Screencasting as a Medium for Communicating Students' Understandings in the High School Mathematics Classroom

by

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Dedications

This work is dedicated to all the teachers who made learning such a positive experience for me.

Abstract

When students are encouraged to reflect on their learning, communicate their reasoning and understandings, and develop their technical vocabulary, many opportunities for feedback and growth arise. Research examining journal writing in the mathematics classroom has supported the notion that reflective writing can help develop students' ability to communicate mathematically and to consolidate their learning. This research has been concentrated on written responses that are primarily intended for the teacher, who acts as the assessor of the work (be it formative or summative). While these responses do allow the teacher to *see* more of a student's thinking process, there could be opportunity for this exposition of thought to be improved by allowing the teacher *see* the process more dynamically while also *hearing* it recounted by the student.

The purpose of this qualitative study is to evaluate the opportunities and challenges brought about by student authored screencasts in the high school mathematics classroom. Three students' solutions to a small set of mathematical problems are shared with two high school teachers through the media of paper and pencil as well as screencasts showing the solution process accompanied by narration. Responses from interviews with these five participants are then analyzed through interpretive inquiry in hopes of making some form of recommendation regarding the value and applications of screencasting in the high school mathematics classroom. This study suggests that student authored screencasts could provide better opportunities to analyze students' misunderstandings and could allow for more informed and detailed formative feedback leading to improved student achievement.

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Chapter One: Plotting Myself

My first experience as a educator came in high school when I became a peer tutor to several of my classmates. I would help them study mathematics and chemistry once or twice per week; mostly, we would work through their more recent assignments and I would elaborate on the concepts underlying each problem. Overall, they seemed very pleased with the help I was giving and I was quite confident that my explanations were thorough and understood. I recall being surprised, however, when, week after week, we would work on problems that seemed so similar. My peers were struggling to retain skills and knowledge from one session to the next and were being challenged by questions that were essentially equivalent to ones they had completed before. I was unsure of how to deal with whatever was causing this trouble, so I simply continued to explain the problems as I had before and my tutorees would, each time, tell me they understood what to do.

It has been nearly twenty years since I began tutoring and my qualifications have changed somewhat. I graduated from the Campus Saint-Jean of the University of Alberta in 2005 with a Bachelor's degree in Education with a major in mathematics and a minor in French, have taught at the junior high, senior high, and university levels, and will soon have a Master's degree in secondary education with a focus on mathematics. Since beginning my career in 2006, I have spent the majority of my time teaching high school mathematics at a large school of nearly 2000 students in an urban setting. My teaching assignments are such that approximately half of my classes are taught in a French Immersion setting. Additionally, I teach diploma preparation courses twice annually, which allows me to meet roughly six hundred grade eleven or twelve students whose primary experience is not in my classroom. In the winters of 2014 and 2015, I taught a university course regarding the curriculum and teaching of secondary mathematics to prospective high school teachers. Recurrent observations throughout these experiences have led me to generate assumptions regarding learning and assessment that may be worth articulating.

First, I believe that students are able to learn and that most desire to do so with the help of their teachers. However, while more confident or self-assured students believe they will learn and actualize this belief, less confident students are often concerned with concealing their current misunderstandings and uncertainties and are therefore unable to focus their full attention on correcting them. Though confidence is not exclusively dependent on prior achievement, students equipped with stronger foundational skills - the ability to articulate understandings of individual topics, quick recall of basic facts and accurate execution of simple calculations - tend to show higher levels of confidence in class. These same students demonstrate a greater capacity for learning new material.

Secondly, teachers' assessments of student work generally rely on assumptions regarding students' reasoning. Though the validity of these assumptions is typically unquestioned, the observable manifestations present in most students' written mathematical solutions are insufficient when trying to determine underlying misconceptions or gaps responsible for erroneous results or thinking. Consequently, clarifications regarding a particular task may be ineffective in treating the more foundational problems, thus limiting the impact of constructive feedback.

These assumptions lead me to believe that the pursuit of strategies for strengthening foundational skills and knowledge is worthwhile. By creating opportunities for students to express their conceptions of the mathematics they have learned, teachers can more effectively diagnose weak or false understandings. This could prove to be a critical first step in improving students' understandings of, and achievement in, mathematics.

Chapter Two: Purpose and Significance of this Research

Throughout my career as a high school teacher, I have consistently observed students struggle with mathematical concepts due to insufficient understanding of the prerequisite foundational knowledge/concepts. In part due to the nature of course scheduling, curricular concepts assigned to a particular scholastic year often seem distinct from associated concepts seen at earlier levels. Do students find them distinct because they are taught this way? Are they taught this way because teachers have low expectations for transfer and recall from earlier courses? Whatever the case may be, as teachers balance the demands of a program of studies against a limited amount of time, the process of folding back is rarely being carried out optimally.

This study was inspired by several central ideas. The first is that there are categorically different ways of understanding mathematical concepts and developing mathematical understandings and these different interations are non-trivially distinct. The second is that the idea of understanding is complex and the process of developing understandings is multi-faceted and is improved through effective activities, scaffolding, and guidance. The third big idea is that the mathematical processes outlined in the Alberta Program of Studies are as significant as the general and specific outcomes associated with each unit.

Within the last decade, a significant increase in the number of teachers creating instructional videos for their students has taken place (for examples, see http://flippedlearning.org/Page/49). At first, these videos were used primarily to provide lessons to students who were unable to attend every class. Soon, teachers recognized the potential to regain the lecture portion of their teaching time by having students view lecture videos as homework. This shift freed up a non-trivial amount of classroom time, allowing the teachers more opportunity to assist students with hands-on work and guided practice and to give each student more individual interaction. This idea of displacing lecture time came to be known as the "Flipped Classroom" and has since attracted much attention (Hamdan, McKnight, McKnight, & Arfstrom, 2013, p. 4).

However, as with so many technologies that find their way into the classroom, there exists a need for evaluation and familiarity prior to implementation. Teachers need to know whether a particular tool will be effective in enhancing *their* practice (with the goal of improving student learning) and if the investment of time (for training, for use, for assessment, etc.) is worthwhile to *them*. And so it is with screencasting.

Purpose

The primary objective of my research will be to answer the question: "*Can screencasting serve as an effective medium for communicating students' understandings of mathematical concepts and skills for the purpose of assessment and feedback in the high school mathematics classroom?"* I would like to determine whether teachers notice significant differences in the amount and/or quality of assessment and feedback they feel capable of offering in response to student generated solutions that are recorded (with audio) using screencasting software and a tablet computer. I propose that the assessment of students' production is an interpretative task which is improved by increased access to students' thinking processes; the closer they get to "showing all their work", the more accurately teachers can respond with feedback.

This project seeks to contrast two media through which students can communicate mathematical understanding: recorded screencasts versus traditional pencil and paper responses. Students were asked to solve mathematical problems independently and to make their thinking process as explicit as possible, so as to best inform the assessor, who was a mathematics teacher they had not met. At least one solution was presented using paper and pencil and at least one solution was presented using a digital tablet and screencasting technology, for which they were given basic technical training.

The data collection consisted of two parts. In the first, three students individually completed several mathematical tasks and were then interviewed. The tasks selected dealt mainly with logical and algebraic reasoning and were predicted to allow a reasonable spectrum of problem-solving and communication skills to be demonstrated. The students prepared some of their solutions using paper and pencil and others using ScreenChomp[1], an iPad application for screencasting (they were given an opportunity to test the screencasting software prior to completing the tasks). Though the students knew that the work was destined for a teacher/assessor, they were asked to solve the problems as though they were explaining their solution to a peer. Then the students took part in a semistructured interview to determine how they felt

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[1] After some technical difficulties, ScreenChomp was abandoned in favour of using a similar application, EduCreations.

about screencasting. In particular, I was interested in knowing if they felt their mathematical understandings were more or less accurately represented.

In the second part of the data collection, the samples of student work were taken to two different teachers to be assessed. Each teacher built a brief scoring rubric for the tasks before assessing the samples accordingly, as though the work were summative in nature. They were also asked to provide written feedback to the students, as though the work were formative in nature. Following this, the teachers were interviewed in order to learn their thoughts regarding the representation and communication of students' mathematical understandings across the two media.

After collecting the data, I partially transcribed the interviews and analyzed the responses in order to draw out commonalities and illuminating insights. My analysis was heavily influenced by Richard Skemp's (1976/2006) seminal article, *Relational Understanding and Instrumental Understanding*, which offers a valuable lens through which to view teacher and student understandings. I compared the two media (screencasting and pencil and paper) in a way that highlights, for teachers, some advantages and disadvantages of incorporating student authored screencasts in the classroom.

Key Vocabulary

As some of the vocabulary used throughout this text may carry a particular connotation or intention, I have presented some of the key terms here.

Screencast

"A screencast is a digital movie in which the setting is partly or wholly a computer screen, and in which audio narration describes the on-screen action" (Kopel, 2010, p. 297).

Flipped Classroom

> In the Flipped Learning model, teachers shift direct learning out of the large group learning space and move it into the individual learning space, with the help of one of several technologies. Teachers record and narrate screencasts of work they do on their computer desktops, create videos of themselves teaching, or curate video lessons from internet sites such as TED-Ed and Khan Academy (Hamdan et al., 2013, p. 4).

Understandings

As my work was heavily inspired by Richard Skemp's (1976/2006) seminal article, *Relational Understanding and Instrumental Understanding*, it is important to share the vocabulary that he used quite specifically to describe student understandings.

i. Instrumental Understanding: The ability to apply an appropriate remembered rule to the solution of a problem without knowing why the rule works.

ii. Relational Understanding: The ability to deduce specific rules or procedures from more general mathematical relationships.

iii. Structural Understanding: The ability to connect mathematical symbolism and notation with relevant mathematical ideas and to combine these ideas into chains of logical reasoning (Skemp, 2009).

Knowledge

Though I am still exploring how knowledge and understanding resonate differently within my writing, I would like to share James Hiebert's (1986) take on different categories of knowledge.

i. Conceptual knowledge: Can be thought of as a connected web of knowledge, which emphasizes the linking relationships as much as the discrete pieces of information, and in which the individual pieces of information are all linked to some network.

ii. Procedural knowledge: Can be thought of as encompassing familiarity with the formal language, or symbol representation system, of mathematics, and with the algorithms or rules for solving mathematical problems (Hiebert, 1986).

Chapter Three: Literature Review

Criteria for Selection of Texts

The texts included in this review have been selected based on their relevance to the three main topics of my research: teacher knowledge, student understandings, and screencasting in the high school mathematics classroom (examples from elementary and junior high levels may also be included). I have included articles of both qualitative and quantitative natures and though many of the articles, especially those concerning mathematics for teaching, were written by North American authors, this should not suggest that I have excluded any texts based on regional considerations. In fact, I believe that diverse and diversely informed perspectives can only enhance discussions surrounding student understandings, by highlighting common and contrasting elements. Moreover, many of the struggles exhibited by students working with algebra seem quite universal.

