problem. In the second version of the interviews, students solved a partitive division and an equal sharing problem, and generated two screencasts (a practice version and a polished version) for both problem types. The practice version contained students' raw, initial thoughts, and in the second, polished version, students were able to revise their explanation. In essence, the initial screencasts represented a window into the students' thinking in the moment of problem solving. The second screencast could be useful for students to generate as they could revise their thinking, gain a deeper understanding of what they know about the problem, or perhaps communicate their explanations in a way that others could understand.

Before solving the problems, each student was told she was going to solve a story problem that was already typed on the tablet. The interviewer expressed that the student should show her work on the screen and talk about the problem, the answer, and her thinking. After these directions, the student read the problems out loud and the interviewer answered any questions she had about the context or specific words in the problem. When the student was ready to solve the problem, she pressed the record button, read the problem out loud again, and solved the problem. Although in typical clinical interviews the researcher stays in the presence of the participant, during this investigation, once students pressed the record button to generate their screencasts, the interviewer stepped away. The interviewer was close enough to view and record any movements students did that were not captured by the audio recordings, but far enough away to not interfere with the recordings and to blend in with the environment.

Once the student finished recording her screencast, she notified the interviewer and they viewed the work together. When students generated two screencasts for the same problem, the interviewer asked each student to reflect on the work and describe any changes she wanted to make for the next polished screencast. Students were also asked to explain their thinking as if they were sharing their solution strategy with a peer. After recording the second, polished screencasts, students reviewed their work and compared their first and second screencasts.

The interviews were audio recorded in their entirety on an Apple iPod Nano digital recording device. Field notes were also taken to capture gestures that were not captured by the audio recording. After the students participated in the interviews, their screencasts, the audio recordings, and field notes were transcribed, analyzed, and used to inform subsequent interviews.

Data Analysis

Data analysis began with the transcription of the interview audio recordings. Interviews were transcribed in full to retain the students' words for future reference (Seidman, 2006). These verbal explanations were transcribed first from the audio recordings and then checked against the screencasts to ensure accuracy. The transcripts were the start of the screencast transcript tables for each student's screencasts. These tables contained four columns: Time, What was said, What was written, and Screenshot. Because screencasts are a dynamic artifact, it was difficult to capture all the nuances they contained. These transcript tables were one attempt to slow down the action into segments for readers.

The screencasts were broken into segments and organized into rows to generate the screencast transcript tables. Screenshots of the screencast were taken every time the student finished writing or drawing a meaningful piece on the screen. A meaningful piece included the final notations that the student generated after solving an equation, the final drawing that the student created, the notations prior to erasing, or use of a particular tool. These screenshots were inserted into the screencast transcript tables in the final column labeled "Screenshot." The screencasts were viewed again as the transcripts were read. The words that were spoken up to the point where the screenshot was taken were then pasted into the column labeled "What was said." The length of each segment was tracked and the start time and finish time were included in the column labeled "Time." The screencasts were then viewed a third time with particular attention to the student's actions, what color or tools the student used, how the student used the pointer, what the student erased, or the student they counted or distributed objects. This information was written in the column labeled "What was written." Included in this column, were field notes that described additional gestures made by the student that were not captured by the screencast or audio recording.

Type of Explanation	Procedures: Concurrent	Procedures: Retrospective	Procedures & Justifications: Concurrent	Procedures & Justifications: Retrospective			
Solution Strategy	Algorithm	Direct Model	Trial and Error	Counting	Derived Fact or Invented Algorithm	Fact	
Congruency of Explanation	Verbalizations, No Notations	Notations, No Verbalizations	Verbalizations & Notations Misalign	Verbalizations & Notations Align, Misalign with Mental Strategy	Verbalizations & Notations Align		
Final Solution	Incorrect Solution	Started with Correct Strategy, Ended with Incorrect Solution	Partially Correct	Started with Incorrect Strategy, Ended with Correct Solution	Correct Solution		
Tools Used	Zero	One	Two	Three	Four	Five	Six

Figure 1. Screencast observation rubric.

