SUPPORTING MATHEMATICAL EXPLANATION, JUSTIFICATION, AND ARGUMENTATION, THROUGH MULTIMEDIA: A QUANTITATIVE STUDY OF STUDENT PERFORMANCE

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The purpose of this quantitative study examined the effects a classroom blog had on student performance in the area of conceptual and procedural understandings of fractions. Specifically, the study examined the effects of self-explaining with a peer (explain, justify, and argumentation) to the solving of traditional paper pencil mathematical tasks alone (solving on your own). The experimental groups (i.e. face-to-face and blog groups) solved identical mathematical tasks to the traditional alone group by explaining their solution through justification with evidence from the task by self-explaining with peers. Both experimental groups engaged in mathematical discourse by explaining and justifying their understandings, as well as critiquing and arguing the thinking of other student responses through self-explaining with peers; however, one group used a multimedia tool. This quasi-experimental design study further explored how interactive and constructive mathematical discourse (i.e. explanation, justification, and argumentation) through a classroom blog supported student performance of fifth-grade students on conceptual and procedural fraction knowledge and the retention of this knowledge over time. To measure the change in student performance, a pretest-posttest, and delayed posttest was administered to measure the conceptual and procedural knowledge of fractions. Participants included 134 fifth grade students, ages 9-11 years old. Data collection was analyzed using repeated measures ANOVA with one between-subjects factor.
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Keri L. Stoyle
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CHAPTER I

INTRODUCTION

Statement of the Problem

‘If we teach students as we taught yesterday's, we rob them of tomorrow’

~ John Dewey

Classrooms should be environments in which students are encouraged to discuss their ideas with one another, where risk-taking is nurtured through respect and valuing of student thinking, and where sufficient time and encouragement is provided for exploration of mathematical ideas (NCTM, 1991, 2000, 2010 & 2014). Effective mathematics teaching engages students in discourse to advance the mathematical learning of the whole class (NCTM, 2014). Discourse in the mathematical classroom gives students opportunities to share ideas and clarify understandings, construct convincing arguments regarding why and how things work, develop a language for expressing mathematical thinking, and learn to see things from other perspectives (Chi, 2009; NCTM, 1991, 2000 & 2014). The process of mathematical thinking is doing what makers and users of mathematics do: framing and solving problems, looking for patterns, making conjectures, examining constraints, making inferences from data, abstracting, inventing, explaining, justifying, and challenging the thinking of others (argumentation) (Stein, Grover, Henningsen, & Grover, 1996). Exposure of students to meaningful and
worthwhile mathematical tasks that are characterized by having more than one solution strategy, as being able to be represented in multiple ways, and as demanding that students explain and justify their procedure and conceptual understandings in written and/or oral form can not only support mathematical thinking through discourse, but is critical for deep mathematical understandings (Stein et al., 1996; Chi, 2009; NCTM, 2000, 2014). Results of International studies have discovered mathematics instruction in the United States, emphasizes procedural fluency, automatic and quick execution of algorithms with less instructional time allocated for problem solving and verification activities (conceptual and procedural understanding) (Gonzales et. al., 2000; TIMMS 2003, 2007, 2011; Baxter et al., 2005). From positions held in factories all the way to Wall Street, a reasonable proficiency in math is a crucial requirement in a modern economy; however, over the past 30 years, mathematics achievement of U.S. high school students have been behind other countries, such as China, Japan, Finland, the Netherlands and Canada (Siegler et al., 2012). These findings demonstrate the need to improve the teaching and learning of fractions and division (Siegler, 2012). Proficiency in mathematics for all students is needed in order to compete globally. The academic progress of our nation’s students has been static and we have lost ground to our international peers, especially with evidence of high remediation rates for US college mathematics students. In the state of Ohio, over fifty percent of students scored below proficient (scored partial or no credit) on extended response questions because the student failed to explain and justify their mathematical thinking on both procedural and

Pedagogy aligned to standards-based education efforts to support student mathematical discourse is needed to increase student performance.

**The Standards**

Currently, the Common Core State Standards for mathematics and English language arts/literacy (ELA) were created to ensure that all students acquire the skills and knowledge necessary to graduate from high school in order to succeed in college, a career, and life, regardless of where they live (CCSSI, 2011). While 45 states, the District of Columbia, four territories, and the Department of Defense Education Activity (DoDEA) have adopted the standards (to date), the implementation of the new Common Core State Standards in both English Language Arts and Mathematics, teachers are expected to provide increased opportunities for students to write in order to communicate their understandings about key concepts. However, this study will focus on the implementation of the standards for mathematics communication and collaboration (CCSSI, 2011; Martin & Polly, 2013).

**21st Century Learning; Technology to Support Collaborative Discourse & Argumentation**

With increased demands of competing in the global economy, it is necessary to increase the rigor in K-12 classrooms through 21st century learning skills by continuing to use best practices in the classroom. The National Technology Standards, including how
multimedia supports critical thinking skills and problem solving through communication and collaboration will be discussed in this section.

In the state of Ohio, former Governor Strickland proposed that 21st century learning initiatives should incorporate critical thinking skills and problem solving, communication, collaboration, and creativity and innovation through the standards (Strickland, 2009). The National Technology Standards and Performance Indicators for Students (NETS-S) published by the International Society for Technology in Education further support the need to develop communication skills simultaneously with technology (ISTE, 2007). Communication and collaboration skills are woven throughout the standards, but are particularly highlighted in Standard 2 of the NET-S (using digital media to communicate and work together collaboratively) (ISTE 2007, Puckett et al., 2011). One of the major developments in learning with computers is the field of Computer-supported collaborative learning (CSCL) environments (Stahl, Koschmann, & Suthers, 2006).

A few projects contributed to the evolution of Computer Supported Collaborative Learning Environments (CSCL). The ENFI Project at Gallaudet University, the CSILE project at the University of Toronto, and the Fifth Dimension Project at the University of California San Diego were the forerunners and all three involved exploring the use of technology to improve literacy learning.

The Computer Supported Intentional Learning Environment (CSILE Project) dealt with the development of technologies and pedagogies to restructure classrooms as
knowledge-building communities. Electronic Networks for Instruction (ENFI) Project at Gallaudet University supported students who are deaf or hearing impaired; many with deficiencies in written-communication skills and provided a new form of meaning making by providing a new medium for textual communication. The next project, Fifth Dimension (5thD) Project, was developed with an interest in improving reading skills at Rockefeller University (Stahl et al., 2006; Cole, 1996). CSILE, ENFI, and Fifth Dimension are all initiatives created to support writing, reading, and problem solving in the field of education, but not in the field of mathematics. Since mathematical problem solving through written explanation, justification, and argumentation crosses into the Language Arts realm, further exploration of these initiatives through Computer Supported Collaborative Learning (CSCL) are needed to support success in mathematics.

Computer Supported Collaborative Learning (CSCL). CSCL considers all levels of formal education from kindergarten through graduate study, as well as informal education to effectively enhance learning through computer support and collaborative learning (Stahl, 2006).

Multimedia learning environments through computer supported collaborative learning also combine multiple sources of information such as text, diagrams/pictures, video, and simulation to help students master cognitively challenging tasks. In order to benefit from these environments, students need to make the necessary connections among the sources of information for learning. The strategy that will be used for this study to
encourage students to think deeply about and engage cognitively with the material to be learned is prompted self-explanation (Wylie & Chi, 2014).

One framework that will be discussed in more detail later is self-explanation through Interactive, Constructive, Active, and Passive Learning Engagement Theory (I-C-A-P) (Chi, 2009; Chi & Wylie, 2014). Chi (2009) defines active engagement as better than passive, and constructive engagement is better than active, therefore interactive engagement is better than constructive. This study will focus on constructive and interactive learning engagement of this framework for purposes of overt evidence of student performance.

Self-explanation is defined as a constructive cognitive skill that facilitates deep and robust learning by making connections to prior knowledge and refining mental models; especially in equation solving and fractions (Chi, 2000; Rittle-Johnson, 2006; Hallett, Nunes, & Bryant, 2010). Self-explanation is a major component in understanding constructive and interactive learning. Self-explanation supports student cognitive engagement with learning material, as well as can occur with or without an expert or peer. When students self-explain, they identify and fill gaps in their knowledge when interacting with the material to be learned. Self-explaining with a peer occurs through interactive learning when students construct meaning together from learning materials through revising errors through feedback, building on a partner’s contribution, arguing, defending, and challenge others (Chi, 2009).
In explaining and justifying understandings (constructive learning activity),
students are expected to use the context of learning material to self-explain
understandings and go beyond the provided material and generate new content (Chi,
2009; Chi & Wylie, 2014). The cognitive processes that occur include interpreting new
knowledge, integrating new information with existing knowledge, and organizing own
knowledge for coherence (Chi, 2009). When students are asked to construct viable
arguments and critiquing the thinking/reasoning of others, this can be done through
interactive learning activity by self-explanation with two or more students working
together to complete a constructive activity (eg. when asking questions about
understandings with evidence from learned material such as peer tutoring) (Chi & Wylie,
2014; CCSS, 2010; Cross et al., 2008). Students jointly create processes that incorporate
a partner’s contributions when taking part in self-explaining (i.e. interactive learning)
with peers (Chi, 2009). Self-explanations can take on many forms with a common feature
that can be done through solving mathematical tasks (Rittle-Johnson, 2006).

Mathematical Proficiency & Discourse

The quality of classroom discourse (communication & collaboration of
understandings) has become an important focus in the discussion of school reform. In
order to obtain “high wage” positions, students should be able to “communicate
effectively, both written and verbal”, as well as “the ability to work in groups with
In 2001, the National Research Council report “Adding it Up” defined the learning of mathematics to include the development of five interrelated strands that, together, constitute mathematical proficiency. The strands include: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. The comprehension and connection of concepts, operations, and relations (conceptual understanding) helps build the foundation necessary for developing meaningful and flexible use of procedures to solve problems (procedural fluency). The ability to formulate, represent, and solve mathematical problems (strategic competence) and the capacity to think logically and to justify and explain one’s thinking (adaptive reasoning) are needed for students to develop mathematical ways of thinking to support solving not only problems in mathematics, but in real life. These ways of thinking are also described as “processes” and “reasoning habits” in the National Council of Teachers of Mathematics documentations (NCTM 2000 & 2009). The Common Core State Standards for Mathematical Practice (CCSSMP) describe a variety of expertise that should be developed in students at all levels, referred to as “mathematical practices” which represent what students are “doing” as they learn mathematics. These practices developed from “proficiencies and processes” with longstanding importance in mathematics education. More than ever there is a need to increase opportunities for students to develop problem solving skills. One way to improve student performance is to enhance mathematical writing processes to help students evaluate the validity and
accuracy of their mathematical thinking through self-explaining and self-explaining with peers.

**Rationale for the Study**

While research addresses the benefits of student-centered collaboration in reform-based classrooms through increased verbal and written communication (Thompson, 2010; Ray 2003) of elementary students (Yackle, Cobb, & Woods, 1991; Cobb & McClain, 1996; Yackle, 2001), there is limited research investigating the benefits of mathematical collaboration through self-explaining of upper elementary students in an online collaborative learning environment. In an attempt to understand one contributing factor for low achievement in the area of written expression in mathematics, this study will investigate student self-explaining of fraction concepts and how they are transferred into written responses through a classroom blog compared to traditional paper pencil written responses. Research in the area of mathematical explanation and justification will attempt to be merged with the idea of self-explaining through constructive understanding, as well as mathematical argumentation involved with the “self-explaining with a peer” through interactive learning. These concepts will be later discussed in detail through the theoretical/conceptual framework.

**Significance of the Study**

Research in the fields of cognitive research and mathematics education characterize mathematics learning as an active process in which each student builds his or her own mathematical knowledge from personal experiences combined with feedback
from peers, teachers, and other adults, as well as themselves through reflection (NCTM, 2014; Vygotsky, 1978; Chi, 2009). Communication with peers develops a back and forth process from thought to word and word to thought that allows learners to move beyond what would be easy for them to grasp on their own (Truxaw, Gorgievski, & De Franco, 2008).

Many schools and teachers pride themselves with being up to date with the latest technology and tools. However, the value of technology depends on whether students actually engage in ways that promote mathematical reasoning and sense making (NCTM, 2014). Mathematics teachers should adopt technology that supports effective instruction, not adopt technology simply for the sake of using more technology in the classroom (NCTM, 2013). While studies have performed on the topics such as self-explanation and cognitive load in a multimedia-learning environment, as well as mathematical argumentation; minimal research has been completed in the area of mathematical explanation, justification, and argumentation using self-explaining with upper elementary students to support constructive and interactive learning utilizing multimedia.

Mathematical Explanation, Justification, and Argumentation & Active, and Interactive Learning through Self-Explaining

Mathematical explanation, justification, and argumentation play an important role in student performance. One way to improve student performance is to enhance mathematical writing processes using technology as a creative, interactive student math blog to help students evaluate the validity and accuracy of their mathematical thinking.
Student self-explanation enhances learning by activating and integrating new and existing knowledge (Chi, 2007). Research suggests self-explaining with a peer or expert is more beneficial than self-explaining alone. Therefore, there is a need to establish a learning environment to support student acquisition of knowledge through collaboration. Cognitive Load Theory and Active-Constructive-Interactive Theory compliment each other in a way that suggests cognitive demands such as the cognitive load can reduce available working memory, which reduces space available for constructing and evaluating new knowledge (Pass, Renkl & Sweller, 2004; Mayer, 2001; Chi, 2007; Kirschner et al., 2009). For example, a blog with well-structured math tasks can reduce extraneous cognitive load (e.g., unnecessary information) and promote germane cognitive load (e.g., information necessary for generating relevant knowledge and schemas) that is important for student learning (Kirschner et al, 2009). Understanding how a schema develops, for example supporting children’s understanding of concepts and their relations, is important when devising appropriate teaching strategies. For example, when facilitating a discussion with children on the relationships between parts and whole of a fraction with a paper folding activity, children may be introduced to vocabulary such as “half, part, and whole” in reference to the paper being folded. Through the activity, children construct meaningful relations between the terms. Later, when the children are introduced to the term “fraction” with discussion about parts and whole, this word enters into Working Memory allowing for the construction of relations between prior concepts, which will be stored in Long Term Memory. Discussion, whether self-explaining or self-
explaining with a peer, improves student understanding by providing support for learning new concepts and their relations to existing knowledge (schemas; Chi, 2007). Self-explanations can take on different forms; however, their common feature is that by prompting students to self-explain, students are encouraged to think deeply and to cognitively engage with learning materials by making connections to prior knowledge and refining mental models (Chi, 2005). Supporters of reform in education view the process mathematics learning as a social endeavor that takes place during the interactions within a classroom community. Interactions that provide opportunity for students to learn through thinking, talking, agreeing, and disagreeing about mathematics (e.g., Ball, 1993; Bauersfeld, 1995; Cobb, Yackel, & Wood, 1993; Lampert, 1990; Nathan & Knuth 2003; NCTM, 2000, 2015).

The merge of mathematical explanation, justification, and argumentation will be described through Constructive and Interactive learning with self-explanation. Such interventions are necessary to strengthen mathematical understanding in the K-12 classroom, which supports the college and career readiness of students.