An important distinction that will not be addressed in this review is that between the terms “knowledge” and “understanding”. Though these words are not the same, they are often treated quite similarly. Consequently, no preference will be assigned to research describing different qualities or types of knowledge (e.g. Shulman, 1986; Hiebert, 1986; Zazkis & Mamolo, 2011) versus different qualities or types of understanding (e.g. Skemp, 1976; Pirie & Kieren, 1994; Simon, 2009).

Methodologies in Research for Mathematics Learning

While the methods and methodologies employed by the various research studies gathered in this review did not play a significant role in the selection of the articles to include, they are certainly cause for discussion. As it has been discussed elsewhere (Hiebert, 2007; Skemp, 2009), the methodologies used in research related to mathematics education are too often weakly defined. There is an interdependent relationship between methodology and theory, and as Steffe has pointed out, "[c]onstructivism, an epistemological theory, has not yet produced a theory of mathematics learning" (as cited in Skemp, 2009, p. 131). In his explanation of behaviourist and neo-behaviourist methodologies, Skemp discusses type 1 theories and type 2 theories, as well as type 1 methodologies and type 2 methodologies.

> Type 1 theories are concerned with operands in the physical world. Collectively, they form the natural sciences, and with their associated technologies these have given us great success in manipulating our physical environment. Type 2 theories, in contrast, are concerned with what happens in our own minds, and those of others. Their operands include type 1 theories, and whatever mental objects go to make up type 1 theories: concepts and relations between these, conceptual structures, statements, conjectures, hypotheses, and all those processes by which type 1 theories are built and tested. [...] To think, or to assume unthinkingly, that it is appropriate to use type 2 theories in the same way as type 1 theories leads rather easily to a manipulative attitude towards other people (Skemp, 2009, p. 130).

Type 2 methodologies are concerned with "constructing (building and testing) models of how type 1 theories are constructed, and how particular plans of action are derived from these" (2009, p. 132). These models, once constructed, are type 2 theories. Skemp addresses three different type 2 methodologies: behaviourist, Piagetian and that of the teaching experiment. He criticizes that teacher methods based on behaviourist models "have been remarkably unsuccessful in bringing about the higher forms of learning [...] of which mathematics is a particularly clear example" (Skemp, 2009, p. 134), and that:

> Classical Piagetian theory takes little account of the function of instruction. In the context of education, however, the relations between instruction and learning, together with the nature and quality of this learning, are among our chief areas of concern (Skemp, 2009, p. 138).

Despite this lack of consideration of instruction, the influence of the Piagetian paradigm and diagnostic interviews in research on mathematics education is undeniable. Still, likely because of this failure to address instruction, some researchers have used the teaching experiment's methodology as their foundation. In many ways, this methodology extends that of the diagnostic interview of Piaget by making and testing hypotheses about how a child's thinking evolves across various stages, rather than how it is at a particular time (Skemp, 2009).

> A major emphasis [...] is that what we can learn with understanding depends on our currently available schemas. These schemas cannot be observed directly in children, or other learners: they have to be inferred from their responses. The kind of responses we need for this purpose, which includes distinguishing between what has been learned with

> understanding and what has just been memorised as a rule, are not written responses to standardised questions, but the kind that are obtained in the situation of the diagnostic interview. So the combination of a teaching situation with the diagnostic interview offers opportunities for inferences both about the states of children's schemas at various stages in their learning, and about the processes by which they progress from one stage to another (Skemp, 2009, p. 139).

I have elaborated on these methodologies not because they have been identified in all of the articles selected, but because of their clear application in constructivist based research. Skemp claims that, in spite of the close relation between methodology and theory, researchers in mathematics learning often do not refer explicitly to this relationship. He suggests several potential reasons, including the content's clear implication of a particular theory, the researcher making systematic observations not yet organized into a theory, or the use of a method without due consideration to a methodology (Skemp, 2009). Some of the selected articles make no explicit reference to their chosen methodologies and, though I will not form any conclusions about why this may be, I thought it worthwhile to present methodological bases which may have been assumed or implied. Since most of the texts discussed have investigated student understandings and show strong foundations in constructivist theory, I considered Skemp's contributions particularly valid.

Teacher Knowledge

In his “Maxims for Revolutionists,” an appendix to his 1903 play *Man and Superman*, George Bernard Shaw wrote that “[h]e who can, does. He who cannot, teaches” (as cited in Shulman, 1986, p. 4). Despite being quite demeaning to the teaching profession, this famous apothegm invited an interesting conversation concerning distinctions between knowledge for doing and knowledge for teaching. This invitation was accepted, albeit many years later, by Lee Shulman (1986) in his seminal paper regarding content knowledge in teaching. Here, Shulman challenged Shaw’s low appraisal of teachers’ abilities and established the need for a theoretical framework that would more coherently address the complexities of teacher knowledge. He sought to trace the intellectual biography of novice secondary teachers - “that set of understandings, conceptions, and orientations that constitutes the source of their comprehension of the subjects they teach” (Shulman, 1986, p.8). Three distinct categories of teacher knowledge emerged from this research: subject matter knowledge, pedagogical content knowledge, and curricular knowledge (Shulman, 1986). The first category is perhaps the most easily understood - what the teacher knows about the subject matter she will teach. Shulman clarified that:

> We expect that the subject matter content understanding of the teacher be at least equal to that of his or her lay colleague, the mere subject matter major. The teacher need not only understand *that* something is so; the teacher must further understand *why* it is so, on what grounds its warrant can be asserted, and under what circumstances our belief in its justification can be weakened and even denied [emphasis in the original] (1986, p. 9).

The second category is where research on teaching and learning most closely coincide, and was considered “among the most fertile topics for cognitive research” (Shulman, 1986, p. 10).

> Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners, because those learners are unlikely to appear before them as blank slates (1986, p. 9).

In regards to teacher education programs, the category of curricular knowledge is perhaps most in need of attention. This should not be surprising given the vast amount of knowledge comprehended by curricula. Indeed, in his discussion of the areas about which teachers needed to be informed, Shulman outlined that:

> The curriculum is represented by the full range of programs designed for the teaching of particular subjects and topics at a given level, the variety of instructional materials available in relation to those programs, and the set of characteristics that serve as both the indications and contraindications for the use of particular curriculum or program materials in particular circumstances (1986, p. 10).

In addition, Shulman pointed to expectations that teachers be familiar with the topics and issues taught within their subject area in years preceding and following their own, as well as with the curricula of other subjects that their students would study concurrently. He called these familiarities vertical curriculum knowledge and lateral curriculum knowledge, respectively.

Clear descriptions and categorizations of teacher knowledge did much more than refute Shaw's undermining of teacher's reputation. It provided an important foundation for future research; in particular, for the work of Deborah Loewenberg Ball (Ball, 1991; Ball & Bass, 2000; Ball, Lubienski, & Mewborn, 2001) regarding mathematics for teaching. Situating the discussion of teacher knowledge firmly in a context of mathematics, Ball (Hill, Ball, & Schilling, 2008) developed Shulman's taxonomy of knowledge further into categories of subject matter knowledge (common content knowledge, specialized content knowledge, and horizon content knowledge) and pedagogical content knowledge (knowledge of content and students, knowledge of content and teaching, knowledge of content and curriculum). Despite most of the categories finding their roots in Shulman's writing, the coining of horizon content knowledge as "an awareness of how mathematical topics are related over the span of mathematics included in the curriculum" (Ball, Thames, & Phelps, 2008, p. 403) offered an innovative tool with which to address teacher knowledge. Ball and Bass (2009) elaborated:

> We define horizon knowledge as an awareness – more as an experienced and appreciative tourist than as a tour guide – of the large mathematical landscape in which the present experience and instruction is situated. It engages those aspects of the mathematics that, while perhaps not contained in the curriculum, are nonetheless useful

> to pupils' present learning, that illuminate and confer a comprehensible sense of the larger significance of what may be only partially revealed in the mathematics of the moment (p. 5).

Only two years later, Zazkis and Mamolo (2011) would offer four classroom examples, ranging from grade 3 to grade 12 settings, in which they showed how teachers' instructional choices, as well as student learning, can be aided by supplementary knowledge of topics which extends beyond that prescribed by school curricula. This additional knowledge was described in terms of the "inner horizon" and "outer horizon" of an object; the understandings and connections that exist in the peripheral of the object on which an individual is focused. Zazkis and Mamolo offered convincing explanations of the value of horizon knowledge, both inner and outer, and built on the work of Ball and Bass (2009) by highlighting the importance of clarifying the greater significance of students' mathematics. Though the examples offered by Zazkis and Mamolo were rather ineffective in demonstrating the worth of horizon knowledge - indeed, in two of the four situations described, the 'insights' achieved as a result of this knowledge seemed to have no significant influence on either the teacher's instructional decisions or the students' learning - the examples were not counterexamples, and did not discredit the central views of the article and its support of the importance of subject matter knowledge.

In 1991, the National Council of Teachers of Mathematics released the *Professional Standards for Teaching Mathematics*, a document which would call for significants shifts in the mathematics classrooms of the United States (as a point of interest, Deborah Ball was the chair for the Mathematics Teaching working group involved with this publication). Shortly after this document was released, Simon (1994) would publish an article presenting a framework for mathematics teacher learning. This framework, made up of six learning cycles, was to address the new vision of the professional standards document by elaborating on the processes involved in preparing teachers for mathematics instruction. Simon proposed that mathematics teachers learn to be mathematics teachers based on their understanding of how students learn mathematics.

> Because mathematics and mathematics teaching are both problem-solving activities, i.e. both predominantly involve solving non-routine problems as opposed to carrying out routine procedures, it seems that the mechanisms by which learning occurs in the two domains might have some important similarities. We assume that conceptual understanding is essential to success in both mathematics and mathematics teaching and is therefore an appropriate goal of instruction. Thus, one of our heuristics for thinking about teachers' learning to teach is analogy with students' learning of mathematics. This requires identifying parallels between the two. (Simon, 1994, p. 72)

While teachers may develop their subject matter knowledge independently of students, Simon suggests that advancing pedagogical content knowledge requires experience with student understandings. This complex topic has been explored from multiple perspectives (e.g. Skemp, 1976/2006; Hiebert, 1986; Sfard, 1991; Pirie & Kieren, 1994; Hewitt, 1999), each seeking to further inform teaching practices.