Screencast Observation Rubric

Once the audio recordings were transcribed and the screencast transcription tables were generated, notes, observations, and interpretations of the students' explanations were added, which turned into codes (these codes are subsequently described and illustrated in Figure 1). These codes were guided by previous literature, specifically, the types of explanations, for example, procedural or procedural and justifications (Kazemi & Stipek, 2001), whether these explanations were concurrent—occurred as students were solving the problem, or retrospective—occurred after the student finished solving the problem (Ericsson & Simon, 1998), the students' solution strategies (Carpenter, Fennema, Peterson, Chiang, & Loef, 1989), the congruency of the student's verbalizations and the student's written notations (Schleppegrell, 2010), whether the student correctly solved the problem, and the number of tools used. Summaries were generated that described the content of each screencast and the interactions that occurred after students recorded their screencasts. Using these summaries, a screencast observation rubric (SOR) was developed and used to analyze and generate a visual summary of all the students' screencasts based on each problem (Figure 1).

Type of explanation. The first category was labeled Type of Explanation and described the verbal explanations students generated in their screencasts. Student explanations that consisted of only procedures focused entirely on how the problem was solved. Those categorized as procedures and justification described how the problem was solved and why the students solved it the way they did (Kazemi & Stipek, 2001). Those explanations that were produced while students solved problems were categorized as concurrent (Ericsson & Simon, 1998). Explanations produced after students solved the problem were categorized as retrospective.

Solution strategy. The second category was labeled *Solution Strategy* and described the strategies students used to solve the problems. The solution strategies were based on research on the trajectory of children's mathematical solution strategies (Carpenter et al., 1989), for example, algorithm, direct modeling, trial and error, counting, derived fact/invented algorithm, and fact.

Congruency of explanation. The third category was labeled Congruency of Explanation, which described whether the verbalizations and the written notations generated by students aligned.

Final solution. The fourth category was labeled Final Solution, which described whether the students correctly solved the problem or whether the students' solution strategies were incorrect or correct.

Tools used. The fifth category was labeled Tools Used, which quantified the number of tools on the app the students used while solving the problem. The different tools that were available for the student to use were the drawing pen, pen color change, shapes, duplicate tool, pointer, text box, eraser, zoom function, and add a new slide tool. Although this category quantifies how many tools were used, it did not provide any information on how and when the students used the tools.

Student-generated screencasts are dynamic and complicated. The SOR was intended to be formative in nature and focus on the content and mathematics included in the screencasts. Even though the SOR helped organize and provide an overview of students' processing and understanding, it did not capture everything. It was still necessary to examine students' screencasts to grasp all the nuances of their thinking, problem solving, and language use. Using these five categories, all participant screencasts were analyzed using the rubric. Each students' interview session was assigned a particular color, each problem type was assigned a particular shape, and an outline represented whether it was the student's second or third attempt (see Figure 2).

The shapes in Figure 2 represent the different story problem types. The multiplication problem was assigned a square, partitive division problems were assigned circles, and the equal sharing problems were assigned ovals. If students solved the problem more than once, their shapes were given an outline to distinguish these from the other problems they solved. For example, when a student solved the problem once, the shapes did not have an outline. The black outlines represented the second attempt at solving a problem and the gray dotted outline represented the third attempt at solving a problem. All 45 of these markings were placed on a master SOR, which produced a visual of the most common attributes that were contained in the students' explanations.