**Conceptual/ Theoretical Framework and Research Goals**

The conceptual-theoretical framework chosen for this study is based on the work of Chi through social constructivist learning (2004, 2007, & 2009) and Cognitive Load Theory of Pass, Renkl, & Sweller (2004), as well as multimedia learning (Chi & Mayer, 2005). These conceptual frameworks were chosen based on the need to understand and
support student cognitive learning and social constructivist learning through the use of multimedia.

Not only are cognitive and constructivist learning theories conceptual frameworks that describe how information is absorbed; but provide strong, empirical support for how to effectively use technology-based learning materials (Bruning, Schraw & Norby, 2010). While there are many forms of constructivism, the following characteristics apply to this particular study. The first characteristic is that learners are active in constructing their own knowledge by discovering and transforming existing knowledge and experiences into new understandings (Loyens, Rikers, & Schmidt, 2009; Chi, 2009; Vygotsky, 1978). The second is that social interactions are important to knowledge construction, which is why it is important to include the learning framework of interactive, constructive, active, and passive (ICAP, Chi, 2009; Chi & Wylie, 2014). In the cognitive and constructive learning sciences, the terms active, constructive, and interactive are commonly used and describe activities conducted by learners (Chi, 2009). While the literature was not explicit about the definition of these terms, Chi provides a framework to offer a way to differentiate active, constructive, and interactive in terms of observable overt activities and the underlying learning processes. Chi & Wylie’s work categories different types of engagement activities based on overt student behaviors and hypothesis that as engagement increases, so does learning (I>C>A>P). A passive activity may include reading a textbook or watching a video, while at minimum, an active activity involves a selection procedure like underlining or highlighting text. A constructive
activity is one in which students go beyond the provided material and generate new content, such as explaining or justifying thinking when solving a mathematical task. Interactive activity includes two or more students working together to complete a constructive activity such as peer tutoring which may include critiquing the reasoning of others by constructing viable arguments (CCSSMP, 2012; Chi, 2009; Chi & Wylie, 2014). Chi & Wylie’s work is especially important because of its close alignment reform based standards known currently as the Common Core State Standard for Mathematical Practice. “Make sense of problems and persevere in solving them” (MP #1) and “construct viable arguments and critique the reasoning of others” (MP #3) (CCSS, 2012). The hypothesis Chi & Wylie states that lessons becoming more cognitively engaging (moving from passive to interactive), student learning should increase will be tested in this study.

Self-explanation is an effective learning strategy that helps learners develop deep understanding of complex phenomena and could be used to support learning from multimedia (Roy & Chi, 2005). Researchers have established benefits of self-explaining across many domains for a range of ages and learning contexts; however this study will focus on self-explaining of 5th grade students utilizing multimedia to explain, justify, and argue mathematical thinking through discourse.

Controlled studies comparing multimedia with combinations of text and illustration or narration and animation with single media resources have discovered that students learn better from a combination of media, provided that the materials are well
designed (Mayer, 1993; Mayer & Anderson, 1991). While there are many advantages of multimedia resources over single media, two main advantages are that different modes and types of external representation provide unique perspectives and tailored descriptions (Roy & Chi, 2005). Text, illustrations, and animations play an important role in learning new information in a multimedia environment. Text may be more effective for describing abstract and general information, while illustrations and animation may be effective describing spatial configurations or dynamic information and relations.

In order to benefit from multimedia descriptions, the learner must actively construct a conceptual knowledge representation that relates and integrates different kinds of information from diverse sources and modalities into a coherent structure (Schnitz & Bannert, 2003 as cited in Roy & Chi, 2005). Learning in a multimedia environment is potentially effective if learners engage in the demanding behaviors of constructing, integrating, and monitoring knowledge in an ongoing manner (Roy & Chi, 2005).

Self-explaining is a cognitively demanding but deeply constructive activity due to several key cognitive mechanisms involved in the process including: generating inferences to fill in missing information, integrating information within the study materials, integrating new information with prior knowledge, and monitoring and repairing faulty knowledge. The act of self-explaining is cognitively demanding and evidence supports that many learners have difficulty engaging in generating a sustained level of quality explanations. Learners would benefit from self-explanation training or
prompting within multimedia environments because these environments are rich in information and afford the potential to generate many opportunities for explaining information and connecting to prior knowledge, particularly for low prior knowledge learners (Roy & Chi, 2005; Chi, 2007; Wylie & Chi, 2014).

During an episode of learning, new information is processed in Working Memory. There are limitations to both the storage and capacity of Working Memory and the length of time new information can be held and processed (Mayer & Moreno, 2003). While learners can process around seven separate items of information, this number decreases with the addition of competing processing demands (Miller, 1956; Kalyuga, 2006; and Chinnappan & Chandler, 2010).

This quantitative, quasi-experimental design study will explore how collaboration through a classroom blog supports mathematical reasoning through explanation, justification, and argumentation of fifth-grade students compared to traditional paper pencil tasks. The focus of the study is on the use of a classroom blog to promote student understanding with the use of high-cognitive demand fraction (mathematical) tasks through self-explaining (explain & justify) and self-explaining with a peer (explain, justify, and argumentation) as defined by research, as well as the Common Core State Standards for Mathematical Practices (CCSSMP). To measure change in student performance, a pretest, posttest, and delayed posttest of fractions will be administered to measure conceptual understanding. Teachers will use a rubric as a tool to score student
explanation, justification, and argumentation on mathematical tasks presented on the blog, as well as traditional pencil paper tasks.

**Research Questions**

1. Does a classroom blog promote mathematical explanation, justification, and argumentation through self-explaining of fraction understanding(s) differently than pencil and paper activities?

2. Does a blog serve as an overt constructive or interactive learning tool to critique the fraction reasoning of others (justify through argument with peer self-explaining) differently than pencil and paper activities?

3. Does the use of a blog impact student performance in fractions differently compared to traditional pencil paper implementation?
Chapter II

Literature Review

Introduction

This chapter will explore constructive and interactive learning of fractions using student mathematical discourse and multimedia to support procedural and conceptual understanding (e.g., explanation, justification, and argumentation of mathematical thinking). The literature will be viewed through the Social Constructivist and Cognitive Theory of Multimedia Learning. Discussion of the literature will be divided among four major sections.

The first section will describe the Social Constructivist and Cognitive Theory of Multimedia Learning Theoretical Framework and the benefits of explanations through discourse in a multimedia learning environment. The second section will discuss the advantages of multimedia learning environments to support constructive and interactive learning through high cognitive-demand mathematical tasks. The importance of mathematical explanation, justification, and argumentation (discourse) of fraction procedural and conceptual knowledge will be investigated in the third section. Lastly, discourse of conceptual and procedural understandings of fractions with mathematical tasks through multimedia to support student performance will be presented.

Cognitive and Social Constructivist Learning Theoretical Framework

The conceptual-theoretical framework chosen for this study is based on Social Constructivist Learning Theory (Chi, 2004, 2007, & 2009; Cobb, 1990; Glasersfeld,
Vygotsky, 1978; & Bandura, 1986) and Cognitive Theory of Multimedia Learning (Chi & Mayer, 2005; Paas, Renkl, & Sweller, 2004). These conceptual frameworks were chosen based on the need to understand and support collaborative student learning through the use of multimedia.

Over the past two decades, a great deal of research focused on peer and adult collaborative problem solving and the effects on the cognitive development of children. Studies have been set within a variety of theoretical perspectives in this area, including the works of Vygotsky (1978) and Bandura (1986). While both investigate the impact of social interaction on cognitive growth, results of studies on collaborative problem solving through explanation with peers (in a multimedia learning environment) have been somewhat inconsistent in the area of elementary mathematics (Tudge et al., 1996).

Not only are cognitive and constructivist learning theories conceptual frameworks that describe how information is absorbed; but they provide strong, empirical support for how to effectively use technology-based learning materials (Bruning, Schraw & Norby, 2010). While there is a vast amount of research in the area of constructivist learning theories of learning, this chapter will focus only on the characteristics that pertain to the study.

Learners are active (involved) in constructing their own knowledge by discovering and transforming existing knowledge and experiences into new understandings (Loyens, Rikers, & Schmidt, 2009; Chi 2009; Vygotsky 1978), and social interactions, along with overt written or oral expressions of understandings, are important
to knowledge construction; which is why it is important to include the learning framework of interactive, constructive, active, and passive (ICAP, Chi 2009; Chi & Wylie 2014).

In the cognitive and constructive learning sciences, the terms active, constructive, and interactive are commonly used and describe activities conducted by learners (Chi 2009). While the literature was not explicit about the definition of these terms, Chi provides a framework to offer a way to differentiate active, constructive, and interactive in terms of observable overt activities and the underlying learning processes. As you will recall in the prior chapter, Chi & Wylie’s work categorizes different types of engagement activities based on overt student behaviors and hypothesis that as engagement (interaction) in the learning material (and with others) increases, so does learning (I>C>A>P). A constructive activity is one in which students go beyond the provided material and generate new content, such as explaining or justifying thinking when solving a mathematical task. Interactive activity includes two or more students working together to complete a constructive activity such as a peer tutoring which may include critiquing the reasoning of others by constructing viable arguments (CCSSMP, 2012; Chi, 2009; Chi & Wylie, 2014). Because Chi & Wylie’s work is especially important, because of its close alignment to reform based standards for Mathematical Practice (i.e. “Make sense of problems and persevere in solving them” (MP #1) and “construct viable arguments and critique the reasoning of others” (MP #3) (CCSS 2012)); therefore, in a reform based instructional design, this work will be used to explore the importance of this study.
Constructivism emphasizes active participation and reflection by the learner, who should control the pace of instruction and construct knowledge (Zhang, 2005). In a study of effectiveness in an interactive multimedia-based e-learning environment, Zhang set out to prove that the major objective of emphasizing learner-content interaction in e-learning is to increase learner engagement and enhance learner control over the content and process. With the higher interactivity, the better learning performance students should be achieved (Northrup, 2001; Zhang, 2005).

Two separate lab experiments were employed using the interactive e-Classroom subsystem in Learning By Asking (LBA) as the e-learning environment to test the hypotheses. The LBA system is described as a learner-centered and highly interactive learning environment. The first experiment study consisted of fifty-one undergraduate students. Two separate lab experiments were employed using the interactive e-Classroom subsystem in LBA as the e-learning environment to test the hypotheses. The second experiment was conducted one month after the first one was finished. It inherited exactly the same treatment, procedure, and measurement used in the first, but with a doubled group size, a different lecture, and different participants. Each was measured after one lecture, not a semester. One hundred four undergraduate students were recruited from several departments at the same university who were taking an introductory course to management information systems. Students were both sophomores and juniors recruited from an introductory database course at large public university in the United States. Groups were randomly assigned to one of three treatments. The treatments included fully
active LBA, less active LBA, and traditional classroom. A questionnaire was given to all groups to control for learner characteristics and prior e-learning experience. According to previous research findings that (1) higher levels of interactivity are hypothesized to generate higher student performance (Merrill, 1994), and (2) multimedia instruction can help maximize learners’ ability to retain information and learner engagement (Chapman, Selvarajah, & Webster, 1999; Syed, 2001), the hypotheses are as follows:

H1: Given the same amount of learning time, students in an interactive multimedia-based e-learning environment can achieve higher test scores than those in a traditional classroom.

H2: Students in an interactive multimedia-based e-learning environment will report higher levels of satisfaction than those in a traditional classroom.

H3: Given the same amount of learning time, students in a multimedia-based e-learning environment that involves more learner–content interaction can achieve higher test scores than those in a less interactive multimedia-based e-learning environment.

H4: Students in a multimedia-based e-learning environment that involves more learner–content interaction will report
higher levels of satisfaction than those in a less interactive multimedia-based e-learning environment.

With three treatments in each experiment: the fully interactive LBA group, the less interactive LBA group, and the traditional classroom group. A total of 155 undergraduate students participated in the experiments. The results of a series of independent-samples t tests are reported showing that students in the fully interactive e-learning group achieved significantly better performance and higher levels of satisfaction than those in the less interactive e-learning group and traditional classroom. Results also indicated that participants in the fully interactive e-learning group achieved significantly better performance and higher levels of satisfaction than those in the less interactive e-learning group and the traditional classroom. Therefore, all four hypotheses were supported again in the second experiment. The margins between pretest scores and posttest scores were used as individual learning gain. The author used an Analyses of Covariance (ANCOVA) by using pretest scores as the covariate. Given the very small p values found in the current report, the results of the ANCOVA should be very similar to what is already reported (Zhang, 2005). This study implies that to create effective learning, e-learning environments should provide interactive instructional content that learners can view on a personalized, self-directed basis (Zhang, 2005).

This study was similar to the study by Revell and McCurry “Effective pedagogies for teaching math to nursing students: A literature review”. Nursing students have been
identified historically for having difficulty in learning dosage calculation. This content has been traditionally taught using paper and pencil and chalkboard examples to more recently PowerPoint and CD-ROM tutorials. Despite the technological advance, undergraduate nursing students continue to struggle with math computation and problem solving skills. Nursing students who are unable to successfully pass math competency exams are often forced to never complete the nursing program. “In turn, nurse educators are challenged to develop innovative teaching and learning approaches that meet the needs of millennial learners and result in achievement of both the conceptual understanding and practical know-how of solving math problems for medication administration” (Revell & McCurry, 2013). The study suggests pedagogies should focus on a constructivist learning approach (Weeks et al., 2001; Revell et al., 2013). Pedagogies should also be tailored to the audience of millennial learners. Students are able to constantly order, classify, and modify knowledge, thereby enabling them to adapt to changes by allowing continuous evolution of mental constructions (Fosnot, 1996; Revell 2013). Teaching through a constructivist approach involves fostering the internal process within the student and can actively build understanding and decrease anxiety. Personal response system (PRS) technology provides one example of a pedagogy that can be used by nurse educators to externalize students' cognitive learning process, making their conceptual linkages visible for evaluation and corrective feedback. There is an abundance of nursing research that supports the integration of PRS technology into the classroom as an effective pedagogy. Researchers have found that PRS technology fosters active
learning, and increased student interaction and participation (Berry, 2009; Smith and Rosenkoetter, 2009; Hunter Revell and McCurry, 2010). Thus, by externalizing students' learning, nurse educators may finally be able to solve the long-standing challenge of achieving math competency in their students.

In comparing both studies in regards to student outcomes, both suggest the use of an interactive multimedia platform that allows for a tutorial, interactivity, and feedback that is needed in order for students to make the most gains on performance. The interactivity is most important because it allows students to create mental constructions of their knowledge that can build understanding and decrease math anxiety as they practice their understandings and share with the teacher. The teacher's job is to foster learning and increase student interaction and participation to get the most out of multimedia learning environments.

In order to benefit from a variety of social constructivist learning environments, students need to make connections among sources of information. One strategy for encouraging students to think deeply and cognitively engage with learning material is prompted self-explanation (Wylie & Chi, 2014). Self explanation is a constructive or generative learning activity that facilitates deep and robust learning by encouraging students to make inferences using the learning materials, identify previously held misconceptions, and repair mental models (2014).
In a recent study conducted with 69 students in grades 2-4 in solving mathematical equivalence problems, the researchers examined the benefits of time spent on self-explanation versus additional practice problems compared to a control group (McEldoon et al., 2013). A pre-post assessment was given to measure the brief intervention on solving mathematical equivalence problems (eg. \(3 + 4 + 8 \ ____ + 8\)). 