Constructing Student Understandings

The influence of constructivist theory is rather ubiquitous in mathematics education research. While some scholars identify this theoretical foundation explicitly (e.g. Simon, 1994; Pirie & Kieren, 1994; Skemp, 2009), elsewhere it seems woven into discussions of students' construction of knowledge (e.g. Leikin & Dinur, 2007; Ball, Thames, & Phelps, 2008). However, the meanings invoked by the term "constructivism" show great diversity. Simon (1994), whose work is based in a social constructivist perspective, discusses two conceptions often falsely associated with constructivist views. The first, which Simon names as a myth, is that "a constructivist perspective results in teachers who have no agenda for what mathematics students will learn" (1994, p. 74). Instead, teaching should be viewed as a goal-directed activity in which the teacher seeks to "create an environment and problematic tasks that are designed to increase the probability that students will generate powerful ideas" (1994, p. 74). This goal offers further motivation for understanding how students construct understanding and for identifying which circumstances are most likely to encourage this. Secondly, Simon addresses the notion of 'constructivist instruction'. Since constructivism views learning as a construction of knowledge regardless of the presence or nature of instruction, he suggests that labelling instruction as constructivist is somewhat inappropriate (Simon, 1994). Instead, mathematics educators should be concerned with the effectiveness of the instruction in consistently achieving its goal and facilitating students' construction of mathematical knowledge. This naturally encourages an examination of the nature of knowledge mathematics education desires for its learners.

Comprehension of how students relate to their learning material - and how teachers affect this - was improved greatly thanks to Hewitt's (1999) distinctions of information as arbitrary or necessary. Hewitt points out that something is arbitrary "if someone could only come to know it to be true by being informed of it by some external means [...]. If something is arbitrary, then it is arbitrary for all learners, and needs to be memorised to be known" (1999, p. 3) and, consequently, this type of information must be addressed by the student's memory. Because this knowledge - words, symbols, notation, conventions - cannot be worked out, teachers must inform their students of it (whether through instruction, texts, the internet, etc.). However, there are also aspects of the mathematics curriculum which can be deduced from previously known properties or relationships. This type of information, named as necessary, is addressed by the student's awareness and can be made evident through suitably constructed tasks (Hewitt, 1999). Hewitt clarifies that the classification of information as necessary "does not imply that all students have the awareness to be able to work this out, only that *someone* is able to work this out without the need to be informed of it" [emphasis in the original] (Hewitt, 1999, p. 4). This gives rise to the notion of educating awareness, an idea held in high regard in the community of mathematics education.

> "[T]he key notions underlying real teaching are the structure of attention and the nature of awareness [...]. A teacher's responsibility can be described [...] as attracting students to become aware of, to stress (and consequently ignore), the way the relative expert does" (Mason, 1998, p. 244-246).

Just as Hewitt characterized the information to be learned, Skemp (1976/2006) characterized students' understanding of it. Skemp introduced two meanings of 'understanding', whose distinction he credits to Stieg Mellin-Olsen, of Bergen University. Here, relational understanding is, stated simply, "knowing both what to do and why" (Skemp, 1976/2006, p. 89). Instrumental understanding, on the other hand, is "what I have in the past described as 'rules without reasons', without realising that for many pupils *and their teachers* the possession of such a rule, and ability to use it, was what they meant by 'understanding'" [emphasis in the orginal] (Skemp, 1976/2006, p. 89). There do exist several advantages to teaching instrumental mathematics. Certainly, some topics which are very difficult to understand relationally may be understood more easily instrumentally. Much like a child who learns to bake a cake from a recipe (without knowing the role of certain ingredients), or a traveler who learns the directions from their hotel to the airport (without an understanding of the city's infrastructure), students are often more easily able to deal with the 'rule' of a topic, than with its 'reason'. Also, somewhat paradoxically, because less knowledge is involved in instrumental understanding, students can often produce correct responses more quickly and reliably than by relational thinking (Skemp, 1976/2006). However, the disadvantages of favouring this style of understanding become more apparent in the long term. Pirie and Kieren (1994), elaborate on the constructivist view of understanding as an individual's ongoing process of organising her knowledge structures, and point out the risks of teaching 'rules':

> Had the teacher offered her the 'rule' she would have had a way of working at the formalising level, but no image in whose roots the formalising lay, to which she could fold back in later times of lack of understanding. This apparent understanding, which

> occurs when a student works with information that does not emerge from or become connected to her own constructured [*sic*] knowledge, we term *disjoint* from her existing understanding. We hypothesise, that students will be unable to successfully build further understanding based on this *disjoint* knowing until they have in fact constructed the connection for themselves [emphasis in original] (Pirie & Kieren, 1994, p. 185).

This notion of connecting understandings from one level to the next is central to the constructivist approaches to mathematics learning. It points to the need for increased continuity throughout students' education; a need which also exists in the research connecting elementary, junior high, and high school learning of algebra.

Screencasting in the Mathematics Classroom

When Jon Udell coined the term "screencast" in 2004, it is unlikely that he would have predicted the impact these recordings would have on education only a few years later. In 2007, Jonathan Bergmann and Aaron Sams, two science teachers from Colorado, were struggling with problems related to student absences; specifically, how to make up for missed instruction. Their response, both resourceful and innovative, was to prepare recorded lessons that could be viewed online. As access to these lessons was not restricted in time or audience, the videos became support tools for homework (Špilka & Maněnová, 2014). Inspired by the response to their work, Bergmann and Sams pioneered the idea of Flipped Learning "in which digital technologies are used to shift direct instruction outside of the group learning space to the individual learning space, usually via videos" (Hamdan et al., 2013).

During a similar time period, Salman Khan, a hedge fund analyst, was tutoring his cousin in math using videoconferencing. As more of his relatives took advantage of this opportunity for help, Khan replaced his live tutoring sessions with recorded instructional videos that he posted on YouTube. As was the case with Bergmann and Sams, the recorded lessons reached a larger-than-anticipated audience. The response was so positive that Khan eventually left his job to devote his full attention to developing the Khan Academy - a website which now offers thousands of free educational videos covering a wide range of topics (Siegle, 2014).

By 2012, Bergmann and Sams had started the not-for-profit Flipped Learning Network to support future "flipped" educators with resources and research, and the Khan Academy had received significant endorsement and financial backing from well known donors such as Bill Gates and Google. In this short time, screencasting had become one of the hottest topics in education. However, though screencasting has reached a very diverse population, the literature regarding its implementations is reasonably narrow in focus, concentrating mostly on student perceptions (Bishop & Verleger, 2013; Bull, 2014; Siegle, 2014; Triantafyllou & Timcenko, 2015) or achievement levels (Hamdan et al., 2013; Špilka & Maněnová, 2014) in flipped classroom settings, where screencasts are teacher-created. Nonetheless, this research shows favourable responses, hinting that the use of screencasts as a central learning tool may endure.

A less modern, but no less significant, endeavour in educational research has been to examine the impact of journalling in the mathematics classroom (Clarke, Waywood, & Stephens ,1993; Pugalee, 2001a; Pugalee, 2001b; Lim & Pugalee, 2004; Ohnemus, 2010; Casler-Failing, 2013). Addressing processes such as communication, reasoning, and problem solving, the practice of expressing one's thought process explicitly, in written form, has proven worthwhile for student's of different ages and abilities (Baxter, Woodward, & Olson, 2005; Casler-Failing, 2013). When students practise writing in mathematics, they integrate and restructure their knowledge by reflecting on prior beliefs and knowledge. This leads to better, more meaningful understanding and improved retention (Lim & Pugalee, 2004).

> Students can then write about the process of solving *while* they are solving the problem. This form of writing becomes reflective as students reread their entries; this writing also helps students gain deeper mathematical understanding. Writing about and reflecting on word problems allow students to connect to previously learned concepts and facilitate the act of finding and correcting their own mistakes (Casler-Failing, 2013, p.180)

If supplementing responses with a written exposition of thinking has improved learning, it seems reasonable to suggest that supplementing mathematical solutions and explanations with oral narration may have a similarly positive effect. As student access to screencasting capable technology increases, more student-created videos are being shared. I believe there is a need for research to address the value of student-authored videos, whether their demonstration of understanding be intended for teaching or for evaluation.

Transitioning from the Literature

This review has presented some of the key literature concerning teachers' knowledge of pedagogical content, in addition to knowledge of subject matter, and relevant extensions of horizon knowledge. It has highlighted the need for this knowledge to include an in-depth comprehension of the nature of students' understanding and how it is constructed based on qualities of the information presented and on the manner in which it is presented. Finally, it noted some of the success that has been achieved by teacher authored screencasts as instructional tools, as well as the positive outcomes related to student journalling in the mathematics classroom, in hopes of justifying an exploration of student authored screencasts. There is reason to further investigate the use of 'folding back' in our instruction of high school mathematics - revisiting and revising inner level models - to strengthen the relations inherent to rich understandings of concepts; those which build capacity for growth and adaptability in future learning. Screencasting software may be an excellent tool for revealing students' inner levels most in need of this strengthening.

Chapter Four: Methodology

In this chapter, my research study will be outlined in greater detail. In particular, I will discuss my research approach, my role as a researcher, ethical considerations, the recruitment process, data collection, data analysis, and the limitations of the study. Later, I will discuss the theoretical lens used to interpret my data.

My Research Approach

This research is focused primarily on "exploring and understanding the meaning individuals or groups ascribe to a social or human problem" (Creswell, 2009, p. 4). With the goal of examining how students' mathematical understandings are communicated through different media, I sought to expand my perspective, rather than refine any preexisting views. I wanted my study to be adaptable and flexible, looking for descriptions rather than measurements or verification. These factors led me to design a qualitative study. Following the advice of Creswell, I identified a worldview, that of the social constructivism, acknowledging that I would "rely as much as possible on the participants' views of the situation" (Creswell, 2009, p. 8), while also reflecting on the filters my background and experiences apply when interpreting data. Though I first looked to case studies as a model for my research strategy, the emphasis on interpreting participants' interpretations of understandings prompts me to label it as an interpretive inquiry.

> [I]nquirers are interpreters of the interpretations people give to their own actions and to the actions of others. People are self-interpreting beings who have reasons for their actions and who are constantly attempting to make sense of their own expressions and of the expressions of others. Inquirers, then, are interpreters of an already interpreted world and inquiry is very much at one with, or continuous with, ordinary conversation (Giddens, Rorty, as cited in Smith, 1992). What inquirers are concerned with is no different from what most people are concerned with - understanding (Smith, 1992, p. 102).

Research Design

In order to guide the development of students' understandings of mathematical concepts and processes, teachers must interpret, assess, and respond to students' productions with appropriate feedback and instructional strategies. The potential for effective and informed instruction is, therefore, limited by the access teachers have to observable manifestations of their students' thinking and awareness.

My investigation was centered around the evaluation of different media's capacity for offering insight into student understandings. With this in mind, I designed the study such that the students and teachers would never meet and anything the teacher would know about the student would have to be gleaned from the work. The participants will be interviewed and asked to reflect on how the different processes used to demonstrate their solutions allowed them to communicate their mathematical understandings. Later, their work will be given to a sample group of teachers who will assess their solutions and comment on the effectiveness of the communication of understanding in each case, considering factors such as clarity, depth, and precision.