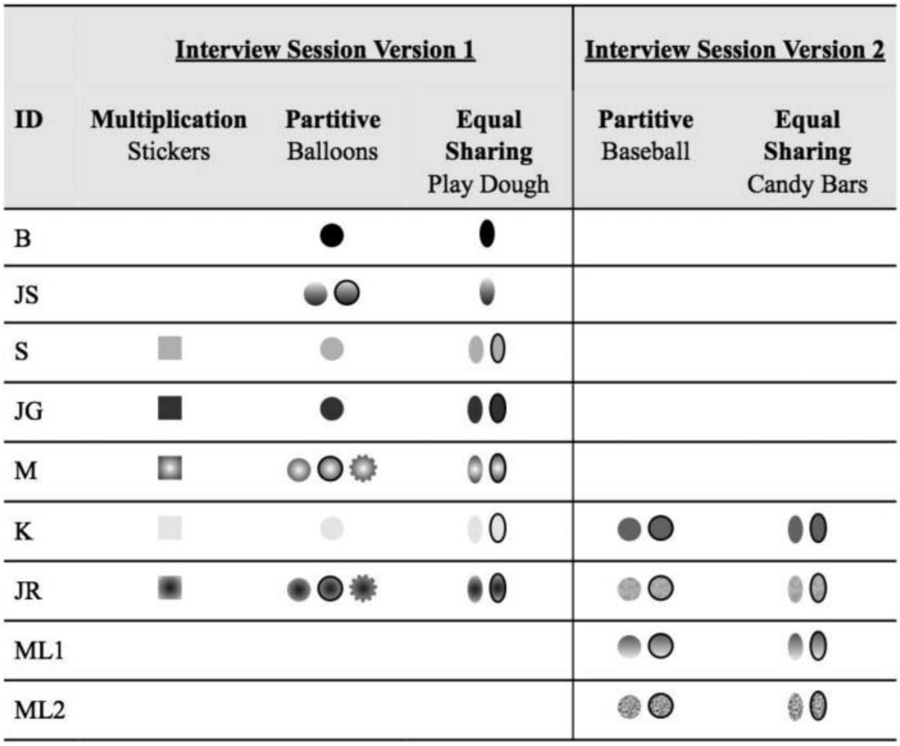


Figure 2. Students' screencast markers by session and problem type. Each student's interview session was assigned a specific color. Squares represent multiplication, circles represent partitive division, and ovals are sharing problems. Black outlines represent second attempts; gray dotted outlines show third attempts.

Student Discourse

Once the summaries were generated, they were analyzed and coded for discourse functions. These codes included use of pronouns, beginning and ending of explanations, contrasting and emphasizing, turn taking, and attention getting (Cassell, 2000; Romero Trillo, 2001). Nonverbal gestures, specifically those conveyed through the pointer, were also analyzed to investigate additional information communicated in the explanations.

Results

The goal of this investigation was to examine the types of explanations students construct when they generate screencasts to solve problems and in what ways students attended to the potential audience. All students' screencasts were analyzed using the screencast observation rubric (SOR), and some patterns, variations, and differences in the categories are next discussed. Based on these results, an example screencast that contained the most common attributes is shared. Then instances in which students assumed teaching personas as they explained their mathematical thinking are discussed, as well as when a student explicitly adjusted her explanation to accommodate the audience.

Types of Mathematical Explanations

Once all 45 student-generated screencasts were analyzed using the SOR, the cells in each row with the most data were determined to be the most common attributes in students' explanations. The data in Figure 3 indicate that the representative explanations students generated with screencasts were procedural mathematical descriptions, used a direct modeling strategy, had verbalizations and

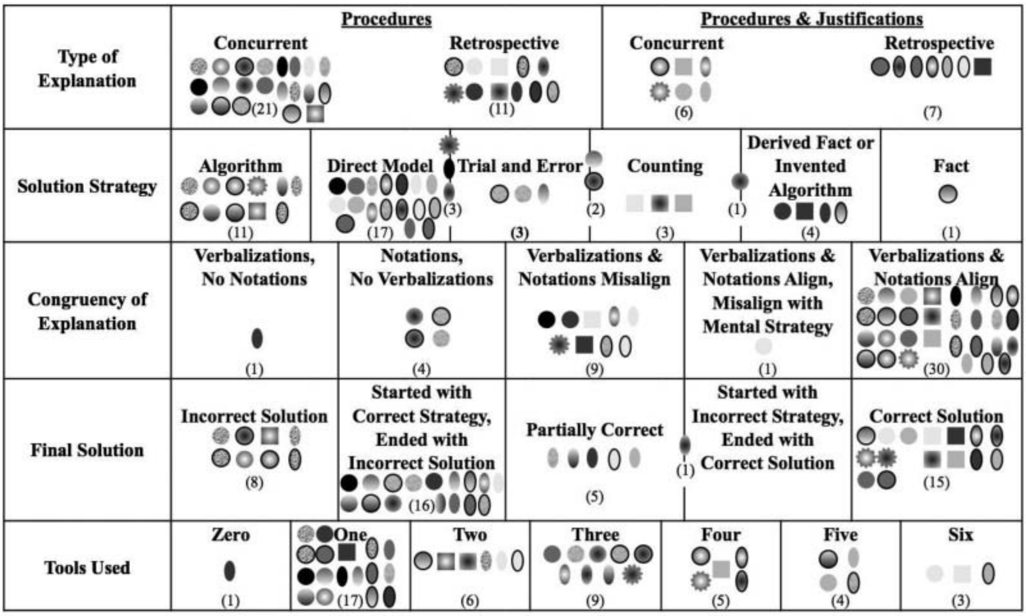


Figure 3. Screencast observation rubric: summary of student data. Each student's interview session was assigned a specific color. Squares represent multiplication, circles partitive division, and ovals sharing problems. Black outlines represent second attempts; gray dotted outlines show third attempts.

notations that aligned, and resulted in correct solution strategies, but the student produced either an incorrect or a correct answer, and used only one of the app options.