Students were randomly assigned to one of the three interventions: self-explain, additional practice, or control group. The self-explain and control group both solved six problems, whereas the additional practice group solved 12 problems. The self-explain group was the only group that self-explained for obvious reasons pertaining to the study.

The results indicated that compared to the control condition, self-explanation prompts promoted conceptual and procedural knowledge (which will be discussed in more detail later), and compared to additional-practice, self-explanation benefits were more modest and apparent on some subscales. Overall, the findings suggest self-explanation prompts have some small unique benefits, but attention to the time spent on self-explanation offers advantage over alternative uses of time (Mc Eldoon et al., 2013).

While forms of self-explanation encourages deep thinking about material that may lead to improved learning versus no-self-explanation controls or extra practice, it is important to take into consideration the educational objectives and the way in which self-explanation is implemented before making broad claims about the generality and applicability of self-explanation. ICAP (interactive, constructive, active, and passive) is a framework for interpreting various forms of self-explanation, which categorizes different
types of engagement activities, as previously mentioned (I>C>A>P) and hypothesizes that learning increases as engagement increases (Chi 2009; Chi & Wylie, 2014).

Instructional activities are categorized in this framework based on overt student behaviors. For example, a constructive activity is one in which students are expected to go beyond the provided material and generate new content, such as writing an essay or constructing a concept map. In this study, students using conceptual and procedural knowledge of fractions to construct meaningful understandings through explaining and justifying their thinking will solve mathematical tasks. Interactive activity is one in which two or more students work together to complete a constructive activity, which may include peer tutoring. As the lesson becomes more cognitively engaging, student learning should increase because engagement is a necessary condition for the type of collaborative reasoning that increases learning (Wylie & Chi, 2014). While constructive self-explanations can be either open-ended or focused since both require students to generate an explanation on their own, in mathematics this is considered explaining and justifying student thinking (NCTM, 2014; CCSS, 2010; Yackel, 2001; Pea, 1987). Interactive self-explanations involve pairs or small groups of students working together to generate or critique each other’s answers. In mathematics, this is considered critiquing the reasoning of others through argumentation (NCTM 2014; CCSS, 2010, Cross et al., 2008; Yackel, 2001; Cobb et al., 2001).

Limitations of current research by Wylie & Chi state the need for a more stringent test of an instructional strategy by being compared to another strategy at the same level of
cognitive engagement such as constructive, open ended self-explanation prompts compared with other constructive tasks (e.g. self-explaining a solution to mathematical task by explaining and justifying mathematical thinking or arguing mathematical thinking by comparing and contrasting two worked mathematical tasks by peers). More studies within multimedia learning environments that compare instructional strategies (that fall within the same level of cognitive engagement) are needed to rigorously test the benefits of the self-explanation effect (Wylie & Chi, 2014).

Why is explanation difficult for students? (Baker et. al, 2001)

1. Kids don’t spontaneously explain or argue thinking- this is a learned strategy
2. Cognitively demanding tasks- high Cognitive load/kids have small working memory
3. Explanation and argumentation requires support

Cognitive architecture is important to take into consideration for optimal learning conditions. This architecture consists of working memory that is limited in capacity when dealing with novel information, and has independent subcomponents to deal with auditory/verbal materials, as well as visual two and three-dimensional information. In Cognitive Load Theory (CLT), there is the assumptions that limited capacity working memory becomes effectively unlimited when dealing with familiar material that has been
previously stored in long-term memory that hold many schemas that vary in degree of automation (Paas, Renkl, & Sweller, 2004).

Schemas put elements of information into categories according to the manner in which they will be used. Skilled performance develops through the construction of complex schemas by combining elements consisting of lower level schemas into higher level schema (2004). Automation of schema allows for unconscious processing of schema which can allow for both schema construction and automations to free working memory capacity. Design of instruction should encourage both the construction and automation of schema. There are three types of cognitive load; intrinsic, extraneous, and germane, where CLT is concerned with techniques for managing working memory load in order to facilitate the changes in long term memory associated with schema construction and automatization. While intrinsic and extraneous load are important in understanding and development proper instructional design, germane load (effective load) is related to information and activities that foster and contribute to schema construction and automation, and is important in understanding the benefits of constructive and interactive learning activities with which may include self-explanations (Paas, Renkl, & Sweller, 2004; Chi, Bassock, Lewis, Reimann & Glaser, 1989; Chi, 2009; Chi & Wylie, 2014), mental imagery (Cooper, Tindall-Ford, Chandler & Sweller, 2001) and study of rich worked examples (Chinnappan & Chandler, 2010).

Cognitive load theory (CLT; Paas, Renkl & Sweller, 2003; Sweller, 1988,
1999) helps explain why it is often difficult to learn with complex cognitive tasks where learners are often overwhelmed by the number of information elements and their interactions that need to be processed simultaneously before meaningful learning can take place (Paas, Renkl, & Sweller, 2004). In Cognitive Load Theory (CLT), during an episode of learning, new information is processed through Working Memory. There are limitations to both the storage and capacity of Working Memory and the length of time new information can be held and processed. While learners can process around seven separate items of information, this number decreases with the addition of competing processing demands (Miller, 1956; Kalyuga, 2006; and Chinnappan & Chandler, 2010). In creating knowledge (Schema) that can be accessed from Long Term Memory instead of requiring processing in Working Memory, students will free up mental space needed for solving high cognitive demand tasks. Schema is then formed in Working Memory and stored in the Long Term Memory that allow us to negotiate the world around us effortlessly. Understanding how a schema develops is important when devising appropriate teaching strategies. Learners are often overwhelmed by the number of information elements and their interactions that need to be processed simultaneously before meaningful learning can take place (Paas, Renkl, & Sweller, 2004).

The Cognitive Theory of Multimedia Learning has underlying assumptions: dual channels, limited capacity, and active processing and draws on dual coding theory, cognitive load theory, and constructivist learning theory in that it is based on the following assumptions (a) working memory includes independent auditory and visual
working memories (Baddeley, 1986); (b) each working memory store has a limited capacity, consistent with Sweller's (1988, 1994; Chandler & Sweller, 1992) cognitive load theory; (c) humans have separate systems for representing verbal and nonverbal information, consistent with Paivio's (1986) dual-code theory; (d) meaningful learning occurs when a learner selects relevant information in each store, organizes the information in each store into a coherent representation, and makes connections between corresponding representations in each store (Mayer & Moreno 1998, 1999, 2000; Mayer, 2005;)

In multiple studies that tested a dual processing model of multimedia learning; the model was based on three major assumptions; (a) learners have at least two different information-processing channels, such as a visual channel and an auditory channel (Baddeley, 1992; Paivio, 1986); (b) each channel (or type of working memory) has a limited capacity (Baddeley, 1992; Chandler & Sweller, 1991); and (c) major steps of cognitive processing within each channel (or each type of working memory) involve selecting relevant material for further processing, organizing the selected material into a coherent representation, and integrating the verbal and visual representations with one another and with relevant material from long-term memory (Mayer & Wittrock, 1996; Paivio, 1986; as cited in Mayer & Moreno, 2000). In a study by Mayer & Moreno; they tested the theory on 75 college psychology majors with limited automobile mechanics knowledge. There were 20 students in the narration group (Group N), 17 in the narration plus mechanical sounds group (Group NS), 18 in the narration plus music group (Group
NM), and 20 in the narration plus mechanical sounds and music group (Group NSM).
The computer-based materials consisted of four computer programs for multimedia presentations explaining how a car's braking system works. All programs contained the same 45 second animation describing how a car’s brake system works. While all four groups received the same message with the animation and narration presented concurrently, the second group was the same as the first group, but had added mechanical sounds corresponding to the movement of the pistons and brakes. The third group was the same as the first group, but with added background music, and the last group consisted of all added auditory (added mechanical sounds and background music to the presentation). Students were given a transfer and matching test to evaluate their understandings. The transfer test consisted of a written explanation of how the car’s brake system worked. The transfer test also consisted of four questions, each typed on a separate sheet of paper that prompted the student to explain elements of what to do if there was a problem with the brake system. The matching test contained a frame from the animation with instructions to circle and write letters next to parts of the brake system. The data were subjected to (a) a one-way analysis of variance with group as the between subjects factor, (b) supplemental Tukey tests (with alpha at .05), and (c) a two-way analysis of variance with the between subjects factors being presence or absence of mechanical sounds. Experiment 1 provided consistent evidence for the hypothesis that adding auditory to multimedia instructional messages that are not complimentary can result in overloading the learner's auditory channel. The findings were also consistent in
that students learn best when given multimedia with animation and text-based materials that were complementary to the information to be learned.

Multimedia environments provide ways of presenting information in a nonlinear or random way, and allowing learners to select what information is needed, as well as how to sequence it in a way that is meaningful. The learner is given learner control over his/her instruction by navigating the terrain of the multimedia learning environments and creating an individual and unique instructional sequence (Shyu & Brown, 1992, 1995; Lawless & Brown, 1997). A learner is able to navigate and acquire this new knowledge by gaining new information and attaching it to prior knowledge or schemata (Lawless & Brown, 1997).

In an unpublished study by Hausmann & Chi, an attempt was made to compare critical discussion with elaborative discussion by peers. Students were asked to challenge and criticize each other in one condition, and build and elaborate on each other’s contributions in another (Chi, 2009). After a content analysis of student discussion, it was revealed that while students were able to elaborate on each other’s contributions, resulting in greater learning, students were hesitant to criticize each other. Many challenges remain in designing ways to elicit a specific activity. Presenting a specific conceptual framework might enable researchers to design better comparison conditions, better elicitation methods, and meaningful interpretation of results, which was also consistent with the research results of a study on Computer-mediated epistemic
interaction for co-constructing scientific notions learned from a five-year research program in 2001 by Baker, Vries, Lund, and Quignard (Chi, 2009).

In the research of Baker et. al., the aim was to create Computer Supported Learning Environment (CSCL) that supported the production of epistemic interaction for the co-constructions of scientific notions. Three systems were discussed; however, the DAMOCLES showed the most success with science problem-solving tasks within constraints of the French secondary school curriculum. DAMOCLES is a system for computer-mediated collaborative construction and argumentative discussion of energy chains, with a goal of argumentative interactions and a research tool for modeling resulting cognitive changes. The eight secondary school students (worked in dyads) for this study began by drawing an individual energy chain that was produced with descriptions on a second interface that invites students to express their degree of certitude with respect to their solution elements, and to give explanations and justification or reasons for them. This allows students to begin subsequent discussion with elaborated arguments through back and forth reflective and language-based activity and their graphic (energy chains) solution until the process is stabilized. The results of the study indicated students were able to express explanations/justifications for all of their solution elements when the CSCL environment relies on a complex set of factors (and tools). In order to be successful, 1) a debatable task is needed 2) cognitive preparation for debate, 3) multiple representations of solutions, 4) compatible partners and 5) a clear ideas of what is to be debated. When it came to argumentation, it may be too ambitious to expect

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argumentation dialogue itself to be a primary vehicle for co-construction of scientific notions studies. Argumentation dialogue may be a means for encouraging critical thinking and awareness about the task, for gaining a better understanding of what the problem is; more research is needed to explore this topic, as well in other content areas (Baker et al., 2001). The current study will provide opportunities for students to construct knowledge through self-explanation of fraction procedural and conceptual understandings on a classroom blog by solving mathematical tasks. Increased opportunities will be given to allow students to critique the reasoning of others through argumentation on worked student explanations.

One promising way to promote self-explanation is to provide prompts to support active processing of multiple representations in a simulation-based learning environment (Van der Meij & de Jong, 2011). In this study of 125 high school students and 86 students from secondary vocational education who specialized in either mechanical engineering or architecture, a between subjects design was used with random assignment to one of the two experimental conditions. Students were asked to self-explain by responding to a general prompt (open-ended self-explanation) and directive self-explanation prompts asking students to explain or justify their answer to worked examples with multiple representations. The trend in favor of the directive self-explanation condition indicates that providing directive self-explanation prompts seems to direct learners to find the right relations between representations. The results showed increased performance under both conditions, but students in the focused self-
explanation self-explanation group showed greater learning gains. Focused prompts are similar to open-ended prompts in that they produce student explanations and do not restrict the student’s reply, but focused prompts provide more explicit instruction regarding what the content of the self-explanation should include. For example, when a teacher asks a student to compare or contrast two worked examples (or solutions) to a math problem. Van der Meij and de Jong’s (2011) directive prompts are another example of focused self-explanation, since the prompts specifically require students to identify relationships between multiple representations (e.g., between a graphical representation and a numeric representation). While open-ended self-explanation prompts simply ask students to explain new material, focused self-explanation prompts direct student explanations in a specific way (Wylie & Chi, 2014). These findings suggest that in multimedia learning contexts, a more focused self-explanation prompt is better than a general open-ended prompt (Wylie & Chi, 2014; van der Meij & de Jong, 2011).

**Multimedia Learning Environments**

Multimedia environments have the potential of promoting meaningful learning through different types of media materials that enhance instruction (Moreno & Valdez, 2005). Pea suggested that educational technologies can and should be used to provide opportunities to stimulate the mind to learn (1985). *Dual Coding Theory* suggests that learning with information presented on multiple modalities (e.g., visual and auditory information) is more effective than learning on one modality (Paivio, 2006). Multimedia
instructional content that is designed consistent with the principles of how the human mind works is more likely to lead to meaningful learning (Mayer, 2005). A multimedia instructional message is a communication containing words and pictures intended for learning (2005).

Multimedia learning environments allow opportunities for students and teachers to present combinations of text, illustrations (e.g., diagrams, figures, and pictures), narration, animation, and video that are typically computer-based (Chi & Wylie, 2014). Learning from multimedia resources is generally better than learning from a single medium (Mayer & Moreno, 2002; Clark & Mayer, 2011). Learning in multimedia environments is potentially very effective if learners engage in the cognitively demanding task of integrating across knowledge sources. Students should be encouraged to reflect during learning in order to integrate and organize new information (Moreno & Mayer, 2007). The constructive and reflective learning activity that is suitable for integrating materials is prompted self-explanation (Wylie & Chi, 2014). Students who self-explained in a multimedia environment with text and diagrams generated more inferences and learned more than those who self-explained in a text-only environment (Butcher, 2006).