I gathered and adapted six math problems, most of which had, at some point, been assigned in one of my high school classes. The interviewed students were asked to select four of the six problems and were then asked to complete two using pencil and paper, and two using an iPad. In the case of the pencil and paper, students were filmed while they worked, but the teachers were never shown the recordings. In the case of the iPad, students used EduCreations[2] to record screencasts of their solution process. This included a verbal explanation and a dynamic video. Though it will be discussed later, it is interesting to note that all three students who were interviewed opted to prepare their solution - to varying degrees - prior to pressing the record button. I had anticipated video recordings of students *thinking through* the problems. Instead, they created recordings in which they were primarily *reflecting on* their work.

After interacting with mathematical tasks or solutions, participants were engaged in semi-structured interviewed where they shared insights and reactions to their experiences. The interview questions were designed to be flexible, allowing me to "respond to the situation at hand, to the emerging worldview of the respondent, and to new ideas on the topic" (Merriam, 2009, p. 90).

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2 ScreenChomp was used during the first student interview, but after unsolvable technical difficulties led to the loss of one recording, it was abandoned.

Ethical Considerations

Though my study presented little to no risk to the participants, the involvement of other people required that I submit an ethics application to the University of Alberta's research ethics board. This application was prepared with the help of my research supervisor and outlined the steps I would take to carry out an ethical research project. The approved procedures were respected and adhered to throughout the study.

The students interviewed in this study were former students of mine. In all three cases, some degree of contact had been maintained since graduation. The students were each emailed a letter of invitation and consent form (Appendix A), which had been approved by the University, inviting them to take part in the study and all participated voluntarily. The interviews were conducted individually in a private meeting room at the University.

The teachers interviewed were colleagues I had met in some capacity outside of teaching in my school district. Much like the students, the teachers were sent a letter of invitation and consent form (Appendix B), approved by the University, inviting them to take part in the study and both participated voluntarily. One of the interviews was conducted in a private meeting room at the University and the other in the interviewee's classroom after school hours.

All participants were made aware in advance that the interviews would be video recorded and that the data could be used for publications or presentations. Additionally, the student interviewees were made aware that their solutions would be shared with the teacher participants. In the interviews and throughout this document, participants' identities have been protected using pseudonyms. All video files have been encrypted and are stored exclusively on a password protected computer where they will be kept for five years. All participants read and signed a printed copy of the consent form and no requests to withdraw participation occurred within the allotted time of seven days following the interview.

Participants

The data collected during this research comes from three university student interviews and two teacher interviews. The three students interviewed are past high school students of mine to whom I taught a 30-level mathematics course. In selecting these candidates, no consideration was given to whether or not their current program of study is related to mathematics or not.

The teachers interviewed were both experienced high school mathematics familiar with the Alberta Mathematics Program of Studies. Though the mathematics problems used in this study align with specific curricular objectives from this program of study, their applications to mathematics curricula are not limited to an Albertan context. Therefore, teachers were not screened based on which courses they have taught in the past.

Data Collection

As participants agreed to take part in my research study, interviews were arranged. The interviews occurred between October of 2014 and April of 2015, with all but one being held at the University of Alberta.

After some casual conversation, I began each interview by sharing the student and teacher task instructions (Appendix C). Both sets of instructions were included on the same page in order to offer participants more insight into the data collection process. Once they had indicated that they were finished reading, I would ask if they had any questions about the study. I also took this opportunity to discuss the relative neutrality of my research: I am hoping to determine how screencasting and pencil and paper communicate students' understanding differently, not to justify a preference of one medium over the other. I felt this discussion was important, particularly with the student participants who may, out of loyalty based on our past relationship, misrepresent or exaggerate their feelings towards screencasting in order to help with what they perceived as my cause.

Though all participants were sent a copy of the information letter and consent form (Appendices A & B) in advance, they were not shown the mathematical tasks prior to the interview. Students were asked to complete four of the six tasks presented, such that two solutions were screencasted and two were presented as a more traditional written response. Of the six tasks, there were two (task #1 and task #2) that were selected by all three student participants and which provided a blend of media and of solution strategies. Given the scope of this study, the six solutions (three per task) seemed sufficient in fostering rich conversations with the teacher participants (though all students responses were brought to the teacher interviews). The teachers had the opportunity to see each question solved in, and each student working in, both media.

All interviews were recorded in full, including working time, using a video camera. I positioned the camera's tripod such that it would record the participant's workspace, allowing me to confirm references such as "here" or "this" when later reviewing. Each meeting lasted between one and two hours. Later, I reviewed each video, taking detailed notes and making partial transcripts. In particular, I attempt to draw out common themes or opinions across the interviews - what did the participants say or do that suggested shared experiences or feelings towards the different media?

Data Analysis

The main focus of my analysis was on the recorded interviews, thus my primary source of data was my partial transcription. Though I observed the students while they completed the tasks, and despite having a prior relationship as an assessor to all three students, I did my best to analyze what was said by the participants without being heavily influenced by what I had observed live during the interviews, or during past exchanges with the students. Based on the interviewees' responses, I identified general themes in order to guide further discussion (Creswell, 2009, p. 186). The main themes which emerged in the interviews were:

1. The spatial organization of written solutions
2. Thought processes while problem solving
3. Enhanced observability of understandings
4. Formative and summative feedback

The responses of the students interviews are discussed with reference to only the first three themes, as they made little reference to the assessment practices of teachers. The teacher interviews address all four topics.

Limitations of the Study

Given that the students have been out of the high school mathematics classroom for several years, the mathematical tasks in this study were designed to be solvable without needing to apply a particular formula or rule that would rely on memory or recall. Furthermore, in order to offer flexibility in terms of solution strategies, the numbers used were of a reasonably manageable magnitude. While this did welcome some responses which applied repeated verification (i.e. solving by "guess and check"), it likely compromised opportunities to draw out more generalized strategies, in which underlying patterns lead the student to consider a wider class of cases (Mason, Burton, & Stacey, 1982, p. 8). Moreover, the initial intent of this study was to examine different types of mathematical understandings. To increase the sharing of observable manifestations of these understandings from students, I requested that screencasts be narrated, hoping that this would lead to an explicit expression of their thought processes. Having now analyzed the data, I recognize that each question could have benefited from a subsequent extension, providing a better opportunity for the assessing teachers to distinguish between understandings that were instrumental and relational, whether those terms were used or not.

The act of judging someone's work can be a very sensitive exercise. In order to communicate the expectations of the marker, problems are often presented in such a way that the question, with its accompanying instructions, tells the value of that problem (in number of marks) and implies its basic marking criteria (e.g. solve this system algebraically using the method of substitution). Not wanting to guide the students in their problem solving strategies, and not wanting to influence the grading of the assessors in any way, I added very little in the way of detail to the questions. Though I was pleased with the variety of mathematical solutions I received from the students, I recognize that this likely affected how, and how severely, the tasks were marked.

Delimitations of the Study

My review of the literature concerning student understandings and journalling indicated a gap in research concerning student authored screencasts. In response to this, my study was designed to demonstrate or disprove the need for further exploration of screencasting's potential as an assessment tool. However, this study was designed to serve as a proof of concept. Some of the key delimitations include the small sample size of interviewed participants, the small sample size of mathematical tasks evaluated, and the limited input of the teachers on the design of each question; which has a significant impact on their assessment decisions particular to that question. If I were to design a follow-up study, I would meet with the teachers both before and after meeting with the students, and would consult with them regarding the presentation and wording of the tasks. This would allow the study to better represent how screencasting responds to the incredibly diverse assessment practices of teachers and may offer insight into the settings in which it is most effective. Furthermore, by interviewing a larger population of students, perhaps at different grade levels, better informed conclusions and recommendations could be made.

Chapter Five: Analyzing the Data

The Students

The three students involved in this study are currently in university and each has completed a 30-level mathematics course, taught by me. In all cases, some level of contact has been maintained since their high school graduation. Though I had not realized it initially, this established relationship was significant to this study. Much of the positive feedback regarding screencasting, particularly from the teachers assessing the work, addressed the additional insight gained from students' narration of their thought processes. Had the interviewed students felt unsure or uncomfortable around me, they may not have spoken quite so freely. As I am optimistic, I believe that a relationship of trust exists between most students and their mathematics teachers and will preserve this assumption throughout further discussion, ignoring the impact associated with weakly or negatively established student-teacher relations.

Another important measure to consider is how far removed the student participants are from the high school math content specific to the assigned tasks. Mathematics evaluations, other than final exams, generally assess recent content; a class will study a particular topic for several weeks and tests related to this topic will only be written during this time period and immediately following it. This format often leads to the phenomenon of cramming, which may prompt concerns regarding retention and enduring understandings. Here, given the unlikelihood that participants have revisited content related to the assigned tasks in recent years, it will be assumed that their solutions are an indication of enduring understandings and not of recall. As the tasks were not given in advance, it is safe to assume the students did not cram to prepare.

Prior to attempting the mathematical tasks, the students were shown how to use the screencasting software, EduCreations. All three showed immediate ease, indicating that the user interface was intuitive and obvious. Any technical issues that arose were clearly not the result of misunderstanding how the technology should be operated. Other concerns regarding communicating student understandings using screencasting are addressed elsewhere.

Stephanie

As an observer, Stephanie had some experience with screencasts. One of her university courses required that assignments be completed online. For every question assigned, there was an example problem whose solution was shared as a screencast. Stephanie commented that the screencasts were more interactive than books and that they allowed to her to see the teacher's thought processes; this made it easier for her follow.

Table 1 shows the time Stephanie spent completing the tasks, as well as the marks awarded by each teacher.

Table 1: Data from Stephanie's tasks

Task	**Order completed**	**Solution medium**	**Time taken**	**Mark awarded by Ms. Martins'**	**Mark awarded by Ms. McLoughlin**
Question 1. Farmer Fiona	2nd	iPad	Prep 23 min 38 sec Rec 2 min 45 sec	10/10	4/4
Question 2. Cube Tower	1st	Pencil & Paper	7 min 3 seconds	7/10	1/3

Spatial organization of the written solution

Stephanie seemed very at ease when creating her screencasts. She liked having different colours readily available, and felt that the work shown was neater than had she done it with pencil and paper. This idea of neatness was brought up again when Stephanie discussed her frustrations vis-à-vis cluttered solution spaces: "[It] makes me feel flustered, looking back on it, just because I have so much work on my paper." Stephanie noted that the quickly clickable eraser was preferred to having to pick up an eraser when trying to keep her space clear of distracting ideas. "Even though I [erased] the pencil marks, you can still see what you've written before and it kind of interferes with trying to have a fresh clean slate."

Thought processes while problem solving

Despite appreciating the orderliness of the screencast's workspace, Stephanie found the field of view limiting when working with the tablet computer. "I found that going back and scrolling was a bit annoying. [It] kind of affects my thought processes." When working with pencil and paper, all the information contained within a page is visible and, therefore, more readily available. While working on her screencasted task (Question #1 - Farmer Fiona), Stephanie would frequently scroll back to the top of the page to look through her work, as though to remind herself of the steps that had led up to her current position.