Of the procedural descriptions, more students spoke as they solved problems, which provided a running record of their thoughts and actions. These explanations were coded as concurrent procedure explanations. However, of the 18 screencasts that were categorized as retrospective, eight were categorized as such because students did not talk while they wrote down their notations. Rather, these students gave a verbal explanation after they finished solving the problem and described what they did.

The students' verbalizations and notations aligned in 30 of the 45 screencasts, which indicate that what students said they did matched with what they wrote on the screen. Students were also more likely to use a direct modeling solution strategy in which they used drawings or shapes to model the action in the problem. For their final solutions, students used a correct strategy and solved the problem, or they went astray and their final solution was incorrect. Also, students mostly used one tool on the app, the drawing pen, when solving problems.

Differences Between First and Second Screencasts

On 16 of 27 occasions, students generated more than one screencast to solve a problem. When analyzing changes between just the first and second versions of the screencasts, there were some differences in terms of procedures versus procedures and justification explanations and between concurrent versus retrospective explanations. Nine students produced a procedures explanation during their first screencast and did the same for their second screencast. Five students changed their type of explanation from procedures in their first to procedures and justifications in their second screencast, while two students had a procedures and justification explanation in their first and also their second screencast. The five students who changed their explanations between the two versions appear to have taken the time to reflect on their solutions and explained it in a way that described "how" and "why" they solved the problems the way they did.

In terms of differences between concurrent and retrospective explanations, more students (eight total) changed their explanations from concurrent on the first screencast to retrospective on the second one. Eight students did not change their explanations, six students had concurrent explanations for both their first and second versions, and two had retrospective for both versions. Upon further investigation, the six students who produced concurrent explanations for both versions of their screencasts incorrectly solved the problem in the first screencast and continued trying to solve the problem in the second version.

Representative Student Example

The following student-generated screencast is a representative explanation. In this example, student JG generated his second, polished version of his explanation to an equal sharing problem involving four children sharing 10 cans of play dough. Figure 4 contains the screencast transcript table. Student JR constructed a retrospective procedures explanation to described what he did to solve the problem. He began by saying that he "did four groups . . . I thought for like a little bit and I thought two." As he said this, he drew four squares and then drew two circles in each square. He then referenced the conversation that occurred after he solved his practice version. During the practice version he also said that each child would receive two cans of play dough. I questioned him about the two remaining cans and he determined that each child would receive an extra half can of play dough. In the second, polished screencast, he included this additional information by saying since he had "two left over dough," he would distributed one half to each square, which he drew as semi circles with the drawing pen tool.

For his explanation, student JG recounted his actions and thoughts in the past tense, "I did four groups," "I thought for a little bit," and "I thought the answer was eight." Although he described how he solved the problem, it was an account rather than an ongoing record of what he thought as he solved the problem. His verbalizations and his notations aligned and they both followed the action in the problem and led to the correct final solution. Student JG only used one tool on the app,

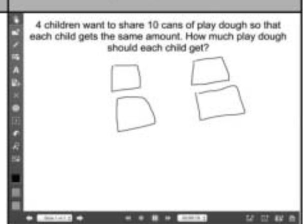
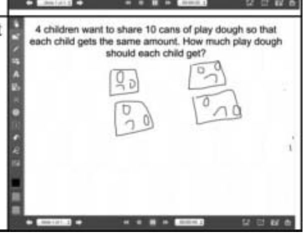
Time	What was said	What was written	Screenshot
0:00-0:17	I did four groups, I usually just draw squares	Used the black pen and drew four unequal sized squares.	
0:18-0:32	and then I thought for like a little bit and I thought two. And then when I thought the answer was eight,	He drew two circles in upper left hand square, then in the square immediately to the right. He then added two circles to the lower left hand square and to the one on the lower right hand side.	
0:33-1:07	then you told me a little bit and then there was only a half. Because there is two left over dough. Like this. So a half a can for all the children and they would each have two more cans. That's all I gotta do.	He drew half circles, starting in the upper left hand square and continued drawing them using the same pattern as above.	