**High Cognitive Demand Mathematical Tasks**

Mathematics educators and philosophers have argued that a full understanding of mathematics consists of more than knowledge of mathematical concepts, principles, and
their structure (Lakatos, 1976; Kitcher, 1984; Schoenfeld, 1992 as cited in Stein et. al 1996). Complete understanding of mathematics should include the capacity to engage in the processes of mathematical thinking as framing and solving problems, looking for patterns, making conjectures, examining, justifying, and challenging (CCSS, 2010; NCTM, 2000; and Stein et. al., 1996). What types of instructional environments might reasonably be expected to produce these kinds of student outcomes? Most reformers agree that classrooms must be communities in which mathematical sense-making of the kind we hope to have students develop is practiced (Schoenfeld, 1992). Consistent engagement in this kind of thinking should lead to a deeper understanding of mathematics and the ability to demonstrate complex problem solving, reasoning, and communication skills on assessments of learning outcomes (Stein et al., 1996). The examination of instruction and thinking processes was framed by the concept of mathematical tasks. Factors that may influence mathematical task setup and implementation include (a) factors influencing setup (i.e. teacher goals, teacher subject matter knowledge, and teacher knowledge of students, (b) factors influencing implementation (i.e. classroom norms, task conditions, teacher instructional habits and dispositions, and student learning habits and dispositions). Mathematical tasks set up and implemented by teachers should include (a) task features and enactment of task features and (b) cognitive demand and cognitive processing in order to promote student learning (Stein. et al., 1996).
Cognitively demanding tasks are not easily implemented in the classroom due to the idea that high-level tasks can be less structured, more complex, and longer than tasks that students are typically exposed to; therefore, the teacher often breaks down the problems and makes them more explicit which leads to reducing or even eliminating the difficulty (Stein et al., 1996). Cognitive psychology instruction research outlines characteristics of instruction for the development of high-level thinking and reasoning skills. Careful selection of tasks that build on students’ prior knowledge, provide the appropriate amount of time to explore ideas and make connections, encouragement of student self-monitoring (metacognition), and presented in an environment of sustained press for explaining, meaning making through justification, and understanding (Stein et al., 1996). The tasks used in mathematics classrooms should highly influence the kinds of thinking processes where students are engaged.

Writing about one's mathematical understanding presents intriguing possibilities for math educators on high cognitive demand tasks. Writing is seen not only as a means to communicate knowledge, but also as a vehicle for learning (Connolly, 1989; King, 1982; McMillen, 1986; Yinger, 1985; Woodward, Monroe & Baxter, 2001; & Morgan, 2000). Writing about mathematical concepts (such as fractions) or solutions to problems can help students critically examine, organize, and refine their understanding (Burns, 1995). In this regard, writing can be an important vehicle for enhancing a student's deeper understanding of important mathematical ideas and of ways of engaging in mathematical inquiry through explanations (Woodward, Monroe & Baxter, 2001; Chi, 2009; Wylie &
Chi, 2014). While Woodward et al. describes performance assessments as a vehicle for helping students with learning disabilities: (a) improve their strategic knowledge, (b) allow for substantive interactions with peers in small-group settings, and (c) facilitate teacher-guided discussions, mathematical tasks can and will be used as these described performance assessments. The writing on performance through explanation, justification, and argumentation on high cognitive demand mathematical tasks can provide useful information to teachers about individual students, while supporting many of the goals of current reform. Mary Kay Stein and Margaret Schwan Smith (1998) describe lower-level demand and higher-level demand tasks. Lower level demand includes memorization and procedures without connections (i.e. converting a fraction into a decimal and percent). High-level Demands include procedures with connections, and doing mathematics (i.e. using a 10 x 10 grid to identify equivalent decimal and percent, as well as solving problems in context (i.e. Shade 6 small square in a 4 x 10 rectangle, explain how to determine the (a) percent of the area shaded, (b) the decimal part, and (c) the fractional part. Factors that are associated with the maintenance of high-level cognitive demand tasks include (a) proper scaffolding of student thinking and reasoning, (b) self monitoring, (c) teacher or capable students model high level performance, and (d) teacher draws frequent conceptual connections and sufficient time is allowed for exploration. Factors associated with the decline of high-level cognitive demand tasks include teacher shift on the emphasis from meaning, concepts, or understanding to the correctness or completeness of the answer and not enough time is provided to wrestle with the
demanding aspects of the task. Task is also inappropriate for a given group or students are not held accountable for high-level products or process.

Based on research, (Stein et al., 1996, 1997, & 2000) teachers should continue to create and curate tasks that allow for focused self-explanation on high cognitive demand tasks that allow for scaffolding of student thinking, allow student to monitor their own progress, provide opportunities for capable students model high level performance, build on student’s prior knowledge, and allow time for constructive interactive learning, especially in the area of fractions.

**Conceptual and Procedural Understandings of Fractions through Discourse**

Researchers in the cognition of mathematics have long attempted to understand how children use their conceptual and procedural knowledge in answering mathematics questions (Hiebert & Wearne, 1986; Rittle-Johnson & Siegler, 1998). When examining children’s performance on fraction problems, the distinction seems clear. For example, given the problem \( \frac{1}{2} + \frac{1}{4} \), conceptually, this could be solved with the understanding that there are 2 quarters in a half and then adding up all the quarters. This same problem could be solved procedurally by applying the lowest (least) common denominator algorithm, or try a combination of the approaches (Hallet et al., 2010).

Conceptual knowledge can be defined by a general consensus as knowledge of concepts whereas the knowledge is richly connected and increases with expertise. In explicit measures of conceptual knowledge, students will provide definitions and explanation of concepts in describing why a procedure works or drawing a concept map
to show connections (Rittle-Johnson & Schneider, 2012). While the tasks may be completed as paper-and-pencil, verbal, or as clinical interviews (Ginsburg, 1997), a prior study on conceptual knowledge that quantitatively assesses how richly connected knowledge can be is not known at this time (Rittle-Johnson & Schneider, 2012). A critical feature of conceptual tasks is that they are unfamiliar to participants in order to derive an answer from conceptual knowledge, rather than implement a known procedure for solving the task.

Procedural knowledge is knowing how or the steps required to attain various goals and in mathematics, this can be algorithms and possible actions that must be sequenced properly to solve a given problem (eg, equation-solving steps) (2012). Measure of procedural knowledge is less varied than conceptual knowledge. Procedural tasks are usually familiar and the goal is to solve problems, and the outcome is almost always the accuracy of the answers or procedures (Rittle-Johnson & Schneider, 2012). Sometimes tasks include near transfer problems that are unfamiliar and require cognitive that a known procedure is relevant or small adaptations of a known procedure to assist the unfamiliar problem feature (Rittle-Johnson, 2006).

While the four different historical theoretical viewpoints have been explored on the causal relations between conceptual and procedural knowledge (ie. Concept-first views, Procedures-first views, inactivation view, and interative view), the iterative view is now the most well accepted perspective (Rittle-Johnson & Schneider, 2012). The iterative view accommodates gradual improvement in each type of knowledge over time.
Rittle-Johnson and her colleagues (Rittle-Johnson & Alibali, 1999; Rittle-Johnson & Siegler, 1998; Rittle-Johnson et al., 2001) have argued, in contrast to the concepts-first or the procedures-first position, that neither kind of knowledge precedes the other. Instead, conceptual knowledge helps children learn, or perhaps create, procedures for solving problems; at the same time, learning procedures can provide motivation for a child to find out why the procedure works (Hallet et al., 2010).

In a study with elementary-school student’s knowledge of fractions, the predictive relations between conceptual and procedural knowledge are present over time. Knowledge of fractions was assessed in the winter of Grade 4 and again in the spring of Grade 5 (Hect & Vagi, 2010). Conceptual knowledge in Grade 4 predicted about 5% of the variance in procedural knowledge in Grade 5 after controlling for other factors, and procedural knowledge in Grade 4 predicted about 2% of the variance in conceptual knowledge in 5th grade. In support of the predictive relations between conceptual and procedural knowledge, there is evidence that experimentally manipulating one type of knowledge can lead to increases in the other type of knowledge (Rittle-Johnson & Alibali, 1999).

Mathematical performance rests on developing both conceptual and procedural knowledge. Instructional methods for supporting both types of knowledge are emerging, such as promoting comparison of alternative solution methods, prompting for self-explanation and providing opportunities for exploration before instruction; however, limited research is in existence on the rigorous measurement of conceptual and
procedural knowledge providing evidence for the validity of the measures and how they
develop through solving mathematical fraction tasks.

The Importance of Mathematical Discourse through Multimedia and the Effects on Student Performance

Research has documented children as young as second grade engaging in sophisticated forms of explanation and justifications that advances as the school year progresses (Yackel, 2001). Explanation and justification are distinguished by the functions they serve; such as when students and teachers given mathematical explanations to clarify aspects of their thinking that might not be apparent to others, and justifications in response to challenges to apparent violations of normative mathematical activity (Cobb et al., 1992; Yackel, 2001). Mathematical explanation and justification as interactional accomplishments and not as logical arguments will be the focus. What the participants take as acceptable, individually and collectively, and not on whether an argument might be considered mathematically valid in of interest with upper elementary students.

When combined, both argumentation and writing seem to activate the cognitive resources necessary to develop rich understandings of mathematical content (Cross 2007). It is important to incorporate writing and group mathematical discourse into the delivery of mathematics through quality high-level mathematical tasks that allow for student engagement through directed explanation, justification, and argumentation. A great deal of research has been completed in illustrating the benefits of writing in mathematics (Adams, 1998; Baxter et al., 2005; Burns, 1995, 2004; Whitin & Whitin,
Mathematics pedagogy is beginning to shift from an independent learning endeavor; however, some educators believe there is not enough time to prepare students for large-scale testing if spending too much time on discussion and journal writing on problem tasks when they feel there is a need to spend more time on drill and practice (Bainbridge, 2003; NCTM, 2014). Too much focus is on learning procedures without any connection to learning, understanding, or the applications that require these procedures (NCTM, 2014). McClain and Cobb (2001) describe the “knowing is action” role of the teacher as vital in the necessary establishment of an environment that is challenged by capitalizing on opportunities for mathematical learning that emerge from student activity and explanations that can contribute to the student written expression.

There must be a change in a range of troubling and unproductive realities that exist in too many classrooms, schools, and districts. In the state of Ohio, student scores on extended response questions are below the proficient level. There is more of a need than ever to increase the expectations of written and oral communication of student conceptual understandings rather than a heavy emphasis on traditional drill and practice in order to obtain high levels of mathematics learning through explanations; especially in the area of fractions.
CHAPTER III
METHODOLOY

Purpose

The purpose of this study is to examine the effect of fraction problem solving by students through the interactivity of explanation, justification, and argumentation using a classroom blog. Students engaged in learning environments in which support is provided for reasoning with mathematical concepts may demonstrate greater understanding of mathematical fraction concepts than students within a more traditional paper-pencil problem solving approach that lacks such supports. Because a blog provides multiple types of support simultaneously (i.e., explanation, justification, and argumentation), this will produce greater achievement than the use of just one or neither. This study will answer the following research questions:

1. As measured by a pre-post, and delayed post assessment tool, will student’s understanding of mathematical fraction concepts be greater on the blog compared to the control group having been immersed in a learning environment combining solving of mathematical tasks and mathematical explanation, justification, and argumentation through writing on a classroom interactive (with others) blog?

2. As measured by a pre-post, and delayed post assessment tool, will student’s understanding of mathematical fraction concepts be greater on the blog compared to
those students who only engage in mathematical explanation, justification, and argumentation with face to face interaction (with others)?

3. Will student’s understanding of mathematical fraction concepts show a different pattern of change over time, as measured by a pre-post, and delayed post assessment tool when examining the three groups (control and two treatment groups)?

**Design Method Summary**

A quasi-experimental design was adopted for this study. Students participated in a pretest, intervention (ie. solving three fraction mathematical tasks) posttest, and delayed posttest. During intervention, all students solved one mathematical task on three separate session intervals. In order to control for equal ability groups for intervention, the top ten percent of each intact math class took part in the control group. The remainder of the students was divided equivalently between the blog and F2F group. The study consisted of three groups: (a) control group (n=19), (b) blog group (n=60), and (c) face-to-face (F2F) group (n= 55). Students from each intact classroom were distributed across the three conditions.

**Operational Definitions**

The independent variable of this study will be the groups (i.e. between subjects factor). Each treatment group will complete common high cognitive demanding mathematical tasks. The three treatment groups consist of the control group (i.e. own you own group), face-to-face treatment group, and blog treatment group. The control group
will solve mathematical fraction tasks through traditional paper pencil techniques by only receiving feedback from the teacher. The face-to-face treatment group will engage in mathematical explanation, justification, and argumentation with face to face interaction (with others) while solving mathematical fraction tasks. The blog group will be immersed in a learning environment combining solving of mathematical tasks and mathematical explanation, justification, and argumentation through writing on a classroom interactive (with others) blog. The dependent variable of student performance in the area of understanding fraction concepts will be measured by a pre-post, and delayed post assessment.

Participants

In establishing the sample size of participants needed for the study, a power analysis formula was run using the G*Power Analysis tool for ANOVA: repeated measures, within-between interaction. While total sample size of N= 54 was calculated with an actual power of .95, the number of participants in this study was N=134. Onwuegbuzie, Jiao, & Bostick (2004) calculated the size of sample needed for experimental research to find at the 5% level of significance to be 21 participants per group. This study consisted of: (a) control group N=19, (b) blog group N=60, and (c) face-to-face group N=55.

The participants in this study are 134 fifth-grade math students in ten intact upper-elementary classrooms in a northeastern suburban community. The elementary school consists of grades 3-5 and a minority population of 10% with a 62% civilian labor force.
and 3% unemployment. There are three 5th grade mathematics teachers and three interventionists who will take part in this study. The teachers and interventionist are varied in ages, however all have been employed in this content area for at least five years.

Data Collection

A 12-item (45 point) Pre-posttest and Delayed-posttest will be used from the current school board adopted resource *Bridges* to measure the students’ learning gains. Over a 5 week period of instruction/intervention of fractions content in *Bridges* 5th grade Unit 2, the content is aligned to four common core state standards of critical focus. The post assessment will be given as pretest, posttest and delayed posttest for validity of results. Three common checkpoints will be given to the control and 2 experimental groups. Three common mathematical tasks will be selected from *Illustrative Math* online resource aligned by grade level and standard and submitted to all experimental groups in this study. Standards addressed, assessments to be given, as well as groups in the study Table 1.

The three separate intervention sessions took place at: (a) session 4, (b) session 10, and (c) session 14. A checkpoint test was given after each intervention to assess student knowledge of procedural and conceptual understandings aligned to each fraction intervention. Checkpoints were given after the three intervention sessions: (a) session 5, (b) session 11, and (c) session 15. A posttest took place immediately after session 22, and delayed posttest took place approximately six-weeks after posttest. Table 1 contains the three mathematical fraction tasks given at each intervention.
Table 1

*Summary of Instruments Used for Study*

<table>
<thead>
<tr>
<th>Content</th>
<th>Session/ Test</th>
<th>Control</th>
<th>Treatment 1: Blog</th>
<th>Treatment 2: F2F</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.NF.2 Solve story problem involving addition and subtraction of fraction referring to the same whole, with like and unlike denominators. In 5.NF.1 Student are expected to Add and subtract fractions with unlike denominators, including mixed numbers. Rewrite fractions with unlike denominators as equivalent fractions with a common denominator in order to find their sum or difference. This will be expected as students problem solve.</td>
<td>Unit 2 Pretest - Posttest &amp; Delayed Posttest (Same Assessment will be used) Session 5: Fractions Work Sample Session 11: Fraction Addition &amp; Subtraction Checkpoint Session 15: Working with Fractions Checkpoint</td>
<td>Session 4 Mathematical Task aligned to 5.NF.2</td>
<td>Session 4 Mathematical Task aligned to 5.NF.2</td>
<td>Session 4 Mathematical Task aligned to 5.NF.2</td>
</tr>
<tr>
<td>5.NF.3 Solve story problems involving division of whole numbers with fraction or mixed number quotients.</td>
<td>Unit 2 Pre-Post &amp; Delayed Post (Same Assessment will be used) Session 11: Fraction Addition &amp; Subtraction Checkpoint Session 15: Working with Fractions Checkpoint</td>
<td>Session 10 Mathematical Task aligned to 5.NF.2</td>
<td>Session 10 Mathematical Task aligned to 5.NF.2</td>
<td>Session 10 Mathematical Task aligned to 5.NF.2</td>
</tr>
</tbody>
</table>
5.NF.4a Solve story problems involving multiplying a whole number by a fraction.