Enhanced observability of understandings

While other participants spoke of how screencasting could potentially help a student clarify her thoughts and understandings to others, Stephanie pointed to the potential for the screencasts to serve as a studying tool. When students are reviewing their course material later, she said:

> It's much nicer to actually be able to hear back on your thoughts, as opposed to if you're looking at a paper, studying for an exam and then you turn back and you don't remember how you did something. So it's a lot easier to understand what you were thinking at the exact moment.

Jordan

Jordan had no prior experience as an author of screencasts but had viewed many, primarily for learning purposes. Like Stephanie, she commented that she found screencasts to be more interactive than printed learning resources.

Table 2 shows the time Jordan spent completing the tasks, as well as the marks awarded by each teacher.

Table 2: Data from Jordan's tasks

Task	Order completed	Solution medium	Time taken	Mark awarded by Ms. Martins'	Mark awarded by Ms. McLoughlin
Question 1. Farmer Fiona	1st	Pencil & Paper	13 min 52 sec	10/10	4/4
Question 2. Cube Tower	2nd	iPad	Prep 6 min 35 sec Rec 0 min 53 sec	9/10	2/3

Spatial organization of the written solution

Jordan explained that while the author's narration of the videos was an enhancement, she wanted to be able to see everything at once. For her, a dynamic presentation of the content in pieces was less helpful that seeing all of the content at the same time. "With math, sometimes you see something at the beginning of what you did and that will lead you to something later." She compared the experience to that of working at a whiteboard and stepping back to take in all that you've done, "and be able to make sense of what you've done."

Jordan commented that screencasting was less intuitive than pencil and paper. "Even though it's the same thing, I think it just feels different…The biggest thing is not being able to see everything at once."

Thought processes while problem solving

When asked about the benefits of recorded narration, Jordan pointed out that for her, the narration was an afterthought. "I didn't really have a process to follow…so if I were to narrate, I would be like 'I don't really know what I'm doing, but I'm going to do this right now because that's what makes sense to me.' " Though Jordan seemed to have a rich understanding of her solution process, she described her problem solving skills as being quite procedural.

> Even when I'm doing algebra, or something like that, where there is a very clear process as to what you should do, or if there's rules…I just naturally do that anyway just because it makes it easier to solve the problem. So I don't think that having to podcast [sic] something would make a different in my process, if I had one. And then it wouldn't make a difference if I didn't have a process, because I don't really know what I'm doing.

Regardless of whether she thought screencasting served her well, she did mention that it would be beneficial for someone who "needs to go step-by-step" or who was struggling and added that saying something out loud and then later learning it doesn't make sense leads to better recall.

Enhanced observability of understandings

In contrast to static solutions in a textbook, Jordan thought the dynamic presentation of a screencast was more helpful to its viewers. When verifying a solution in a textbook, "you almost have to know what to do, then the textbook gives you a shove in the right direction. It doesn't really show you what to do. With a podcast [sic], if you're very confused about what to do, I think that helps because it's actually telling what you do."

Interestingly, she expected that her own screencasted solution would be of being of little benefit to an assessor. “When I was speaking, I just told you what I did. I don’t think I really added anything that you wouldn’t understand by looking at it.” For her, there was little to add with the narration as “a lot of the steps that go through your head, you don’t even know you’re doing them.”

Abe

When asked of his prior experience with screencasts, Abe mentioned having seen videos such as those of Khan Academy. He seemed to have the least exposure of the students and had never created a screencast before.

Table 3, below, shows the time Abe spent completing the tasks, as well as the marks awarded by each teacher.

Table 3: Data from Abe’s tasks

Task	Order completed	Solution medium	Time taken	Mark awarded by Ms. Martins’	Mark awarded by Ms. McLoughlin
Question 1. Farmer Fiona	1st	Pencil & Paper	18 min 13 sec	10/10	4/4
Question 2. Cube Tower	2nd	iPad	Prep 6 min 38 sec Rec 6 min 44 sec	6/10	2/3

Spatial organization of the written solution

The organization of Abe’s work would receive significant attention from the teachers’ assessments. Regardless, Abe indicated a preference for the screencasts’ spatial options. “You have infinite space… [and] you can write you steps in a wider format. Some paper work can be cramped.” Of the student participants, Abe’s screencasted solution took up the most (virtual) space and was the only one that used multiples pages within EduCreations. He also had some challenges using the stylus pen and opted to write using his fingertip instead. Given that many of the comments regarding his organization were directed at his paper and pencil work, I have considered the use of his fingertip as a writing tool to be negligible in its effect on his presentation.

Thought processes while problem solving

As they worked on their screencasted tasks, both Stephanie and Jordan completed the full solution to their problem before pressing record on the iPad. This led to recordings of them reflecting on what they had done, commenting along the way. Though Abe attempted the problem prior to recording, he had not written out a complete solution. Despite saying that his screencast “wasn’t live, I was rewriting my steps,” it was clear from the video that his work was still in progress. This evidence of processing - instead of reflecting - would prove to be significant later, as Abe’s recorded comments served as cairns for the assessing teachers, who may have otherwise been lost following one of his thought paths. These same opportunities to get back on track helped Abe in his own work.

> Making screencasts helps you notice issues sooner. With paper and pencil, I would keep going. On the iPad, I would be saying things out loud and that would be a cue for checking things over. [I] caught a mistake I wouldn’t have caught [because] I was reading through.

Enhanced observability of understandings

Referring to screencasts he had viewed, Abe said that narration added “more sway” to the video, as if to suggest that the video was made more convincing or credible. He also appreciated the individuality that is communicated in a screencast. “Everyone has their own little tropes. With me explaining ‘this is what this is, this is what this is,’ you get a little better understanding.”

Abe’s comments contrasted Jordan’s in tone. Where she believed her narration would do little to enhance her written solution, he felt it was showing his style. “You’re kind of putting your spin on how to solve the question… You’re getting a new way of thinking out of it.” In addition to him stating that his understandings were better represented when he could include his voice, this observation of including his own style showed a sort of appreciation for the screencasting medium.

The Teachers

Both of the teacher participants involved in this study are experienced high school mathematics teachers, knowledgeable in the Alberta Program of Studies. Though I knew them prior to these interviews, I had never witnessed them teaching a high school math lesson, nor had I worked collaboratively with them on any form of assessment. Furthermore, as I did not want to influence any of their marking decisions, I kept any discussion regarding the assessment of the tasks to a minimum; if I was asked a question for reasons of clarity or the teacher requested help recalling or confirming a particular formula, I would answer. However, I would add no suggestions that might influence the teacher's solution or opinions regarding potential solutions. An exception to this would be when I, unprompted, pointed out to Ms. Martins that she had misread a particular question and, thus, had an incomplete answer key.

In knowing so little of my teacher participants' pedagogical and assessment practices, I was free of personalized assumptions. Though I anticipated certain responses from them as teachers, none of these anticipations were informed by past observations of Ms. Martins' or Ms. McLoughlin's teaching. I had expected some of their interview responses to differ to as a result of the current teaching settings (Ms. McLoughlin is actively teaching mathematics in a high school setting, Ms. Martins' is currently working and studying in a university setting) and hoped this variety would improve the study by helping to consider diverse perspectives. However, it is beyond the scope of this study (and of my ability) to determine to what degree their responses differed as a result of pedagogy as opposed to personality.

Ms. Martins

Ms. Martins' prior experience with screencasting was limited to viewing videos made by others. She had not used screencasted videos as a medium for assessment before, but did tell of one video she had recently seen in which a grade two student described strategies for multiplication. She explained that this screencast had piqued her curiosity and had left her with questions for the student author.

Spatial organization of the written solution

In both of the teacher interviews, the orderliness of Abe's paper and pencil response to Question #1 (Farmer Fiona) attracted some attention. The response showed several different partial solution attempts. One sequence of four steps was crossed out with an X (though still legible), while the rest were left for the assessor to interpret. Amongst these steps, almost all of the steps outlined in Ms. Martins' solution could be found (her solution had made use of the method of elimination to solve a system, while Abe has used the method of substitution). Despite Abe's solution having many of the same steps, Ms. Martins had questions regarding the incomplete attempts and their role in solving of this problem, stating that "all of the different paths are part of the process." She noted that she wouldn't deduct marks for wrong paths, "but would encourage better organization." In her feedback she encouraged him to number his attempts, in order to help her follow his solution in the order in which it was created. Ultimately, his presentation was a major focus of the assessment.

Much like the student comments regarding the ability to see the entire solution at one time, Ms. Martins commented that watching the screencasts in their entirety made it difficult to consider all parts of the solution simultaneously. The challenge here could lay in the cognitive overload created by *representational holding*, in which the assessor must hold in their working memory a representation of information shared either visually or verbally, while processing new information (Mayer & Moreno, 2003, p. 45). Ms. Martins could rewind to anything she wished to view again; however as students are inherently required to show their complete solution when using paper as the communication medium, this feature of the screencast was identified as a minor drawback.

Thought processes while problem solving

Prior to conducting the interviews, I had expected the teachers to emphasize the additional time that would be required to assess screencasts in lieu of paper solutions. Instead, Ms. Martins praised the additional information she became privy to. Though she did mention that evaluating recordings of the full solution process of each student may be problematic, she indicated several benefits: (1) increased insight into students' thought processes helps to inform future pedagogical choices; (2) students are given an opportunity to develop their written and verbal expressions of thought, reinforcing clarity and the use of technical vocabulary; (3) the process is reflective , effectively requiring the student to consider the problem twice and increasing the emphasis on troubleshooting and verification; and (4) the use of technology may be engaging for some students.

A more practical advantage was simply being able to follow the students' thought process. "For [Abe], I think the screencast is really useful. At first, it was hard to interpret his label." Ms. Martins explained that by assessing "live work", she could follow his thinking despite being distracted by incorrect labels and variable assignments (which he caught later).

Also, had the solution been completed with paper and pencil, he may have erased errors made along the way, which Ms. Martins considers valuable information for the teacher. “I prefer to listen to thinking through error than to see that he corrected it later.”

Enhanced observability of understandings

One of my primary interests throughout the teacher interviews was to hear their thoughts regarding how students’ understandings were more or less describable based on viewing the screencasts. More than just discussing how they could follow the student’s thought process, I was curious to know if they felt justified in appraising understandings as being more developed, based on the solution’s medium. Though there were fewer opportunities to judge this than hoped, Stephanie’s screencasted solution to Question #1 (Farmer Fiona) did provide some insight. Ms. Martins explained that when assessing student work, it’s not only about determining whether it is correct.