Figure 4. Student JG's second equal sharing play dough screencast transcript.

the drawing pen, to represent how he solved the problem. He used the drawing to communicate how he solved the problem, rather than using it to help him think through it.

If this were the only record of student JG solving the problem, the audience could not be certain whether this account accurately described his thought process. However, this was his second attempt at generating an explanation for this problem, and when compared to his first version, his second explanation was more concrete. In his first version, student JG solved the problem using a derived fact, $4 \times 3 = 12$. He realized that the product was too large for the situation and decided that each person should receive two cans of play dough. Also, in his first version, student JG did not write any notations on the screen; he simply used verbalizations to explain his thinking. Once he finished recording his first version, I asked him if he could represent his thinking and solution on the screen for his second version. As his second explanation was retrospective, student JG may have generated his explanation as a way to teach others less knowledgeable how to solve the problem. This rationale may explain his flexibility in thinking about the problem, solving it in multiple ways, and his attention to the audience. Or, he may not have known how to represent his first solution strategy on the screen and decided to communicate his thinking with a drawing.

In the next section, students' attention to a potential audience while generating their explanations and how some of these explanations assumed "teacher-like" attributes are discussed.

Attention to Audience

Students in this study did demonstrate an awareness of an audience while generating their screencasts in multiple ways. First, five of the nine students generated 18 screencasts in which they not only described how or why they solved the problem, but also assumed teaching personas in their descriptions and "taught" the potential audience how to solve the problem. These instances occurred consistently throughout the five participants' screencasts, meaning they were evenly distributed between their first or second screencast and throughout the interview. This persona was defined in many ways, such as using "we" versus "I" pronouns in their explanations. For example, when student S began most of her explanations by saying, "so what we need to do is divide" (student S Balloons Transcript), this suggests she intended to include the audience and demonstrate how to solve the problem. Students also included specific beginning and endings to their explanations, such as, "So that's what I taught you today" (student K Play-Dough two Transcript). Some of the students included attention getting statements that encouraged the audience to attend to the explanation, for example, "Pretend this is the candy bar and we will cut it like this" (student JR Candy two Transcript). In other instances, students contrasted representations. In the next example, student S distributed two cans each of play dough to four children and had two cans remaining. She indicated that if she distributed the remaining two cans to the first two children, whom she represented as circles, "it wouldn't be fair," because "these two circles [the last two children] wouldn't have third ones, right?" (student S Play-Dough two Transcript).

Another way students' attention to the audience took on a teaching persona was when they emphasized certain points by using the pointer option on the app. When explaining a solution to someone standing next to them, students are able to point to different notations on their paper or refer to the problem. However, when students point to something on the screen, the audience watching the screencast cannot see what the students reference. Students used the pointer to emphasize what they wanted to reference on the screen without adding additional stray lines. Sometimes, when students counted dots or objects on the screen, they used the pointer to draw attention to the objects that were being counted. Students also used this tool to emphasize what would occur if they completed particular actions. For example, in the preceding quote by student JR where he wanted the audience to "pretend," he used the laser pointer to "cut" the rectangle he drew on the screen into fourths.

Second, the attention to a potential audience may have the potential to help students generate clearer explanations. For example, student K changed her representations as she solved a partitive