Unit 2 Pre-Post & Delayed Post (Same Assessment will be used)
Session 11: Fraction Addition & Subtraction Checkpoint
Session 15: Working with Fractions Checkpoint

<table>
<thead>
<tr>
<th>Session 14</th>
<th>Mathematical Task aligned to 5.NF.4.a</th>
</tr>
</thead>
</table>

Note: Mathematical Tasks given to all groups due to typical classroom planning and implementation.

### Measurable Research Concept

<table>
<thead>
<tr>
<th>Groups</th>
<th>Pretest</th>
<th>MT 1</th>
<th>CP 1</th>
<th>MT 2</th>
<th>CP 2</th>
<th>MT 3</th>
<th>CP 3</th>
<th>Posttest</th>
<th>Delayed – Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem solving through writing “On Own”</td>
<td>O1</td>
<td>X1</td>
<td>O2</td>
<td>X2</td>
<td>O3</td>
<td>X3</td>
<td>O4</td>
<td>O5</td>
<td>O6</td>
</tr>
<tr>
<td>Interactive problem solving through explanation, justification, and argumentation with others (face to face) “Face to Face/F2F”</td>
<td>O7</td>
<td>X4</td>
<td>O8</td>
<td>X5</td>
<td>O9</td>
<td>X6</td>
<td>O10</td>
<td>O11</td>
<td>O12</td>
</tr>
<tr>
<td>Interactive problem solving through written explanation, justification, and argumentation with others (blog/online) “Blog”</td>
<td>O13</td>
<td>X7</td>
<td>O14</td>
<td>X8</td>
<td>O15</td>
<td>X9</td>
<td>O16</td>
<td>O17</td>
<td>O18</td>
</tr>
</tbody>
</table>

*Figure 1.* Measurable research concept. Grid is used to illustrate the Repeated Measures Quasi-Experimental Quantitative study design with pre-post and delayed posttest, as well as treatments (i.e. mathematical tasks) and checkpoints. MT = Mathematical Task given to each treatment group, and CP = Checkpoint given to each group between tests to check for student understanding.
### Table 2

**Mathematical Fraction Tasks**

<table>
<thead>
<tr>
<th>Concept</th>
<th>*Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF.1 Add and subtract fractions with unlike denominators, including mixed numbers. Rewrite fractions with unlike denominators as equivalent fractions with a common denominator in order to find their sum or difference</td>
<td>Sinead and Shaeleigh solved the following problem: $\frac{7}{8} + \frac{9}{16}$. Sinead said, “I can add 7 and 9 to get 16 and add 8 and 16 to get 24. The answer is $\frac{16}{24}$. Shaeleigh said, “I think the answer is more than one”. Who do you agree or disagree with and why? Explain and justify your thinking.</td>
</tr>
<tr>
<td>NF.2 Solve story problem involving addition and subtraction of fraction referring to the same whole, with like and unlike denominators.</td>
<td>Bella is training for his school’s Jog-A-Thon and needs to run at least 1 mile per day. If Bella runs to her grandma’s house, which is $\frac{5}{8}$ of a mile away, and then to her cousin Sophia’s house, which is $\frac{1}{2}$ of a mile away, will she have trained enough for the day? Explain and justify your thinking.</td>
</tr>
</tbody>
</table>
whole, with like and unlike denominators.

NF.3 Solve story problems involving division of whole numbers with fraction or mixed number quotients. Sheamus was working on finding the better buy for cans of pumpkin for Thanksgiving dinner: 12 cans for $15 or 16 cans for $20. Which is the better buy, explain and justify your thinking.

Note: *Tasks are listed in order intervention occurred.

The same written assessment of fraction conceptual and procedural knowledge was administered at pretest, posttest, and delayed posttest. The assessment consisted of a 12-item (45 point) test to measure the students’ learning gains in the area of solving both conceptual and procedural knowledge of adding and subtracting fractions with like and unlike denominators, as well as division of whole number with fraction or mixed number quotients. The pretest was used to identify a baseline of student ability in the area of fractions. Information about each question of the pretest, posttest, and delayed posttest are found in Table 2. Students who scored within the top ten percent of each intact group were placed in the control group. This design was inspired by a study by Rittle-Johnson titled “Promoting Transfer: Effects of Self-Explanation and Direct Instruction (2006). Children who scored half or more of the mathematical equivalence problems correctly at pretest were excluded from the study, however due to consent, the top ten percent were included in the study as the control group. The remainder of the students was placed in equivalent experiment groups of blog and F2F based on pretest performance, gender, and parental consent.
Procedure

The study took place during a five-week (22 sessions) fraction unit of study. Students were administered the written pretest in their intact classrooms during a one 30-minute session. Within one week of the pretest, students completed an intervention session lasting approximately 30 minutes. Classroom teachers of each intact group conducted the sessions. During the intervention session, each student received the fractional mathematical task on paper. All groups were first asked to solve the task independently for explaining and justifying their thinking (i.e., solving and using evidence to prove thinking) for approximately fifteen minutes. All students are encouraged to show their thinking and calculations when solving the problems. The control group was asked to check their work and turn in the paper to the teacher. The only feedback was given to this group from the teacher on a separate day. The blog group logged onto a classroom computer device and posted their answer to the mathematical task through a classroom, password protected blogging platform. “Kidblog” was the blogging platform used for this study due to the user friendliness and security with the age group of this population of students. Once students posted their response to the mathematical task through self-explanation, they were asked to comment on three other student posts by arguing the thinking of others and proving their argument with evidence. The F2F group were placed in groups of 3 and 4 depending on the number of students in each classroom after they solved the task independently through self-explanation by justifying with
evidence from the problem on their own. Once in the group, students would self explain with their peers how they solved the mathematical task by justifying their answers. Time was then given for the students to argue and critique the reasoning of their peers. The process of each intervention took place on three separate occasions lasting approximately 15 - 20 minutes each session.

Coding

Table 3 contains each of the twelve items on the pretest, posttest, and delayed posttest along with the point value for each item. Including in this table is also the procedural and conceptual knowledge concept, as well as items aligned to each fraction mathematical task given for each intervention.
Table 3
Pretest, Posttest, and Delayed Posttest Items

<table>
<thead>
<tr>
<th>Item</th>
<th>Pt.</th>
<th>P/C Concept</th>
<th>Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>Procedural</td>
<td>*NF. 1</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>Procedural</td>
<td>NF. 1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>Procedural</td>
<td>NF. 4a</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Conceptual</td>
<td>NF. 4a</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>Procedural</td>
<td>NF. 1</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>Conceptual</td>
<td>NF.3</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>Conceptual</td>
<td>NF. 2</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>Conceptual</td>
<td>NF. 2</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>Conceptual</td>
<td>NF. 2</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>Conceptual</td>
<td>NF. 1 &amp; 2</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>Conceptual</td>
<td>NF. 1 &amp; 2</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>Conceptual</td>
<td>NF. 1 &amp; 2</td>
</tr>
</tbody>
</table>

Total 45 Pt.

Note. Pt. = Point Value; P/C= Procedural or Conceptual Understanding Skill; Int.= Intervention. * See Table 1 for Concept description for each; NF. 1, NF. 2, NF.3. NF 4a= Solve story problems involving multiplying a whole number by a fraction.
Limitations

Internal validity threats include testing effect; because of the pretest, posttest, and delayed posttest will be identical. While the groups are randomly selected, the differences between groups could be a limitation depending on the teacher’s use of technology. Instructional effect may or may not be a threat to internal validity, again depending on the teacher’s comfort using technology. Good teachers keep students engaged and challenged by working with language and content to develop student skills, abilities, knowledge, and experience. Each type of technology affords opportunities for different actions and can help fulfill learning goals in different ways. By providing opportunities to elementary mathematics students in an online learning environment, this will not only help improve communication skills about math, but a deeper understanding of critical concepts through collaboration and reflection with peers through writing.

Expected Results

With modeling and guidance of increased mathematical journaling in both traditional and online methods, students will make at least (numbers to be determined) growth. When comparing the growth of the experimental group and control group, the experimental group should make more growth because these students have more than just the teacher as their audience compared to the traditional math journal group (paper pencil only).
CHAPTER IV
ANALYSIS OF THE FINDINGS

Introduction

As stated in chapter 1, results of International studies have discovered mathematics instruction in the United States, emphasizes procedural fluency, automatic and quick execution of algorithms with less instructional time allocated for problem solving and verification activities (conceptual and procedural understanding) (Gonzales et al., 2000, TIMMS 2003, 2007, 2011; Baxter et al., 2005). Mathematics achievement of U.S. high school students has been behind other countries, such as China, Japan, Finland, the Netherlands and Canada (Siegler et al., 2012). In the state of Ohio, over fifty percent of students scored below proficient (scored partial or no credit) on extended response questions because the student failed to explain and justify their mathematical thinking on both procedural and conceptual knowledge type questions (ODE, 2011, 2012, and 2013; NCTM, 2014). These findings demonstrate the need to improve the teaching and learning of fractions and division (Siegler, 2012). Pedagogy aligned to standards-based education efforts to support student mathematical discourse is needed to increase student performance.

This chapter presents the results of data collected and analyzed using Statistical Package for the Social Sciences (SPSS) Version 22.0. Descriptive statistics were used to analyze participant characteristics.
Restatement of Purpose and Research Questions

The purpose of this study is to examine the effect of fraction problem solving by students through the interactivity of explanation, justification, and argumentation using a classroom blog compared to face-to-face (F2F) and no interaction. Students engaged in learning environments in which support is provided for reasoning with mathematical concepts may demonstrate greater understanding of mathematical fraction concepts than students within a more traditional paper-pencil problem solving approach that lacks such supports. Because a blog provides multiple types of support simultaneously (i.e., explanation, justification, and argumentation), the hypothesis in this study was that this kind of treatment will produce greater achievement than the use of just one or neither.

Instructional method was expected to influence student performance and retention of conceptual and procedural understandings of fractions on posttest and delayed posttest. The results of this study will be discussed through the following research questions:

1. As measured by a pre-post, and delayed post assessment tool, will student’s understanding of mathematical fraction concepts be greater on the blog compared to the control group having been immersed in a learning environment combining solving of mathematical tasks and mathematical explanation, justification, and argumentation through writing on a classroom interactive (with others) blog?
2. As measured by a pre-post, and delayed post assessment tool, will student’s understanding of mathematical fraction concepts be greater on the blog compared to those students who only engage in mathematical explanation, justification, and argumentation with face to face interaction (with others)?

3. Will student’s understanding of mathematical fraction concepts show a different pattern of change over time, as measured by a pre-post, and delayed post assessment tool when examining the three groups (control and two treatment groups)?

**Data Analysis**

A repeated measure ANOVA with one between-subjects factor was utilized for data analysis to determine if there were differences at pretest, posttest, and delayed posttest between the three groups in the area of fraction conceptual understanding (i.e. adding and subtracting fractions and mixed numbers with unlike denominators). The between-subject (group) factor is the independent variable, which is defined by the three conditions: (a) control group, (b) blog group, and (c) face-to-face group. The dependent variable for this study is student performance on posttest and delayed posttest with time as a within-subject factor that deals with the three separate times each group is assessed (i.e. pretest, posttest, and delayed posttest). In examining the difference between the three groups (i.e. Control, Blog, and F2F), on the pretest, posttest, and delayed-posttest, the pattern of change over time at the same time was interpreted by viewing the interaction of the between-subject factor (group) and within-subject factor (time). In running a separate
ANOVA on the results of the three checkpoints given immediately after each treatment, no significance within or between subjects were indicated, therefore this data will not be discussed further in this study. A repeated measure ANOVA was also used to determine if each group improved in conceptual understanding (ie. posttest) and the retention of conceptual understanding (ie. delayed posttest) of fraction concepts through an item analysis. An alpha level of .05 is used for all statistical tests.

Sphericity was violated due to an error covariance matrix was not proportional to an identity matrix, therefore Greenhouse-Geisser epsilon ($\varepsilon$) 0.628, is used to correct the one-way repeated measures ANOVA (Greenhouse & Geisser, 1959). Greenhouse-Geisser $F(3, 164) = 16.28, p < .001, \eta^2 = .199$.

The results from the multivariate test indicate the main effect of the within-subjects factor (time) was significant. Specifically, Wilk’s $\Lambda = .104, F(2, 130) = 559.5, p < .001, \eta^2 = .90$ and a statistically significant interaction between the within- subjects factor (time) and the between-subject factor (group), Wilk’s $\Lambda = .725, F(4, 260) = 11.35, p < .001, \eta^2 = .149$. This indicates that the within-subjects effects, which were found to be significant, change across the levels of the between-subjects factor.

1. As measured by a pre-post, and delayed post assessment tool, will student’s understanding of mathematical fraction concepts be greater on the blog compared to the control group having been immersed in a learning environment combining solving of
mathematical tasks and mathematical explanation, justification, and argumentation through writing on a classroom interactive (with others) blog?

**Pretest, Posttest, and Delayed-Posttest Results**

In order to determine whether the performance of students who received the treatment of solving fraction mathematical tasks on a blog will be greater than the control group the mean scores on pretest, posttest and delayed posttest were compared. Recall that there was within-group factor of time and a between-group effect of condition.

The main effect student performance in control group and blog group both increased from pretest to posttest. The results from the multivariate tests indicate a statistically significant effect of Time within each level combination. Specifically, in comparing the control and blog groups Wilk’s $\Lambda$ for control group = .525, $F(2, 130) = 58.77$, $p < .001$, $\eta^2 = .48$, and Wilk’s $\Lambda$ for the blog group = .125, $F(2, 130) = 454.94$, $p < .001$, $\eta^2 = .875$. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means. The control group pretest results ($M = 22.21$, $SD = 12.06$) to posttest results at approximately five weeks ($M = 43.05$, $SD = 2.17$). The blog group pretest results ($M = 6.95$, $SD = 5.21$) to posttest results at five weeks ($M = 39.73$, $SD = 6.81$). While both groups increased from pretest to immediate posttest, the blog groups overall mean difference ($MD = 32.78$) is greater compared to the control group ($MD = 20.84$) by calculating the difference between the mean differences
(i.e. 32.78 - 20.84) for a difference of 11.94. This increase (i.e. gain in knowledge) by all
groups could be contributed to being exposed to rich mathematical fraction tasks.