> When she [Stephanie] is factoring or simplifying, you can see that she knows how to do that. At some point, I would be able to say that she has understanding about what she’s doing by the way she’s talking about that, because some students they just simplify because they think ‘oh, I have to do that.’ But sometimes, by the way that student is describing, you can have a clue if the student really understands that or if she’s just doing [it] because at some point somebody told her that she should be doing that.

For Ms. Martins, the verbal justifications of why Stephanie had performed certain steps confirmed that her solution was possible because she had mathematical understanding, not simply because she recalled instructed steps. Moreover, Ms. Martins emphasized that she would "totally prefer to assess this one [Stephanie's] instead of the other two [Farmer Fiona examples], because she's explaining what she's doing."

In several of the paper and pencil assessments, Ms. Martins indicated particular steps for which she wanted to know what the student was thinking about and why. In Abe's written response she couldn't "see *why* he changed…if it was just a mistake or if he was thinking something else." Even in Stephanie's work, which she praised for its layout and clarity, she had problems interpreting. "I like this [columns] strategy, but where did this 11 come from?" She was, however, more sure of Jordan's written solution and suggested questions to further extend her understanding of the question. "I like the way this student was thinking. I would ask: 'if the numbers were too big, what strategies would you use?' "

Formative and summative feedback

It was interested to notice the variation in time and intensity as Ms. Martins deliberated on how to assess the student productions summatively versus formatively. Where her formative evaluation took several minutes for each student and had her inquiring about what they may or may not be thinking, her summative evaluation seem rather quick and decisive.

> If [the students] have a solution with correct process, 10 marks [out of 10]. But if I understand the process, I understand something to help improve the teaching process. This is the kind of stuff the teacher needs to know; maybe a misunderstanding to address in class.

Ms. Martins interview responses suggested that she was more focused on gleaning information to modify and improve her teaching process than to offer individual student feedback or corrections to a specific question. She also indicated that the screencasts would aid in identifying “which students need more help, and which are more confident - something I would like to know.” She pointed out that sometimes this can be determined during class discussion, but not as easily during exams or written evaluations.

When asked if she thought time would be a concern in the assessment process, she replied that “I might be saving time, because in only one example I can understand what the student is thinking.” She wondered if assigning one screencast might be more valuable [to her] than assigning ten practice problems.

Ms. McLoughlin

Ms. McLoughlin had no prior experience making screencasts and though she may have seen some in the past, was not familiar with this term. She did, however, mention that she had used the recording features of an iPad to have her students create short self-assessment videos after completing class projects. Though this would not be described as a screencast (as the activity being captured was not on the screen), it does demonstrate a focus on student reflection, assessment, and the integration of technology in the classroom.

Ms. McLoughlin did mention some concerns regarding the implementation of screencasting as a classroom practice. In particular, she questioned the likelihood of most teachers having a classroom set of tablet devices, such as iPads, available. Secondly, she pointed out that the wifi connection in her classroom was of very poor quality (though wifi is not necessary to run the app, it would be needed to upload any files made and share them with the teacher). Finally, she wondered if a class of over thirty students would allow for audio recordings that weren't ruin by excessive background noise. These are important considerations and in some schools could prove quite challenging to resolve. However, as they help to better understand the effectiveness of screencasting in communicating students' understandings, they will not be discussed further in this study.

Spatial organization of the written solution

From our interview, it was clear that Ms. McLoughlin places significant value on the organization of students' written work. Though she did state that she would not "test it", as she considered the organization of one's thought process to be too subjective, she emphasized that the ability to display mathematical thinking in an orderly fashion is "an important lifeskill". Furthermore, she explained that this skill transfers more generally to all cases in which one must communicate directions for others to follow.

Upon examining Jordan's written work, Ms. McLoughlin's first comment was that her "work is lined up so that I can follow…their vertical organization here. I know exactly what the process of thinking was." Even in her response to Question #2 (The Cube Tower), where she had produced an incorrect answer, Ms. McLoughlin described her as "linear and organized" and explained that she would only deduct one mark because the answer was wrong; "I see that she has it up to here [indicating the final step]."

Meanwhile, both of Abe's solutions received significant criticism based on the layout of his work. Ms. McLoughlin characterized the work as "hard to follow because they were all over the paper…I wasn't able to follow it." She suggested arrows to indicate the order of solution and discussed lining the steps up vertically to help the reader. “This guy needs a lot of work on linear organization, he’s [even] having trouble explaining this orally.” Despite this being the focus of her feedback, her summative evaluation was unaffected by these comments. Abe’s solutions were awarded 4/4 and 2/3 (his second solution was incomplete).

Thought processes while problem solving

It was important to Ms. McLoughlin that her assessments be fair. As she read through the student solutions, I noticed a desire to follow each of their steps, as though she was recreating the process for herself. “They definitely have a different way of thinking than me.” When a step had been skipped by the student, she would pause as if to consider what they might have been thinking. “In their head, they already reduced. I didn’t follow that right off the bat because I can’t see it explained here. [It] took me a minute to pick up that that’s what they did in their head.”

She explained that in her classroom, she often uses an activity which she called an “out-loud” or “do-out-loud”. Here, students solve a problem by working vertically down one side of the page and write out their thinking process, in detail, on the other side of the page, as though they were explaining it “out-loud” to a partner. Sometimes, students will partner up after writing out their solution to compare answers. Based on her success with this activity, she expected that the talking associated with the screencasts could only be constructive. After assessing the screencasts, she indicated that the narration was a helpful support to both the assessor and the author, but that she found Stephanie’s narration to be redundant, “because she’s already showing every step”.

Interestingly, Stephanie's paper and pencil solution may have provided the most challenge of the non-screencasted solutions.

> Let's start backwards. *Pause.* I can't follow her thinking. *Pause.* Maybe I can find an error in here, but I would have to call her up and ask what's going on with these columns and these cubes. *Pause.* I think I got it…I think I know what she's doing. *Pause.* I can't follow what she's doing…she's making me doubt my own answer. *Pause.* Am I missing something?

Ms. McLoughlin even went so far as to suggest assigning a temporary mark of 1/3, and waiting until she could discuss the solution with Stephanie.

I asked Ms. McLoughlin how she thought a screencast would change the representation of a student's solution. She pointed to Abe's screencasted response to Question #2 (The Cube Tower) and said "I bet he gets the right answer on a screencast and maybe a wrong answer over here [using paper and pencil] - or me not understanding his method [with] paper and pen. For some people…they would get different answers."

Ms. McLoughlin told me that some of her students receive special exam accommodations and write their test "in isolation" so that they may talk out loud to themselves. She felt that these students would benefit from screencasting solutions, as would all auditory learners.

Enhanced observability of understandings

Ms. McLoughlin's comments were primarily focused on the progression of individual steps within the solving process. Of the few references made regarding student understandings, most emphasized the student's ability to explain their knowledge in a way that readers, in this case the teacher, could follow and understand correctly. “[You] always understand better if you can break it down and verbally explain it”. She also mentioned that as a marker, it was easier to “see” understanding with screencasts.

A common observation made by both teachers was made about Stephanie’s screencast. Though Ms. McLoughlin did think the recorded narration was unnecessary given how complete the written work was, she noted that Stephanie justified steps verbally where she wouldn’t have written out justifications, and suggested that this indicated mathematical understanding. “[But] even if this was on paper, I’d be able to understand.”

Formative and summative feedback

Our discussion regarding the specifics of her assessment practices made it clear that Ms. McLoughlin very clearly distinguishes between can and cannot be assessed summatively. “For an assessment, if I’m going to be fair to the students, they need to know what I’m looking for.”

As our discussion continued, I asked how she might respond to misunderstandings that materialize during a solution, but are not directly related to the target outcome. For example, when solving Question #1 (Farmer Fiona), Jordan listed multiples of 4 and of 2, but labeled the lists as “factors of 4” and “factors of 2”. “I’m not testing multiples and factors. It’s important to bring up, but not for grading. I’m only assessing that from that question, otherwise it’s not fair. So many things could come into play.”

Ms. McLoughlin proclaimed a lot of respect for the colleagues in her department and explained that summative assessment decisions are often made collaboratively. As such, while formative practices may vary greatly from class to class, summative assessments should not.

Chapter Six: Suggestions and Reflections

The intent of this study was to focus on the capacity of screencasts in communicating students' mathematical understanding for the purposes of assessment and feedback. In describing the mathematical processes critical to learning, doing, and understanding mathematics, the *Alberta Mathematics Program of Studies* highlights that:

> Communication is important in clarifying, reinforcing and modifying ideas, attitudes, and beliefs about mathematics. Students should be encouraged to use a variety of forms of communication while learning mathematics. Students also need to communicate their learning by using mathematical technology (Alberta Education, 2008, p. 6).

My interviews with three students and two experienced high school teachers suggest that the medium of screencasting is at least as effective as that of paper and pencil in communicating understandings and may provide additional information to the assessor. While the small number of participants and tasks explored limits the assertive strength of any conclusions, I believe that the findings justify pursuing a richer investigation of screencasting's potential role in assessment. Based on the major themes identified in Chapter Five, I will address here some of the advantages and disadvantages of student authored screencasts, and will suggest possibilities for further research regarding this educational tool.

Spatial organization of the written solution

Throughout the interviews, it was clear that the teachers judged the spatial organization of students' work to be meaningful, both to support the communication of their understandings and for the purposes of assessment. For example, both teachers criticized Abe's paper solution of Question #1 (Farmer Fiona) for not indicating the order of his steps; Ms. Martins suggested numbering his attempts and Ms. McLoughlin suggested the use of arrows. They claimed to have difficulty following the flow of his thoughts and felt that this limited their ability to assess his understandings. Importantly, both indicated uncertainty about what he might have been thinking specifically because of the poor organization of his solution, implying that better organization would lead to a better communication of one's understanding. In contrast, in their evaluation of Abe's screencast solution to Question #2 (The Cube Tower), though the teachers were still critical of his poor organizational skills, they felt less limited in their ability to assess since the chronology of the solution was revealed by the video. Ms. Loughlin, addressed his screencast by saying:

> He's getting lost in his own work, because his linear organization isn't great. So, having him say it out loud probably helped him figure out his mistake and then definitely helped me follow through after his mistake, versus a whole bunch of scribbles on the paper.

Meanwhile, Ms. Loughlin suggested that because Jordan was "linear and organized" in her screencasted solution to Question #2 (The Cube Tower), elements of her narrated explanation were perhaps redundant. "Even if this [were] on paper, I'd be able to understand what was going on here."

It is important to clarify that if it is deemed important to teach students how to organize their thoughts such that the logical progression is communicated to the reader - something which Ms. Loughlin referred to repeatedly as a "lifeskill" - then the screencast has not independently furthered this goal. No particular feature of the EduCreations software, nor of the iPad hardware's design, offered any formatting help beyond the working space it provided (which, in this sense, is functionally equivalent to the space provided on a piece of paper). However, with this lack of formatting support in mind, the audio and video recording of the screencast provide the assessor with enough information to determine the progression of thought - assuming that the author either recorded the entire solution process or spoke, in order, through all steps displayed.