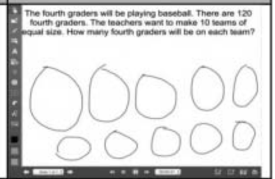
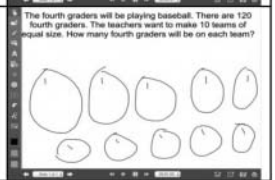
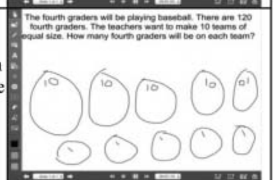
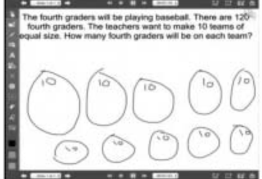
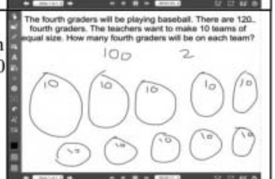
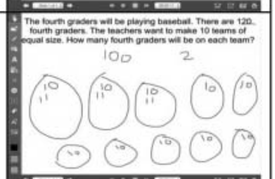
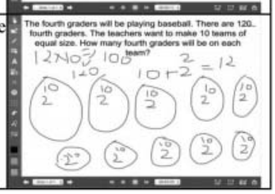
Time	What was said	What was written	Screenshot
0:00-0:47	The fourth graders will be playing baseball there are 120 fourth graders. The teachers want to make 10 teams of equal size. How many fourth graders will be on each team? So. I would have to, let's see here. I'm gonna make 10 teams. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.	Used the black pen and drew 10 unequal circles in 2 rows, 5 in each row.	
0:47-1:03	So there's 120, each team so that's. Can do, let's see, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.	Drew a tally mark in each circle.	
1:06-1:43	I'm just gonna put 10 in each. There's 10. 10, 10. So if I split, so if I would split 20...	She transformed the tally marks into tens by added a zero in each circle. In the fifth circle, she wrote the zero in front of the one. She then used the eraser to change the "01" to "10." She finished making all the tens in the circles. Then she used the arrow pointer and circled the 120 in the problem.	 
1:43-2:11	I have 100 right now and if I split 20, that would be 5, 10, 15, 20, no. 2, 4, 6, 8, 10 (inaudible). So I would split 20 into 2.	She used the black pen and wrote the number 100 on the screen. Then wrote the number 2 on the screen when she said she would split the 20 into 2.	
2:11-2:46	That'd be. 2, 2, 2, wait that looks like 11. 2, 2, 2, 2, 2, 2, 2, 2, 2, 2.	She then added 2 tally marks under the 10 in each circle. After drawing the two tally marks in the first three circles, she erased them and then wrote the numeral two in each circle.	
2:46-3:23	So that would be saying 10 plus 2 equals 12 and, um, saying that's this 12, and 12 times 10 equals 120.	She wrote an addition sentence 10+2=12 above the ten circles. Then she finished by writing the multiplication sentence 12x10=120.	

Figure 5. Student K's first partitive division baseball screencast transcript.

division problem (Figure 5). The interviewer did not indicate to student K that she would have an audience for her practice screencast; rather, it was a form of scratch work.

She generated a concurrent procedures explanation as she provided a running commentary of her thoughts and actions while solving the problem. She began by using a direct modeling by ones solution strategy, first drawing the number of teams and commenting that "I'm gonna make 10 teams." After making 10 circles, she distributed the students to the teams by ones using tally marks. Rather than continuing to distribute the students by ones, she decided to transform the tally marks into tens. Once she distributed the tens, she said, "I have 100 right now and if I split 20," suggesting she decomposed the 120, which she circled with the arrow pointer, into 100 and 20. At this point, her verbalizations changed from talking about her actions aloud for the audience to hear, to being more private as she tried different ways to decompose the 20.

She first counted quietly by fives, “5, 10, 15, 20, no,” and decided that was not valid. Her voice trailed off as she counted by twos but then she said aloud, “I would split 20 into two.” She then distributed two tally marks under the 10 already in each of the first three circles, then erased them because they “look like 11,” and replaced them with the numeral two. She then added the 10 and two and finished by writing the number sentence “$12 \times 10 = 120$” at the top of her paper.

The screencast documented how she curtailed her use of individual objects to groups of objects. After student K distributed the first tally marks to each circle, she paused and said, “I’m just gonna put 10 in each” (student K Baseball one Transcript) and changed the tally marks to tens. It was not until she distributed the first 10 tally marks that she realized she could distribute chunks of 10. During the second screencast she generated for this problem she also said “I am going to put 10 in each, I don’t want to just put tally marks because that would be way too hard. So I’m gonna put 10 in each” (student K Baseball two Transcript). This was the first curtailment in her strategy where she transitioned from distributing individual objects to groups of objects.