In analyzing student performance from immediate posttest to delayed posttest (i.e.
approximately 6 weeks after posttest), a post hoc analysis with a Bonferroni adjustment
revealed both the control group and blog group had a decrease on delayed posttest results
compared to posttest. The control group ($M = 40.74, SD = 2.9$) with a decrease
difference ($M = 2.32, 95\% CI [.361, 4.27], p = 0.14$). The blog group ($M = 39.59, SD =
5.89$) with no significant change in scores ($M = .142, 95\% CI [-.959, 1.24], p = 1.0$).
While both groups had a decrease in performance between immediate posttest and
delayed posttest, the blog intervention group retained more information compared to the
control group ($M = .142 < 2.32$), based on the confidence interval some participants also
gained information CI (-.959, 1.24). This difference in scores can be contributed to the
treatment the blog group received compared to the control group.

2. As measured by a pre-post, and delayed post assessment tool, will student’s
understanding of mathematical fraction concepts be greater on the blog compared to
those students who only engage in mathematical explanation, justification, and
argumentation with face to face interaction (with others)?

In order to determine whether the performance of students who received the
treatment of solving fraction mathematical tasks engaged in explanation, justification,
and argumentation on a blog will be greater than students who only engaged in
explanation, justification, and argumentation with face-to-face interaction (with others);
the mean scores on pre-post-delayed posttest were compared. Student performance in face-to-face (F2F) group and blog group both increased from pretest to posttest. A one-way repeated measure ANOVA was also conducted to determine the following results. The results from the multivariate tests indicate a statistically significant effect of Time within each level combination. Specifically, in comparing the control and blog groups Wilk’s $\Lambda$ for face-to-face (F2F) group = .156, $F(2, 130) = 351.02, p < .001, \eta^2 = .84$, and Wilk’s $\Lambda$ for the blog group = .125, $F(2, 130) = 454.94, p < .001, \eta^2 = .88$. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means. The F2F pretest results ($M = 10.35, SD = 9.06$) to posttest results at approximately five weeks ($M = 40.5, SD = 4$). The blog group pretest results ($M = 6.95, SD = 5.21$) to posttest results at five weeks ($M = 39.73, SD = 6.81$). Both group gains can be contributed to not only normal classroom instruction and expected learning gains to new content, but could be contributed to a gain in knowledge by all groups due to being exposed to rich mathematical fraction tasks.

In analyzing student performance from immediate posttest to delayed posttest (ie. approximately 6 weeks after posttest), a post hoc analysis with a Bonferroni adjustment revealed both the control group and blog group had a decrease on delayed posttest results compared to posttest. The F2F group ($M = 37.94, SD = 5.37$) with a decrease difference ($M= 2.56, 95\% CI [.1.42, 3.71], p = 0.00$). The blog group ($M = 39.59, SD = 5.89$) reported no significant difference ($M = .142, 95\% CI [-.959, 1.24], p = 1.0$). While the F2F group had a decrease in performance between immediate posttest and delayed
posttest, the blog intervention group retained more information compared to the F2F group ($M_{142} < 2.56$). This difference in scores can be contributed to the treatment the blog group received compared to the face-to-face group. See Table 4 for further explanation of Time * Group.

3. Will student’s understanding of mathematical fraction concepts show a different pattern of change over time, as measured by a pre-post, and delayed-posttest tool when examining the three groups (control and two treatment groups)?

In summary, a different pattern of change over time did occur, as measured by a pretest, posttest, and delayed posttest to illustrate student’s understanding of mathematical fraction concepts given rich mathematical tasks to all groups. Blog and face-to-face (F2F) treatment groups received intervention of explaining, justifying, and argumentation of mathematical tasks. The blog group performed this mathematical discourse online through a multimedia tool titled Kidblog ©, while the F2F group met in small groups of 3 and 4 to discuss the tasks. While scores from all three groups increased from pretest to posttest, a different pattern of change occurred from posttest to delayed posttest between conditions.

In analyzing student performance from immediate posttest to delayed posttest (i.e. approximately 6 weeks after posttest), the post hoc analysis with a Bonferroni adjustment revealed the control group, blog group, and F2F group had a decrease on delayed posttest results compared to posttest. The results of the change between both experimental conditions and control were significant ($p < 0.05$), with the exception of the blog group.
(p=1.0) (see Table 4). The control group (M = 40.74, SD = 2.9) with a decrease difference (M= 2.32, 95% CI [.361, 4.27], p = 0.14). The blog group (M = 39.59, SD = 5.89) with a decrease difference (M = .142, 95% CI [ -.959, 1.24], p = 1.0), and the F2F group (M = 37.94, SD = 5.37) with a decrease difference (M= 2.56, 95% CI [.1.42, 3.71], p = 0.00). The pattern of change is illustrated in Figure 2.
Results of One-Way Design Using Error Bars to Represent Mean of Pretest, Posttest, and Delayed Posttest by Group Performance

Figure 2. Results of One-Way Design Using Error Bars to Represent Mean of Pretest, Posttest, and Delayed Posttest by Group Performance. The first bar in each group represents student performance on the pretest. The posttest is the second bar, and delayed posttest is represented by the third bar in each group. Error bars represent standard errors on each assessment.
Table 4

*Group * Time  Mean & Standard Error Between-Subjects Factor (Group) and Within-Subjects Factor (Time)*

<table>
<thead>
<tr>
<th>Group</th>
<th>Time</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>On Own</td>
<td>1</td>
<td>22.211</td>
<td>1.864</td>
<td>18.523</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>43.053</td>
<td>1.217</td>
<td>40.645</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>40.737</td>
<td>1.228</td>
<td>38.307</td>
</tr>
<tr>
<td>Blog</td>
<td>1</td>
<td>6.950</td>
<td>1.049</td>
<td>4.875</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>39.733</td>
<td>.685</td>
<td>38.378</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>39.592</td>
<td>.691</td>
<td>38.224</td>
</tr>
<tr>
<td>F2F</td>
<td>1</td>
<td>10.345</td>
<td>1.096</td>
<td>8.178</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>40.500</td>
<td>.715</td>
<td>39.085</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>37.936</td>
<td>.722</td>
<td>36.508</td>
</tr>
</tbody>
</table>

Note: Group= Control (On Own, N = 19), Treatment 1 (Blog, N=60 ; explaining, justifying, and argumentation to fraction mathematical tasks through blog), Treatment 2 (F2F, N= 55; explaining, justifying [on paper], and verbal argumentation to fraction mathematical tasks face-to-face). Time = 1 (pretest), 2 (posttest), and 3 (delayed posttest). Mean = average test score out of 45 maximum points on each assessment.)
Table 5

*Interaction Between Within-Subjects Factor (Time) and Between-Subjects Factor (Group)*

<table>
<thead>
<tr>
<th>Group</th>
<th>(I) Time</th>
<th>(J) Time</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Own</td>
<td>1</td>
<td>2</td>
<td>-20.842</td>
<td>1.936</td>
<td>.000</td>
<td>-25.537</td>
<td>-16.148</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>-18.526</td>
<td>2.005</td>
<td>.000</td>
<td>-23.389</td>
<td>-13.663</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td>2.316</td>
<td>.806</td>
<td>.014</td>
<td>.361</td>
<td>4.271</td>
</tr>
<tr>
<td>Blog</td>
<td>1</td>
<td>2</td>
<td>-32.783</td>
<td>1.089</td>
<td>.000</td>
<td>-35.425</td>
<td>-30.142</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>-32.642</td>
<td>1.128</td>
<td>.000</td>
<td>-35.378</td>
<td>-29.905</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1</td>
<td>32.783</td>
<td>1.089</td>
<td>.000</td>
<td>30.142</td>
<td>35.425</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td>.142</td>
<td>.454</td>
<td>1.000</td>
<td>-.959</td>
<td>1.242</td>
</tr>
<tr>
<td>F2F</td>
<td>1</td>
<td>2</td>
<td>-30.155</td>
<td>1.138</td>
<td>.000</td>
<td>-32.914</td>
<td>-27.395</td>
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<tr>
<td></td>
<td>3</td>
<td></td>
<td>-27.591</td>
<td>1.179</td>
<td>.000</td>
<td>-30.449</td>
<td>-24.733</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>3</td>
<td>2.564</td>
<td>.474</td>
<td>.000</td>
<td>1.415</td>
<td>3.713</td>
</tr>
</tbody>
</table>

Notes: Based on estimated marginal means
* The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.
4. Itemized Analysis to explain pre-posttest, and delayed posttest performance

**Conceptual and Procedural Understandings**

To be mathematically proficient, as defined by the The National Research Council (2001) in the document *Adding It Up: Helping Children Learn Mathematics*, a student must have:

- Conceptual understanding: comprehension of mathematical concepts, operations, and relationships
- Procedural fluency: skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
- Strategic competence: ability to formulate, represent, and solve mathematical problems
- Adaptive reasoning: capacity for logical thought, reflection, explanation, and justification
- Productive disposition: habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

For the purpose of this study, we are looking at student understanding of fraction concepts through mathematical explanation, justification, and argumentation to support student performance (ie. be mathematically proficient). When discussing questions that are aligned on the pre-post, and delayed-posttest, and mathematical tasks used for treatment, conceptual understanding was operationally defined as questions that provided
students with opportunities to comprehend fraction concepts, operations, and relationships with reflecting (self-explaining), explaining and justifying thinking, as well as arguing the thinking of others. Therefore, the definition used for this study will combine the two strands listed above of Conceptual understanding and Adaptive reasoning. For questions on the pre-post, and delayed-posttest aligned to procedural understanding, the above definition of Procedural fluency will be used.

**Procedural Knowledge/ Fluency**

Table 2, 3 & 6 shows the 12 items assessed on the pre-post, and delayed posttest. Items 1, 2, 3, and 5 were aligned with procedural understanding. While the mathematical tasks used for each treatment/intervention utilized both procedural and conceptual understanding, mathematical tasks were not given that asked a student to carry out a procedure without explaining and justifying understanding. Figure 3 below shows student performance in this area. Students in all conditions scored lower on items measuring procedural knowledge of adding and subtracting fractions with unlike denominators, as well as multiplying a fraction by a whole number when presented without context (ie. Add or Subtract: $\frac{1}{3} + \frac{1}{5} = \; ; \; 1 \frac{3}{5} - 6/10 = \; ; \frac{1}{3} \times 24 = $).
Figure 3: Student performance of posttest (Time 1) and delayed posttest (Time 2) on items 1, 2, 3, and 5 procedural type questions.
Table 6

Mathematical Fraction Tasks Used for Treatment And Concepts Tested on Pretest, Posttest, and Delayed Posttest

<table>
<thead>
<tr>
<th>Concept</th>
<th>*Task</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>NF.1 Add and subtract fractions with unlike denominators, including mixed numbers. Rewrite fractions with unlike denominators as equivalent fractions with a common denominator in order to find their sum or difference</td>
<td>Sinead and Shaeleigh solved the following problem: ( \frac{7}{8} + \frac{9}{16} ). Sinead said, “I can add 7 and 9 to get 16 and add 8 and 16 to get 24. The answer is 16/24”. Shaeleigh said, “I think the answer is more than one”. Who do you agree or disagree with and why? Explain and justify your thinking.</td>
<td>10,12</td>
</tr>
<tr>
<td>NF.2 Solve story problem involving addition and subtraction of fraction referring to the same whole, with like and unlike denominators.</td>
<td>Bella is training for his school’s Jog-A-Thon and needs to run at least 1 mile per day. If Bella runs to her grandma’s house, which is ( \frac{3}{8} ) of a mile away, and then to her cousin Sophia’s house, which is ( \frac{1}{2} ) of a mile away, will she have trained enough for the day? Explain and justify your thinking.</td>
<td>7,8,9,11</td>
</tr>
<tr>
<td>NF.3 Solve story problems involving division of whole numbers with fraction or mixed number quotients.</td>
<td>Sheamus was working on finding the better buy for cans of pumpkin for Thanksgiving dinner: 12 cans for $15 or 16 cans for $20. Which is the better buy, explain and justify your thinking.</td>
<td>6</td>
</tr>
</tbody>
</table>

Note: *Tasks are listed in order intervention occurred. Item= Item on pretest, posttest, delayed posttest aligned to task and concept.
**Conceptual Understanding**

Table 6 represents the questions that measured conceptual understandings on pretest, posttest, and delayed posttest, as well as how they are aligned (i.e. by item) with the mathematical fraction tasks used for each intervention, with the exception of question 4. This question was introduced in this unit of study; however, will be the focus of a future unit of study.

In review, the three mathematical tasks were given to all groups (See Table 6) during session 4, 10, and 14. The following section will explain the results of each item on the posttest and delayed posttest that are aligned to the three mathematical tasks given for each treatment. Session 4, task 1 was given as treatment (i.e. *Sinead and Shaeleigh solved the following problem: 7/8 + 9/16. Sinead said, “I can add 7 and 9 to get 16 and add 8 and 16 to get 24. The answer is 16/24”. Shaeleigh said, “I think the answer is more than one”. Who do you agree or disagree with and why? Explain and justify your thinking.*) The concept of this task (NF. 1 & 2) was assessed through items 10 and 12 on the posttest and delayed posttest.

Session 10, task 2 was administered as treatment (i.e. *Bella is training for his school’s Jog-A-Thon and needs to run at least 1 mile per day. If Bella runs to her grandma’s house, which is ⅝ of a mile away, and then to her cousin Sophia’s house, which is ½ of a mile away, will she have trained enough for the day? Explain and justify your thinking.*) The concept of this task (NF.1. & NF. 2) was assessed through items 7, 8, 9, and 11 on posttest and delayed posttest.
Session 14, task 3 was given as the final treatment (i.e. Sheamus was working on finding the better buy for cans of pumpkin for Thanksgiving dinner: 12 cans for $15 or 16 cans for $20. Which is the better buy, explain and justify your thinking?). The concept of this task (NF. 3) was assessed through item 6 on the posttest and delayed posttest.