Though this feature of the students' solutions was not an anticipated focus of this study, the importance attributed to it by both student and teacher participants suggests that it is worth considering. The teachers commented that the organizational aspect of the solution would not affect a student's marks on a summative evaluation, however a poor sense of organization might be enough to obscure understandings that would otherwise earn marks for proper understanding.

Thought processes while problem solving

One important advantage of screencasted solutions highlighted in this study is the additional information provided regarding students' thought processes. In the creation of a screencast, the student author is asked to reflect on the steps taken to solve problem and to make these reflections observable. If not prompted, the author may not consciously consider what she did nor why, as "students do not naturally think about their solution processes, they often just do the math" (Casler-Failing, 2013, p. 181). Jordan's comment that "a lot of the steps that go through your head, you don't even know you're doing them," is substantiated by Skemp's (2009) elaboration of a resonance model, by which he describes the storage and retrieval of conceptualized information.

> We all have enormous stores of conceptualized knowledge, collected together to form a large number of different schemas. Most of this is for most of the time quiescent, like books on a shelf, not books that are open and being read. Sometimes, to continue the analogy, we scan the shelves for a book on a particular subject; but often, it is as though the right book came to our hands of its own accord, open at the page we need (Skemp, 2009, p. 118)

In many ways, the process of narrating the solution is akin to journalling, which asks the student to not only show a mathematical solution, but also discuss *how* she solved the problem. By drawing the student's awareness to her methods and asking her articulate these methods, the teacher is allowed to "see" the student's thinking processes and gain better insight into what she has done (Casler-Failing, 2013, p. 181). Berlinghoff points out that, even "[i]f the student does not know how to answer the problem, he or she can still write about what is known (the given information), what needs to be known (what the question is asking), and what information is needed to solve the problem (how the given information is used)" (as cited in Casler-Failing, 2013, p. 180). These details are helpful in limiting the assumptions the assessor must make in her evaluations. Moreover, this reflective report of thoughts helps the student evoke prior knowledge, connect previously learned concepts, and discover and correct errors (Lim and Pugalee, 2004).

There is value in learning to synthesize information and present it in a concise form. Indeed, it could be argued that in many cases this is a primary goal of written expression. Pugalee (2001b) proposes that "[w]ritten words require the writer to maximally compact inner speech so that it is fully understandable, thus making necessary the deliberate structuring of a web of meaning forming associations between current and new knowledge" (p. 236). While this observation seems to place high value on written expression, it does not diminish the important role of speech in pre-writing reflection. Indeed, prior to compacting one's thoughts, they must exist and be understood. Here lies the potential value in screencasting as an important tool in the process leading to the meaning forming associations.

Enhanced observability of understandings

In the design of this research study, six problems were gathered in hopes of providing enough challenge and engagement to elicit multi-step solutions which would offer insight into the author's thought processes and level of understanding. The study was focused on the media used for the response - namely paper and pencil, in the first case, and a screencast created on an iPad in the other. However, I see now that there was a major oversight in my design. The depth and detail of a solution is more dependent on the question provoking it than on the medium of its presentation. This is not to suggest that one medium could not allow for a clearer conveyance of one's understanding, but that in order to draw out a richer answer you must ask for it. By including a follow-up questions which asked the students to extend their thinking by, for example, generalizing their solution's strategy, I could have seized the opportunity to expose each medium's capacity for communicating relational understandings by better ensuring that these understandings be made observable. As a result, I may have confused the evaluation of how a screencasting medium communicates students' mathematical understandings with an evaluation of how it draws out students' mathematical understandings *when they are not specifically drawn out by the question.* Put simply: If I wanted to see relational understandings, and have them differentiated from instrumental ones, I should have asked for them.

> Learning to manipulate symbols in such a way as to obtain the approved answer may be very hard to distinguish in its early stages from conceptual learning. The learner cannot distinguish between the two if he has no experience of genuinely understanding mathematics. And all the teachers can see (or hear) are the symbols. Not being thought-readers, they have no direct knowledge of whether or not the right concepts, or any at all, are attached (Skemp, 2009, p. 33).

Not wanting to influence the study's results with the bias of my experiences (or perhaps of my desire for particular responses), I did not discuss Skemp's article (1976/2006) with the teachers prior to the interview. It is impossible to determine whether the teachers would have made use of language of the article or not, or whether it would have helped to see something more than they did, but ultimately no comments were made about the types of understandings exhibited in the students' work. However, going beyond the design of the study and including myself as a participating assessor, I confess that despite knowing of Skemp's descriptions of relational and instrumental understandings, I do not find myself any more inclined to apply these terms based on either solution medium.

I propose that richer mathematical understandings are often represented by the ability to perform mental operations more concisely and efficiently. Consider a computer program, in which multiple lines of code dedicated to a specific task are often grouped as a *function*. Programmers will call upon these functions throughout the program rather than repeatedly type out the same set of steps at different instances. This sophisticated approach is both more elegant and more efficient, but while it makes the overall program easier to read, it hides the detailed sub steps of the function from the reader (excepting when the function is first introduced). I believe the creation of these functions is similar to conceptual schema used to solve mathematical problems. Groups of basic steps are treated as functions, which allow the student's thought process to appear in a more streamlined state. While this is highly desirable for the purposes of problem solving, the resulting manifestation of the thought process is reduced to a code revealing the main architecture, but not the underlying subtleties.

Thus, I conjecture that screencasting's capacity for supporting assessment varies directly with the depth of the student's understanding. If a student has a less advanced understanding of a mathematical concept or problem, then her solution will be less streamlined and the narrational component of the screencast will serve as catalyst for the expression of the more basics steps of her solution. This may reveal valuable information regarding the gaps, misunderstandings, or inefficiencies in her thought process and provide the teacher rich opportunities for formative feedback. However, if the student's understanding is quite advanced, this will often be characterized by a more concealing architecture of thought process functions. The better someone understands something, the *less* they have to think about it in action. In this case, the screencast will be less effective in providing additional information regarding the student's understanding, unless they are explicitly asked to reveal the individual sub steps of their thinking process. Therefore, this medium which shows more evidence of the misunderstandings and underdeveloped knowledge, but may do little to expose the underlying architecture of more sophisticated relational understanding on the part of the student.

Formative and summative feedback

As explained in the previous section, screencasting may hold great value for formative assessment.

> An assessment functions formatively to the extent that evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have made in the absence of that evidence. (Wiliam, 2011, p. 43)

As teachers analyze student authored screencasts, they may identify misunderstandings and areas in need or reteaching or extended activities. Moreover, this teaching tool gives an opportunity to support students' uniqueness and creativity into the mathematics classroom (Casler-Failing, 2013, p. 183). Providing detailed, descriptive feedback to students is time consuming, but worthwhile. With an emphasis on learning, rather than ranking, formative assessment can lead to improved student achievement (Lim & Pugalee, 2004).

However, while this study may have supported screencasting's efficiency in formative assessment insofar as it allows the teacher to gain more information per solution analyzed, it offered little to suggest that screencasting will improve the speed and efficiency of summative assessment. While some examples, such as Abe's poorly assigned variables or Stephanie's unclear "column strategy" in her paper response to Question #2 (The Cube Tower), suggest that a screencast could improve the accuracy of a teacher's assessment, it seemed that the inability to communicate one's understanding may be justification for assigning lower marks. Simply, whether screencasted or written on paper, not knowing how to communicate was deemed functionally equivalent to not knowing.

Final Remarks

In order to best respond to the needs of their students, teachers need to first identify these needs. In the absence of rich relational understanding, students seem to struggle to incorporate new knowledge. By not adequately treating the underlying deficiencies, it is though teachers are asking students to build a house of cards on a shaky table. Again and again, we explain how to balance the cards against one another. Again and again, the house collapses. This study aimed to support assessment practices which go beyond marking missed understandings by evaluating a tool which may help to expose student misunderstandings. With this information, teachers may be able to better rehabilitate students' capacities to develop new understandings and be successful in their mathematics classes.

While this project is not a comprehensive summary of the experiences of my master's program, it is influenced in some way by all of them. In particular, it has highlighted and furthered my exploration of the different types of understandings as presented by Richard Skemp (1976/2006; 2009). I was hoping that this new-to-me medium of screencasting would allow me to see *differently*; to somehow assess in a new way. I have assessed written work before. I have assessed students' oral responses before. How did I expect the act of combining the two together to produce something radically different? The study's participants agreed: The screencast offers at least as much information as the paper and pencil solution. But does this additional information tell us something meaningful about the students' understandings? Was the screencasting leading to new insight? In their book on assessment in mathematics, Lesh and Lamon (1992) elaborate:

> To assess the types of models that individual students have constructed, and to assess the stability of these models in a variety of situations and conditions, assessment must go beyond testing the *amount* of information that a student notices in a given situation; it must also assess the nature of the *patterns* of information that are noticed and identify valid and invalid assumptions that are made about underlying regularities [emphasis in the original] (p. 31).

This study suggests that student authored screencasts can serve as an effective medium for communicating mathematical understandings. Though screencasting may not distinguish between different types of understandings without questions designed to do so, it can help to offer better feedback by more richly informing the assessment of the subtleties of each student's understandings. This added detail enables to teachers to more accurately address misunderstandings and areas in need of development. Ultimately, the use of screencasting leads to richer formative assessments and the potential for improved student achievement.

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Appendices

Appendix A: Student Information Letter and Consent Form

INFORMATION LETTER and CONSENT FORM

Study Title: Screencasting as a Medium for Communicating Students' Understandings in the High School Mathematics Classroom

Research Investigator:
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Supervisor:
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832 Education South
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780 492 0998

Dear [Name of student],

I am a student in the Faculty of Education at the University of Alberta. As part of my MEd program, I am conducting a study investigating the ways by which high school students communicate their understandings of mathematics. My hope is that you might allow me to make video recordings of you completing several mathematical tasks followed by a brief interview. The tasks will be completed using either paper and pencil or a tablet computer, which I will provide. I anticipate that the tasks and interview together will take approximately 90 minutes of your time.

The purpose of my study is to compare how different media (specifically paper and pencil versus screencasting using tablet computers) allow students to show teachers their mathematical skills and understandings. I hope that this research might help mathematics teachers develop a better idea of how practical and effective screencasting can be as an assessment tool for high school mathematics teachers.

In order to accomplish these goals, I will be collecting samples of mathematical work from you and two other participants which I will show to two mathematics teachers. These teachers will be asked to assess the samples done with paper and pencil and those done with screencast recordings and will then offer their feedback. I will be writing a paper based on your work, your interview responses, and the teachers' feedback. Though publication is not a primarily goal, it is possible that some form of the paper would be published or used for presentations in the future. At no time would you be identified.