The second time she curtailed her thinking was when she distributed the remaining two students to each group. She distributed the two students as individual tally marks, again direct modeling by ones; however, after the third circle she paused and said, “wait that looks like 11” (student K Baseball one Transcript). At that point, she erased the tally marks and made the numeral 2. When asked why she changed the two tally marks to the numeral two she said, “Cause those looked like 11, then it would get all mixed up and kids probably won’t know what would be the difference” (student K Audio Transcript). It was here that student K explicitly acknowledged the potential audience and how her explanation might have confused them. It is possible that as student K generated her screencast, her awareness of a potential audience led her to reflect on how her work would appear to them. She curtailed her use of the tally marks and used the numeral 2 to clarify for the “kids” that she imagined might view her work. This change showed advancement in her thinking and might not have occurred without the awareness of the potential audience.

This phenomenon of curtailment while generating screencasts was not common in this study, and because it was not controlled for, it is not possible to claim that generating screencasts will help students curtail their counting because of their awareness of a potential audience. This was an interesting example that leads to more questions as to whether this awareness of a potential audience could lead to curtailment, and further research would need to be conducted to investigate this potential.

Discussion

This investigation examined the types of mathematical explanations elementary students constructed as they generated screencasts while solving multiplication and division story problems, as well as how they attended to a potential audience. Key finding related to each of the research questions are discussed next.

Key Findings

Types of mathematical explanations. Utilizing the screencast observation rubric, 45 student-generated screencasts were categorized by Types of Explanation, Solution Strategies, Congruency of Explanation, Final Solution, and Tools. The most representative mathematical explanation from this data set focused on the procedures students used to solve the problems, rather than on why they solved the problem the way they did. These procedures explanations tended to be concurrent, meaning they were constructed as the student solved the problem. Along with the concurrent procedures explanation, students mostly generated a direct modeling solution strategy by either drawing or using shapes to represent the quantities and modeling the actions in the problems. Students’ verbalizations and written notations were congruent, indicating that what students said they did accurately described how they solved the problem. Students also interpreted the story problems context correctly, as the majority of the screencasts, 36 total, began with descriptions of a correct solution strategy. Although the majority contained viable solution strategies, not all of the students produced correct solutions. However, as students' problem solving was recorded, it was possible to identify where students' thinking went astray and to target interventions (Soto & Ambrose, 2015; Soto & Hargis, 2014). Although students participated in an app training session before their clinical interview to learn about the options available on the app, students mostly used one option, the pen tool with black ink.

In this investigation, students were given the opportunity to use any strategy to solve the story problems. It may be that since students were asked to explain their thinking as they solved the problems and to explain as if they were sharing their solution strategy with a peer, they deliberately used more concrete strategies and focused on what they did to solve the problem to generate clearer explanations. Research investigating the differences between girls' and boys' solutions strategies found that girls were more likely to use and share direct modeling and counting strategies (Fennema, Carpenter, Jacobs, Franke, & Levi, 1998). Two hypotheses suggested by the authors for this difference were that perhaps those students who used more concrete strategies were aware that they were generating explanations for their teacher so they wanted to ensure that their solution strategy was understood, or that it may have been difficult to describe more abstract strategies. Although both girls and boys in the current investigation mostly generated concrete strategies, it may be that the perceived audience had an effect on the mathematical explanations that were generated.

Attending to the potential audience. In this investigation, the majority of students displayed some evidence of their awareness of a potential audience. Five students assumed teaching personas in 40% of the screencasts to teach others how they solved problems. These student explanations contained the pronoun "we," which may indicate students were thinking of the audience. The students also invited the audience to contrast different representations and held their attention by asking the audience to consider possible options, such as "let's pretend." There were times when students introduced turn taking language in which they asked the audience members whether they "want to check" the reasonableness of a solution. Students also began and ended their explanations using words and phrases that were similar to "teacher talk" found in classrooms, such as "that's what I taught you." These students also tended to use the pointer to draw attention to and emphasize particular objects or words on their screens.

The NCTM *Principles and Standards for School Mathematics*' Communication Standard (NCTM, 2000) states, "Students should become more aware of, and responsive to, their audience as they explain their ideas in mathematics class. They should learn to be aware of whether they are convincing and whether others can understand them." It is through this metacognitive process and having an audience to generate an explanation for that learning increases. Rittle-Johnson et al. (2008) found that when young children were asked to describe patterns to their parents, they provided more details than when they explained to themselves on a tape recorder, even without the parents providing feedback. The benefits of tailoring an explanation for an audience have also been found when students write answers to conceptual questions and are told they are writing for either a peer or a younger student (Gunel, Hand, & McDermott, 2009). In this investigation, student K indicated explicitly how she adjusted her notations to ensure that her explanation was clear for the audience. It may be that knowing others could view their screencasts helps students generate clearer explanations.