**Student performance results items 10 & 12 (treatment 1).** The results of analyzing within subject factors (ie. posttest-delayed posttest) and between-subject factors (ie. Control, Blog, and F2F groups) indicated significant within-subjects effects on delayed posttest for questions 10 & 12 ($M = 7.98, SD = 1.61$), $F (2, 129) = 7.16, p = .001$. Student’s conceptual knowledge was expected to improve as a result of their explanation, justification, and argumentation interaction with peers through self-explanation during treatment. In comparing posttest and delayed posttest results, the blog group maintained the gains in conceptual understanding of addition and subtracting fractions compared to the F2F and control groups. In comparing the means on posttest to delayed posttest on items 10 & 12 with a total point score of 10, the blog group ($M = 8.8, SD = 2$) vs. ($M = 8.39, SD = 1.63$) compared to F2F ($M = 9.11, SD = .97$) vs. ($M = 7.49, SD = 1.50$) the blog group maintained more conceptual understanding by explaining, justifying, and argumentation through the blog than the F2F group. When comparing the blog group to the control group, this also proved significant. The blog group ($M = 8.8, SD = 2$) vs. ($M = 8.39, SD = 1.63$) compared to the control group / on own ($M = 9.55, SD = .76$) vs. ($M = 8.05, SD = 1.54$). Overall, on the delayed posttest, the mean of the blog group was higher ($M = 8.4, SD 1.63$) than the other two groups (ie. F2F $M = 7.49, SD =
on the delayed posttest as listed in Figure 4. Students in the blog group retained more conceptual understanding of fraction concepts in the area of adding and subtracting fractions with like and unlike denominators over time.
Figure 4. Student performance posttest (Time 1) and delayed posttest (Time 2) on question 10 & 12 aligned to the first treatment. Total points a student can score on questions 10 & 12 = 10 points.
**Student performance results items 7, 8, 9, & 11 (treatment 2).** The results of analyzing within subject factors (ie. posttest-delayed posttest) and between-subject factors (ie. Control, Blog, and F2F groups) indicated significant within-subjects effects on delayed posttest for questions 7, 8, 9, & 11 \((M = 10.76, SD = 1.76), F(2, 131) = 4.18, p = .017\). Student’s conceptual knowledge was expected to improve as a result of their explanation, justification, and argumentation interaction with peers through self-explanation during treatment the second treatment. In comparing posttest and delayed posttest results, the blog group not only maintained the gains in conceptual understanding of addition and subtracting fractions compared to the F2F and control groups, but made growth in this area on the delayed posttest. In comparing the means on posttest to delayed posttest on items 7,8,9, & 11 with a total score of 12 points, the blog group \((M = 10.71, SD =1.96)\) vs. \((M = 11.03, SD = 1.79)\) compared to F2F \((M = 10.83, SD = 1.49)\) vs. \((M = 10.40, SD 1.85)\) the blog group made growth of conceptual understanding than the F2F group on the delayed posttest. When comparing the blog group to the control group, this also proved significant. The blog group \((M = 10.71, SD =1.96)\) vs. \((M = 11.03, SD = 1.79)\) compared to the control group/ on own group \((M = 11.63, SD = .74)\) vs. \((M = 10.95, SD = 1.18)\). Overall, on the delayed posttest, the mean of the blog group was higher \((M = 11.03, SD = 1.79)\) than the other two groups (ie. F2F M = 10.40, SD 1.85; Control M = 10.95, SD = 1.18) on the delayed posttest as listed in Figure
5. Students in the blog group retained more conceptual understanding of fraction concepts over time compared to the control and F2F group.

*Figure 5*: Student performance posttest (Time 1) and delayed posttest (Time 2) on question 7, 8, 9, & 11 aligned to the second treatment. Total points a student can score on questions 7,8,9, &11 = 12 points.
Student performance results item 6 (treatment 3). The results of analyzing within subject factors (ie. posttest-delayed posttest) and between-subject factors (ie. Control, Blog, and F2F groups) did not indicate significant within-subjects effects on delayed posttest for question 6. \((M = 3.54, SD = .78), F (2, 131) = 1.91, p = .152\). Student’s conceptual knowledge was expected to improve as a result of their explanation, justification, and argumentation interaction with peers through self-explanation during treatment the second treatment. In comparing posttest and delayed posttest results, the blog group not only maintained the gains in conceptual understanding solving story problems involving division of whole numbers with fraction or mixed number quotients compared to the F2F and control groups, but made growth in this area on the delayed posttest. In comparing the means on posttest to delayed posttest on item 6 with a total score of 4 points, the blog group \((M = 3.4, SD = .98)\) vs. \((M = 3.65, SD = .80)\) compared to F2F \((M = 3.51, SD = .72)\) vs. \((M = 3.38, SD .80)\) the blog group made growth of conceptual understanding compared to the F2F group on the delayed posttest. When comparing the blog group to the control group, this also proved to be of interest. The blog group \((M = 3.4, SD = .98)\) vs. \((M = 3.65, SD = .80)\) compared to the control group/ on own group \((M = 3.58, SD = .77)\) vs. \((M = 3.63, SD = .60)\). Overall, on the delayed posttest, the mean of the blog group was higher \((M = 3.65, SD = .80)\) than the
other two groups (ie. F2F \( M = 3.38, SD .80 \); Control \( M = 3.63, SD = .60 \) ) on the delayed posttest as listed in Figure 6. Students in the blog group not only retained more conceptual understanding of fraction concepts solving story problems involving division of whole numbers with fraction or mixed number quotients over time compared to the control and F2F group, but made growth in this area.
Figure 6. Student performance posttest (Time 1) and delayed posttest (Time 2) on question 6 aligned to the third and last treatment. Total points a student can score on question 6 = 4 points.
Summary of the Results

Overall, students did make significant gains from pretest to posttest after the three mathematical tasks were given as treatments at session 4, 10, and 14 during the instructional unit. While all groups main gains being exposed to the mathematical tasks as treatment, students did show significance between the groups on the delayed posttest compared to posttest.

While the control and F2F group decreased (i.e. statistically significant p< .05) in overall average points from posttest to delayed posttest, the blog groups maintained more conceptual knowledge overtime compared to the control and F2F groups with no significant change in score (p = 1.0).

When aligning the three treatment mathematical tasks to the posttest and delayed posttest, further analysis on items 10 & 12 (i.e. aligned to first treatment) and items 7, 8, 9, & 11 (i.e. aligned to second treatment) proved the blog group maintained conceptual understanding of solving addition and subtraction of fractions and mixed numbers with unlike denominators in story problems. Item 6, solving story problems involving division of whole numbers with fraction or mixed number quotients, aligned to treatment three did not show significance.
CHAPTER V
CONCLUSIONS AND DISCUSSION

Introduction

Research in the fields of cognitive research and mathematics education characterize mathematics learning as an active process in which each student builds mathematical knowledge from personal experiences combined with feedback from peers, teachers, and other adults, as well as themselves through reflection (NCTM, 2014; Vygotsky, 1978; Chi, 2009). Communication with peers provides a critical support for learning in which students develop an interaction that allows learners to move beyond the limitation of their current knowledge to grasp increasingly difficult concepts on their own and with their peers (Truxaw, Gorgievski, & De Franco 2008; Chi, 2009).

Technological pedagogical content knowledge (TPACK) is what is truly underlying effective and highly skilled teaching with technology (Harris, Mishra, & Koehler, 2009). Teachers’ knowledge for effective practice requires the transformation of content into pedagogical forms and the critical role that technology can play (Shulman, 1986 & Harris et.al., 2009). TPACK is a form of professional knowledge that technologically and pedagogically adept, curriculum focused educators, utilize when they deliver instruction (Harris et. al., 2009). The teachers in this study provided opportunities for students to solve cognitive demanding mathematical tasks through self-explanation (i.e. explanation, justification, and argumentation) of thinking both in the traditional classroom setting and online through a multimedia tool (i.e. blogging platform). These
pedagogical techniques applied technologies appropriately to teach content in
differentiated ways according to students’ learning needs. Through self-explanation (both
face-to-face and with multimedia use) provided students opportunities to build on
existing understanding to help student’s share and build on existing understanding to help
students develop new epistemologies or strengthen old ones in the area of fractions (Chi,
2009; Cross, 2008; Harris et. al., 2009; Chi & Wylie, 2014).

This chapter includes the purpose of the investigation with a restatement of the
guiding research questions. The following sections include a discussion of results,
limitations of the study, recommendation for future research, and a final summary. The
focus remains on the following questions:

1. As measured by a pre-post, and delayed post assessment tool, will student’s
understanding of mathematical fraction concepts be greater on the blog compared to the
control group having been immersed in a learning environment combining solving of
mathematical tasks and mathematical explanation, justification, and argumentation
through writing on a classroom interactive (with others) blog?

2. As measured by a pre-post, and delayed post assessment tool, will student’s
understanding of mathematical fraction concepts be greater on the blog compared to
those students who only engage in mathematical explanation, justification, and
argumentation with face to face interaction (with others)?
3. Will student’s understanding of mathematical fraction concepts show a different pattern of change over time, as measured by a pre-post, and delayed post assessment tool when examining the three groups (control and two treatment groups)?

**Main findings**

The results demonstrate that students who are engaged with a multimedia platform (i.e. blog), not only performed at posttest assessment, but also maintained the information at delayed posttest compared to the other conditions, because of what multimedia affords learners. Recall that the blog condition supported student explanation, justification, and argumentation of fraction concepts, specifically on solving problems that required adding and subtracting fractions and mixed numbers with unlike denominators. Within the six weeks of delay from posttest to delayed posttest, all students experienced a two-week break from school due to winter vacation. When analyzing pretest to posttest data, the results showed increased performance under all conditions, but students in the blog treatment group showed a greater retention in learning gains overtime (i.e. delayed posttest). Well-structured, high cognitive demand mathematical tasks were selected and implemented in all groups as a part of planned classroom instruction. These tasks require students to explain and justifying their thinking through self-explanation of one’s mathematical understandings that allow for multiple strategies to solve. Self-explanation and writing is an important vehicle for enhancing a student’s deeper understanding of fraction conceptual understandings (Woodward, Monroe & Baxter, 2001; Chi, 2009; Wylie & Chi, 2014). The gain from
pretest to posttest by all conditions (i.e. groups) can be contributed to the exposure each
group had to the mathematical tasks.

When compared to the control group (i.e. solving tasks with explanation and
justification without peer interaction) and face-to-face group (i.e. solving tasks with
explanation, justification and argumentation with peer interaction), the blog group
retained more information over time when comparing the difference in mean scores of
each group on posttest and delayed posttest. The blog group retained more information as
demonstrated by a difference in the mean scores of (a) blog group .142 compared to (b)
control group 2.32, and (c) face-to face group 2.56). By providing constructive and
interactive activities (i.e. solving mathematical tasks on a blog or face-to-face with
peers), students go beyond the provided material and generate new content, such as
explaining or justifying thinking when solving a mathematical task involving two or more
students working together to complete that includes critiquing the reasoning of other by
constructing viable arguments (CCSSMP 2012; Chi, 2009; Chi & Wylie, 2014). As the
interaction in the learning material (and with others) increased, so did the learning (Chi &
Wylie, 2014). A multimedia tool, such as a blog, emphasized learner –content interaction
to increase learner engagement and enhanced learner control over the content and process
with the higher interactivity the better learning performance students achieved compared
to the control and face-to-face treatment group (Northrup, 2001; Zhang, 2005). This
study pushed beyond a media comparison study, because the multimedia afforded
opportunities for explanation and justification of understandings (i.e. through self-
explanations), and argumentation (i.e. self-explaining with peers) beyond the interaction provided in traditional classroom through mathematical discourse. Through written explanation, justification, and argumentation on the classroom blog, students gained a deeper conceptual understanding and increased mathematical achievement (Cross, 2008). Higher order thinking originated in and was developed through the internalization of interactions with others to help support development of metacognitive awareness of the fraction concepts addressed in the study through self-explaining and self-explaining with peers (Vygotsky, 1978; Chi, 2009; Chi & Wylie, 2014).

While all conditions were given the pretest, posttest, and delayed posttest, and all three mathematical tasks, an item analysis was conducted on the test items that were aligned to each of the three of the conceptual understanding mathematical tasks, as well as the four test items that were aligned to procedural knowledge, and one test item (i.e. question 4) that will be further assessed later in the year.

The item analysis is included to better understand the results in performance of the blog, F2F, and control group from posttest to delayed posttest. The procedural understanding questions on the pretest, posttest, and delayed posttest (i.e. questions 1, 2, 3, 4 and 5 questions) were not given directly in the treatment conditions (i.e. as mathematical tasks), however part of regular classroom instruction. The following test items are aligned to each of the three treatment mathematical tasks implemented (i.e. session 4, session 10, and session 14) in the order they are listed, (a) questions 10 & 12, (b) questions, 7, 8, 9, &11, and (c) question 6.
In the test item analysis of the posttest and delayed posttest, students in all conditions scored lower compared to the posttest on the delayed posttest on items measuring procedural knowledge (i.e. items 1, 2, 3, & 5) of adding and subtracting fractions with unlike denominators, as well as multiplying a fraction by a whole number when presented without context (i.e. Add or Subtract: \( \frac{1}{5} + \frac{1}{3} = \); \( 1 \frac{2}{5} - 6\frac{1}{10} = \); \( \frac{1}{3} \times 24 = \)). Statistical significance was found on items 10 & 12, as well as items 7, 8, 9, & 11 on the delayed posttest with both time and interaction between the groups. In the test item analysis, the blog group retained slightly more knowledge in this area of fractions compared to the control and face-to-face group. Test items numbers 7, 8, 9, & 11 aligned to the second conceptual mathematical fraction treatment task also proved to be statistically significant. Students in the blog group not only retained more conceptual understanding of fraction concepts in the area of adding and subtracting fractions with like and unlike denominators over time compared to the control and F2F group, but made growth in this area from pre- to delayed post. The final mathematical fraction treatment task was aligned to item 6 on the pretest, posttest, and delayed posttest. This item and task was different than the other two because it addressed solving story problems involving division of whole numbers with fraction or mixed number quotients. While there was a gain in knowledge by the blog group and control group in this area, it was not statistically significant. This standard is also further reviewed and taught in more detail in a unit of instruction later in the school year.
Implications of Findings

The results suggest that student learning can be improved with supports for self-explanation implemented using technology. Specifically, students showed significantly better performance when they were provided with opportunities to self-explain their understanding of solving rich mathematical tasks using a blog. The results suggest that self-explanation should include student explanation and justification of how the task was thought about as well as solved.

Self-explanation. The interactivity between students solving math tasks on the blog provided opportunities for students to evaluate the validity and accuracy of their mathematical thinking through self-explanation. Self-explanation is a constructive or generative learning activity that facilitates deep and robust learning by encouraging students to make inferences using learning materials, identify previously held misconceptions, and repair mental models (Wylie & Chi, 2014). Student self-explanation on the blog enhanced learning by activating and integrating new knowledge to prior knowledge by self-explaining with peers. Whether self-explanation (i.e. explanation and justification of thinking) or self-explanation with a peer (i.e. explanation, justification, and argumentation), discussion improves student understanding by supporting the learning of new concepts and how they are related to prior knowledge. Using the blog to solve mathematical tasks provided cognitive engagement and increased student learning, because engagement is necessary for collaborative reasoning that increases learning (2014). Supporters of reform in education view the process mathematics learning as a
social endeavor that takes place during the interactions within a classroom community. Interactions that provide opportunity for students to learn through thinking, talking, agreeing, and disagreeing about mathematics, and a classroom blog can help enhance those opportunities for students (Ball, 1993; Bauersfeld, 1995; Cobb, Yackel, & Wood, 1993; Lampert, 1990; Nathan & Knuth 2003; NCTM 2000, 2015).

Argumentation should also take place when justifying the thinking of others. Interactive self-explanation involved small groups of students working together to generate or critique each other’s answers through mathematical argumentation (NCTM, 2014; CCSS, 2010; Yackel, 2001; Pea, 1987; Wylie & Chi, 2014). While the top ten-percent of each group were placed in the control group, this group did not retain information over time and this decline in performance could be attributed to the lack of argumentation exposure of this group. The interaction of students working together to complete the constructive activity of peer tutoring through argumentation (i.e. critiquing the reasoning of others by constructing viable arguments) had proven success in student performance on the posttest and delayed posttest for the blog group. When combined, both argumentation and writing seem to activate the cognitive resources necessary to develop rich understandings of mathematical content (Cross, 2007).