In order to protect your privacy, the samples shared with the teachers will not identify you in any way, nor will the teachers be given any information regarding your identity. Though they will hear your voice in the screencast recording, your face will never be shown. I do not foresee any harm resulting from this activity. Rather, I believe you may find the opportunities to learn about screencasting and to reflect on your mathematical experiences to be of personal benefit. I will offer basic training on how to use the screencasting software and will be present for technical support throughout the process.

You are under no obligation to participate in this study. Your participation is completely voluntary. Furthermore, should you feel uncomfortable completing a particular mathematical task or answering any specific question, you may abstain from that task or question. If you consent to be involved in this study, your anonymity will be maintained. Even if you agree to be in the study, you can change your mind and withdraw at any time during the first seven days after your interview. Should you decide to withdraw your participation after our meeting, any data collected from you would be withdrawn from my study. I will be video and audio recording our meeting and will partially transcribe the audio recordings. You will be given the opportunity to review the transcription prior to it being included in my research paper. The recordings will not be shared with anyone other than my research supervisor and I will use a pseudonym to represent you in all work that is written. After the participating teachers have assessed your work samples, they will be scanned and then destroyed. The digital files will be encrypted and stored along with the screencasts and interview recordings on a computer that is password protected for a minimum of five years following completion of this research activity.

If you have any further questions about participating in this study, please feel free to contact me at (780) 292-4494 or my supervisor, Dr. Elaine Simmt, at (780) 492-0998. The plan for this study has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780) 492-2615.

Thank you for considering my request. If you would like to participate in this study, please complete the consent form and contact Dean Walls at dwalls@ualberta.ca or (780) 292-4494 to set up a meeting time.

Yours sincerely,

Dean Walls

Appendix B: Teacher Information Letter and Consent Form

INFORMATION LETTER and CONSENT FORM

Study Title: Screencasting as a Medium for Communicating Students' Understandings in the High School Mathematics Classroom

Research Investigator:
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780 492 0998

Dear [Name of Teacher],

I am a student in the Faculty of Education at the University of Alberta. As part of my MEd program, I am conducting a study investigating the ways by which high school students communicate their understandings of mathematics. My hope is that you might assess some student work for me and then allow me to video record a brief interview in which you explain your assessment and offer feedback. I anticipate that the assessments and interview together will take less than two hours of your time.

The purpose of my study is to compare how different media (specifically paper and pencil versus screencasting using tablet computers) allow students to show teachers their mathematical skills and understandings. I hope that this research might help mathematics teachers develop a better idea of how practical and effective screencasting can be as an assessment tool for high school mathematics teachers.

In order to accomplish these goals, I will be collecting samples of mathematical work from three participants which I will show to you and, on a separate occasion, to one other mathematics teacher. You will be asked to assess the samples done with paper and pencil and those done with screencast recordings and to share your thoughts regarding the different ways in which they offer insight into the students' mathematical understandings. I will be writing a paper based on the student work, their interview responses, and then your assessment and interview responses. Though publication is not a primarily goal, it is possible that some form of the paper would be published or used for presentations in the future. At no time would you be identified. A pseudonym will be used to protect your privacy.

I do not foresee any harm resulting from this activity. Rather, I believe you may find the opportunities to learn about screencasting and to reflect on your mathematical experiences to be of personal benefit. I will offer basic training on how to use the screencasting software, should you be interested.

You are under no obligation to participate in this study. Your participation is completely voluntary. Furthermore, should you feel uncomfortable answering any specific question, you may abstain from that question. If you consent to be involved in this study, your anonymity will be maintained. Even if you agree to be in the study, you can change your mind and withdraw at any time during the first seven days after your interview. Should you decide to withdraw your participation after our meeting, any data collected from you would be withdrawn from my study. I will be video and audio recording our meeting and will partially transcribe the audio recordings. You will be given the opportunity to review the transcription prior to it being included in my research paper. The recordings will not be shared with anyone other than my research supervisor and I will use a pseudonym to represent you in all work that is written. The interview recordings will be encrypted and stored on a computer that is password protected for a minimum of five years following completion of this research activity.

If you have any further questions about participating in this study, please feel free to contact me at (780) 292-4494 or my supervisor, Dr. Elaine Simmt, at (780) 492-0998. The plan for this study has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the University of Alberta. For questions regarding participant rights and ethical conduct of research, contact the Research Ethics Office at (780) 492-2615.

Thank you for considering my request. If you would like to participate in this study, please complete the consent form and contact Dean Walls at dwalls@ualberta.ca or (780) 292-4494 to set up a meeting time.

Yours sincerely,

Dean Walls

Appendix C: Student and Teacher Task Instructions

Student Instructions

First, let me thank you for taking part in this study. My research could not happen without you and I am very appreciative of your time.

Today, you will be completing some mathematical tasks using different media. For two of the tasks, you will use a paper and pencil to show your work. For the other two tasks, you will be using an iPad to record a screencast of you solutions. Anyone who watches your screencast will see what you wrote and will also hear what you said while writing it. In both cases, you will have access to a calculator.

These tasks, once completed, will be assessed by some mathematics teachers. For this reason, it is important that you “show your work”. Though I will be with you throughout the process and will be video recording, those who will perform the assessment will only see what is written on the paper or recorded in the screencast.

As much as possible, I would ask that you complete these tasks independently. If a task is unclear in any way or if you require any technical assistance with the screencasting software, please ask for help.

Though your time is not limited, I will be timing how long is spent on each task. For this reason, please indicate to me when you have finished one task and are starting the next. When you have finished all four tasks, I have some questions to ask you about your experience.

Once again, thank you for your time.

Teacher Instructions

First, let me thank you for taking part in this study. My research could not happen without you and I am very appreciative of your time.

Today, you will be assessing some mathematical tasks completed by students. Two of the tasks were completed using paper and pencil and two were completed using an iPad to record a screencast. Each of the four tasks may have up to three samples to assess.

I would like the way you assess today to reflect, as best as possible, your typical assessment practices. For this reason, I will first ask you to complete the four tasks that were given and consider what skills and understandings you would expect your students to demonstrate in their solutions. Based on your criteria, please determine the marking scale you would use for each question, as if it were part of a summative evaluation. Then, I will present you with the student examples and ask you to provide written feedback in response to the students’ productions and decide what mark you would award based on your predetermined scale.

When you have finished, I have some questions to ask you about your experience.

Once again, thank you for your time.

Appendix D: Mathematical Tasks

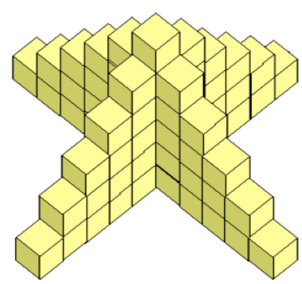
Mathematical Tasks

The student tasks will be selected from or will resemble the examples below.

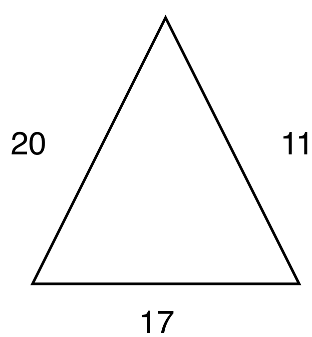
For each mathematical task, your goal is to show your full understanding of the problem and its solution and to communicate this understanding using the assigned medium (pencil and paper or tablet computer). Please be sure to ***show your work*** *as clearly and explicitly as possible.*

1. Farmer Fiona has pigs and chickens. Last Tuesday, she counted 34 eyes and 46 feet. How many chickens does she have?

2. The cube tower shown below has one cube in its top layer and five cubes in its second layer. The diagram shows six layers. If each cube costs 12 cents, how much would it cost to build a cube tower with thirteen layers?



3. A secret number is assigned to each vertex of a triangle. On each side of the triangle is written the sum of the secret numbers at its ends. Explain a simple rule for revealing the secret numbers. An example has been given below.



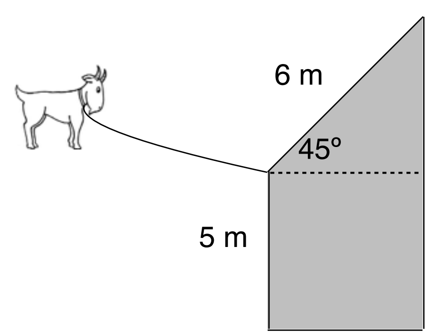
4. Three people carry five pails (each with capacity 8L) to a place where there are three springs. One of the springs gives 2 litres per minute and the other two give 1 litre per minute. It is not possible to use one spring to fill two pails simultaneously. It takes less than two minutes and more than one minute to take a pail from one spring to another. What is the shortest time it takes for them to fill all five pails? How is this accomplished?

5. "How many girls were at the party?" asked Carina's mother.

   "I do not know," said Kadija's mother, "but every two used a dish for noodles between them, every three used a dish for green onion cakes between them and every four used a dish for spring rolls between them."

   There were 65 dishes in all. How many girls were there at Kadija's party?

6. A goat is tied with a rope to the corner of a shed as shown below (the diagram represents a view from above). If the rope's length when fully stretched is 7 metres, what is the maximum area that the goat can graze, to the nearest tenth of a square metre?



Appendix E: Student Interview Questions

Interview Plan

Students

The primary goal of my interviews with the student participants will be to elicit their reactions to using screencasting, in contrast to paper and pencil, when demonstrating their mathematical understandings. The interviews will be semistructured and many of the questions and probes will be in reaction to comments that arise during the interview.

Some of the main guiding questions may include:

- This study asked you to answer some mathematical questions using pencil and paper and some using screencasting software. Have you had any past experience with screencasts?
- Was your experience of screencasting a mathematical solution different from what you expected?
- Was there anything about the tablet or screencasting software that made it difficult to use?
- If you were to answer the same question twice, once with paper and pencil and once with a screencast, in what ways would your solutions look different?
- Some people would say that making screencasts takes too much time. What would you tell them?
- Did you feel that your mathematical understandings were represented better using one medium over the other?
- If you were a teacher, what would make you use or not use screencasting with your students?

Appendix F: Teacher Interview Questions

Interview Plan

Teachers

The primary goals of my interviews with the teachers will be to determine how student authored screencasts affect their assessments of students' work and whether they believe this is a viable method of evaluating students' mathematical understandings. Theses interviews will also be semistructured and many of the questions and probes will be in reaction to comments that arise during the interview.

- This study asked students to answer some mathematical questions using pencil and paper and others using screencasting software. Have you had any past experience with screencasts?
- Was your experience of assessing a screencast different from what you expected?
- Was there anything about the screencast that made it particularly difficult to assess the students' work?
- If you were to compare two student solutions to the same question, one completed with paper and pencil and one with a screencast, in what ways would you expect them to look different?
- Some people would say that having students create screencasts takes too much time. What would you tell them?
- Did you feel that students' mathematical understandings were represented differently depending on the medium used?
- As a mathematics teacher, what factors would lead you to use or not use screencasting with your students?