Limitations

There are a few limitations to this study, with the first being the participant sample. The sample may not have been representative and it is unclear how typical the group was; thus, these data cannot be generalized to a larger population. Although students described their mathematics classrooms, it is uncertain to what extent generating mathematical explanations was the norm in their classrooms. Students may not have been accustomed to verbalizing their thoughts and solution strategies, which could have affected their mathematical explanations. Also, this investigation was completed as one-on-one clinical interviews with students. Although attempts were made to create an authentic classroom experience, it was still a contrived environment that was different from what many students encounter in schools.

Although a representative example was shared based on the data collected, this may be different from what students might generate in a classroom setting. For example, students had unlimited time to generate their screencasts and were able to have in-depth conversations with the interviewer after they generated their screencasts. This additional attention may have provided more feedback than they may normally receive, which may have affected their explanations. With time constraints and other classroom realities, students may generate different kinds of screencasts not observed in this investigation. This research study was intentionally developed to create a “best case scenario” and investigate the possibilities of using this tool under optimal conditions.

Implications for Practice

As the most representative mathematical explanation generated contained a concurrent, procedural account, a direct modeling strategy, and one app option, it appears that students mostly used the technology as a substitute for paper and pencil. In order to implement the technology in ways the NCTM (2014) suggests, one app training session may not suffice. Interactions between students and teachers or students and there peers could be particularly important at the beginning of implementation of any technology in the classroom. With more practice and exposure to other students' screencasts and mathematical explanations, students could learn how to use the technology in more transformational ways.

When students use only paper and pencil to solve problems, they may only use drawings, symbols, and/or written words to express their thinking. This may be difficult for young students, as they may have trouble expressing themselves in writing (Crespo, 2000). Also, when students write their explanations on paper they must mentally imagine an audience, anticipate how the audience might react to their explanations, and respond to those reactions in the text (Deane et al., 2008). It could be difficult for students to address all of this in a written explanation. When students have a live audience, such as when they explain their thinking in front of a classroom, evidence exists that they express themselves more clearly (Littleton, 1998; Roscoe & Chi, 2004), as they can adjust their explanation based on verbal and nonverbal feedback, and they are able to draw upon multiple modalities to express their understanding. However, students do not always have this option because teachers may only select a few students to share their solution strategies with the class.

When generating screencasts, students have a potential audience without distractions, which could help them provide clearer explanations and take on a teaching persona. They can include verbalizations and gestures in their explanations, which could provide additional data that may have been omitted in a written explanation. Also, since it appeared that students were attending to a potential audience, there could also be the potential for learning to take place as students generate them. Although other forms of technology could be used to capture explanations, such as video cameras or digital voice recorders (Soto & Ambrose, 2014), screencasts allow for greater anonymity because students' faces are not recorded as with video cameras and because they collect more data than voice recorders.

Recommendation for Future Research

Since these explanations were constructed during clinical interviews, future work could investigate how screencasts could be used in classrooms as catalysts for discussions. As technology continues to be integrated in classrooms, it would also seem important to investigate more logistical uses of screencasts, particularly how teachers organize, collect, and analyze screencasts in a whole-group setting. The files produce large amounts of data, so examining ways to effectively data mine, plan instruction, and implement changes could be beneficial. Although the amount of data produced could be overwhelming for teachers, the information gained on students' thinking is valuable and worth the time to collect and analyze.

Future work could also investigate whether generating screencasts increases student learning. Research on peer tutoring indicated that students learned more when they had an audience. In this current investigation, it appeared that students attended to a potential audience, which would suggest that students could learn more by generating screencasts. Because this was not controlled for in this particular study, future work could potentially assess learning gains and compare it to those of students who explain to a live audience.

If educators are to truly implement the changes called for by NCTM and the CCSS in Mathematics, then explanations and reasoning will need to take a more prominent role in mathematics classrooms. One possible way to accomplish this is through the use of screencasts. In this investigation, students drew upon multiple modalities including speech, symbols, and gestures to communicate their understanding and construct robust explanations as they took on teaching personas and addressed a potential audience. This ability to use their strengths when communicating their understanding can empower all students by giving them a voice in mathematics classrooms.

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