**Interactive & constructive learning through multimedia.** Students who self-explained in a multimedia environment with text and diagrams generated more explanations and justification and made greater gains than those who self-explained in a face-to-face collaborative learning group or own their own. The blogging multimedia tool
used as an intervention in this study allowed for the traditional classroom task to become more cognitively engaging. Therefore, an increase in student learning occurred through interactive and constructive learning that may not have otherwise taken place in the traditional classroom setting (ICAP, Chi, 2009). Multimedia provided opportunities for learners to actively construct their own knowledge by discovering and transforming existing knowledge and experiences into new understandings through overt written expressions of understandings through social interactions that lead to knowledge construction (Loyens, Rikers, & Schmidt, 2009; Chi, 2009; Vygotsky, 1978). While a blog offers opportunities to reduce cognitive load and support Multimedia learning theories (Mayer & Moreno, 1999, 2002 & 2003), other multimedia may offer similar (or potentially better) supports for explanation, justification, and argumentation in the mathematics classroom. Given the same amount of learning time, students in an interactive multimedia learning environment can achieve higher test scores that those in a traditional classroom (Zhang, 2005). Multimedia instruction can help maximize learners’ ability to retain information over time by supporting cognitive processes when used appropriately (Mayer & Moreno, 2000; Mayer, 2005; Lawless & Brown, 1997; Chapman, Selvarajah, and Webster, 1999; Syed, 2001). Instructional applications of educational technologies can be pedagogically unsophisticated when they are limited in breadth, variety, and depth, and not integrated properly into the curriculum (Harris, Mishra & Koehler, 2009). Multimedia, such a blog, proved to be a transformative device that transformed student understandings of fractions by allowing students to create lasting
cognitive connections of content through efficient interaction with peers (Harris, et. al., 2009; Chi, 2009). The impact of multimedia on human mental capacities can be significant when they allow individuals to accomplish cognitive tasks that might otherwise be difficult or even impossible to contemplate and affect not only knowledge structures, but also cognitive operations (Salomon & Gardner, 1986). A blog gives a student ownership of understandings and allows them to visualize and interact with abstract ideas, as well as provide full control and ownership of their content (O’Shea, 1999; Ferdig & Trammell, 2004). In supporting constructivist pedagogy, the multimedia tool in this study focused student meaning making and creation of content while allowing students to take ownerships of their learning and publish their understandings as an artifact to be utilized by others (Ferdig & Trammell, 2004).

**Rich mathematical tasks.** The constructive activity in which students went beyond the provided material by generating new content to support explanations by justifying thinking when solving a mathematical task had proven success on the posttest for all groups (Paas, Renkl, & Sweller, 2004; Chi, 2007; and Chi & Wylie, 2014). Selection of tasks that provide opportunities for mathematical justification, explanation, and argumentation (i.e., a task that is well structured) may have reduced extraneous cognitive load and promote the use necessary information on the page used for generating relevant knowledge and schemas for student learning (Paas, Renkl, & Sweller, 2004; Mayer & Moreno, 1998, 1999, 2000;; Mayer, 2005; Stein, Grover, Henningsen, & Grover 1996).
Implementing cognitively demanding tasks takes time in the classroom to set up (i.e. curate and create), establish norms, allow time for healthy struggle, and assess for student understanding, classrooms must be communities in which mathematical sense-making is developed and practiced (Schoenfeld, 1992; Stein et al., 1996; and Stein & Smith, 1998 & 2000). Careful selection of tasks should build on students’ prior knowledge, provide time to explore ideas and make connections, encourage self-monitoring (metacognition), and presented in a sustained learning environment of explaining, meaning making through justification and argumentation for understanding (Stein et al., 1996). Writing through explanation, justification, and argumentation of mathematical understandings presented an important vehicle for enhancing a student’s deeper understanding of important ideas and ways of engaging in mathematical inquiry through explanations (Stein & Smith, 1998; Morgan, 2000; Woodward, Monroe & Baxter, 2001; Chi, 2009; and Chi & Wylie, 2014).

Limitations

Internal validity threats include testing effect. Because the pretest, posttest, and delayed posttest are the same instrument, student performance may increase because of familiarity and practice with the test items. While the groups are randomly selected, the differences between groups could be a limitation depending on the teacher’s use of technology. Instructional effect may or may not be a threat to internal validity, again depending on the teacher’s comfort using technology.
Teachers need to develop fluency and cognitive flexibility not only in content, pedagogy, and technology, but also in the way these domains are interrelated so they can effect maximally successful, differentiated, contextually sensitive performance learning (Harris, Mishra, & Koehler, 2009). Each type of technology affords opportunities for different actions and can help fulfill learning goals in different ways. By providing opportunities to elementary mathematics students in an online learning environment, this will not only help improve communication skills about math, but a deeper understanding of critical concepts through collaboration and reflection with peers through writing.

**Delimitation**

Generalization of the results of fifth grade students on the entire population may pose as an external threat because of the study sample of approximately 134 students broken down into (a) control group, N=19 (b) blog group, N= 60, and (c) face-to-face, group N=55. Perhaps a larger sample study population will be needed to make the results more generalizable, as well as conducted in multiple school districts with similar and different demographics.

**Future Research**

Implications of the results for instructional condition are limited to teacher classroom blogs in this study. Students had the opportunity to use the multimedia blogging tool, Kidblog© with significant results. Will other multimedia tools offer similar results? While this study incorporated the use of pictures (and illustrations) with text to reduce cognitive load, can tools within the multimedia platforms, such as video or
audio, be used to effectively to communicate student explanation, justifications, and argumentation of conceptual understandings? (Paas, Renkl, & Sweller, 2004).

Will solving mathematical tasks through multimedia close learning gaps of students who are identified in the lower 20th percentile on high stakes assessments compared? Can multimedia tools be used to provide cognitive supports necessary for students to access the regular education curriculum that may otherwise not be possible through self-explanation and justification? Can a blog be used in other content areas other than mathematics to support explanation, justification, and argumentation of key understandings through written self-explanation?

Future research will also explore scalability and dosage of this study with students in grades 1-8. Whether in agreement or not, the implementation of the Common Core State Standards (CCSS) provides an advantage for scalability, efficiency, and productivity in online models of education that allows for vetting, aggregating, and sharing of high quality curriculum and teaching materials on a national scale (Ferdig & Kennedy, 2014). This study can be scaled to grade levels other than 5th grade aligned to that particular grades content standards. Since most states adopted the Common Core State Standards, this study can be scalable to not only school districts within a specific state, but nationally. Future research can also focus on scalability to other content areas, such as Language Arts, that requires students to explain, justify, and argue their thinking and the thinking of others through proven self-explanation methods.
In the same way medical studies examine dosage as a factor of effect, future research will examine the effect of increased treatments (i.e. mathematical tasks) on the performance of students. Will increased exposure (dosage) to cognitive demanding mathematical tasks that allow students to justify, explain, and argue their reasoning through self-explanation effect student performance? Will increased exposure to a variety of student examples (i.e. multiple classroom connected blogs) support student’s justification, explanation, and argumentation of mathematical reasoning and understanding or create cognitive load issues? The appropriate amount of dosage to produce the maximum student learning will be explored in future research.

Summary

In this study, the interaction between mathematical explanation, justification, and argumentation using self-explaining to support constructive and interactive learning using multimedia was investigated. Exposure to cognitively demanding mathematical tasks for explaining and justifying conceptual understandings of fractions through self-explanation led to greater learning and transfer that was maintained over a six-week delay, regardless of instructional condition. Student’s who took part in the argumentation of conceptual understandings (i.e. critiquing and analyzing the thinking of others) through multimedia, rather than face-to-face or none at all, retained significantly greater information over the delay. Multimedia affords cognitive learning opportunities for students that otherwise do not exist in a traditional classroom setting. Teachers should allow time to not only learn how to use tools to support learning, but provide the time for
facilitating meaningful explanation, justification, and argumentation of student understandings through self-explanation. Opportunities to self-explain through mathematical explanation, justification, and argumentation with peers should occur both in the traditional classroom setting as well as through the proper use of multimedia to transcend learning.
APPENDIXES (20)
APPENDIX A

Study Description for Parent Consent

Dear Parent or Guardian:

Study Description for
Supporting Mathematical Explanation, Justification, and Argumentation

Students learn and understand math best when they can explain concepts to themselves and others. It is helpful to expose students to math tasks that have more than one possible solution strategy and allow students to explain and justify their mathematical thinking to their teachers and to other students. For example, if a child thinks through the steps of a problem by explaining their thinking with others, they will not only share knowledge, but also gain knowledge from others by being a part of the discussion, compared to solving the problem/task alone.

Our study investigates how explaining, justifying, and argumentation supports student learning of fractions. Understanding fractions is a critical skill for understanding higher-order mathematics (e.g., algebra; The National Mathematics Advisory Panel, 2008). Each student will be given the same amount of practice time, three 30-45 minute sessions solving fraction mathematical tasks (story problems). Some students will have their three sessions solving fraction math tasks independently. Some students will have three sessions with a small group of students, and some will have three study sessions with a small group of students through an online, password protected blog only accessible through their classroom. Each group will have a pre-test before their first study session, a brief assessment one day after each of their sessions, and a post-test at the end of the fraction unit of study (each lasting approximately 30 min.). Assessments part of the regular district math instruction and the final assessment (post-test) will be a part of your child’s classroom grade.

The results will inform future work about which session of mathematical explanation, justification, and argumentation is the most helpful for student learning and performance.

Copies of all materials, scripts, and protocols will be provided to your school and will be available to any interested parent/guardian. Additionally, I am happy to answer any questions about this project, before, during, or after its completion at (330-672-0590) or at bmorri20@kent.edu. Thank you for your time and consideration.

Sincerely,

Bradley J. Morris, Ph.D.
Associate Professor, Educational Psychology
Associate Director, Science of Learning and Education (SOLE) Center
Kent State University
bmorris20@kent.edu
330-672-0590

Keri L. Stoye
Doctoral Candidate, Educational Psychology/ Instructional Technology
kstoyl@kent.edu
(Phone) 330-281-9367
Dear Parent or Guardian:

I am conducting a research study titled “Supporting Mathematical Explanation, Justification, and Argumentation through Multimedia”. Recent research suggests that learning is often improved when children are asked to explain and justifying their thinking to themselves or to others. Our study will test these strategies in classroom-based math instruction. Specifically, we will investigate how writing and discussion, both in the classroom face-to-face and through a password protected classroom blog, might improve children’s understanding of fractions. I am requesting permission to allow your child to participate in this study because they are between the ages of 7 and 11.

Children’s participation is entirely voluntary and it will be made clear to your child that (s)he will be able to withdraw at any time and for any reason *. A more detailed description of the study has been enclosed (see Study Description). Children who participate will complete two-three training sessions through a classroom blog. This five week study will consist of three sessions lasting 30-45 minutes each and spread over the 5 week period. Sessions will be conducted in the children’s classroom at Leighton Elementary Schools in Aurora, Ohio. This procedure is part of current classroom practice and has been approved by Principal Goodwin at Leighton Elementary School and the Kent State University Institutional Review Board.

Your child’s individual responses and information will be kept confidential as all information pertaining to the child will be kept separate from the child’s performance. Finally, the identity of all participants is protected in the event of any presentation or publication as a result of this study.

I will begin conducting the sessions of this research on October 19, 2015. There are no identified risks associated with this study. If you have any questions, you may contact me using the information provided. Thank you for your time!

Please sign the consent form if you would like to have your child participate in this study and return it to your child’s classroom teacher.

Sincerely,

Bradley J. Morris
Associate Professor, Educational Psychology
330-672-0590
bmorris20@kent.edu

Keri L. Stoye
Doctoral Candidate, Educational Psychology/ Instructional Technology
(Phone) 330-281-9367
klstoyl@kent.edu

* If any problem arises in conducting the study, you should contact me (Dr. Bradley J. Morris, Associate Professor, Dept. of Educational Psychology, 412A White Hall, Kent State University, Kent, OH 44242; Phone 330-672-0590).
APPENDIX C
INFORMED CONSENT
Informed Consent to Participate in a Research Study

Study Title: Supporting Mathematical Explanation, Justification, and Argumentation through Multimedia

Principal Investigator: Bradley J. Morris

Co-Investigators: Keri Stoyle

Your child is being invited to participate in a research study. This consent form will provide you with information on the research project, what your child will need to do, and the associated risks and benefits of the research. Your child’s participation is voluntary. Please read this form carefully. It is important that you ask questions and fully understand the research in order to make an informed decision. If requested, you will receive a copy of this document.

Purpose: Mathematical explanation, justification, and argumentation is important for learning mathematics when solving math tasks, however, some ways in which math tasks are solved prove to be more effective in learning than others. A multimedia Web 2.0 tool, such as a blog can promote learning by allowing students to take ownership in authoring their own problem solving (explaining and justifying), that allows for the entire class to read. A blog also provides opportunities for students to understand and critique the reasoning of others through argumentative writing. We are investigating whether solving math problems through a classroom blog compared to pencil/paper classroom interactions will benefit children learning to problem solve with fractions. Please see Study Description for more information.

Procedures
Your child will first be given a pre-test, three training sessions and a post-test related to fraction problems. As a part of typical classroom practice, student will also be given 2-3 formative assessments to evaluate performance. The pre-test will be compared to the post-test and the formative assessment data points in order to analyze the effects of the blogging training sessions. The strategies and procedures your child used throughout the training packet will also be analyzed to better understand the benefits of blogging for mathematical explanation, justification, and argumentation. The study will be divided into three separate sessions over the course of five weeks and each session will last approximately 30-45 minutes.

Benefits
This research may not benefit you or your child directly, however, your child’s participation in this study will help us to better understand how children benefit from explaining, justifying, and critiquing the reasoning of others through argumentative writing by solving math tasks on a classroom blog. These results may be beneficial in improving future math instruction.

Risks and Discomforts
There are no anticipated risks beyond those encountered in everyday life.

Privacy and Confidentiality
No identifying information will be collected. This signed parental consent form will be kept separate from study data, and responses will not be linked to your child.

Compensation
Participation or non-participation will have no effect on your child’s grade in the classroom.

Voluntary Participation
Taking part in this research study is entirely up to you and your child. You and/or your child may choose not to participate or may discontinue their participation at any time without penalty or loss of benefits to which he/she is otherwise entitled. You will be informed of any new, relevant information that may affect your child’s health, welfare, or willingness to continue participation in this study.

Contact Information
If you have any questions or concerns about this research, you may contact Dr. Bradley J. Morris at 330-672-0590. This project has been approved by the Kent State University Institutional Review Board. If you have any questions about your rights as a research participant or complaints about the research, you may call the IRB at 330-672-2704.

Consent Statement and Signature
I have read this consent form and have had the opportunity to have my questions answered to my satisfaction. I voluntarily agree to grant permission for my child to participate in this study. I understand that a copy of this consent will be provided to me for future reference.

Please print child’s name

Child’s birthdate

Signature of Parent/Guardian

Date

Informed Consent Requirements for Minors
Assent is required of children age 12 years and younger, as well as parental permission. Assent is a child’s affirmative agreement to participate in research.

Assent Script for
Supporting Mathematical Explanation, Justification, and Argumentation through Multimedia

Procedure for obtaining assent from children
"Hi, [child's name]. My name is ____________, and I am trying to learn more about how kids learn about math. You will be explaining your thinking and critiquing the thinking of others by solving some fraction math tasks (story problems) online through the classroom blog. Do you want to do this? [If the child does not indicate affirmative agreement, you cannot continue with this child]. Do you have any questions before we start? [Clarify if necessary]. If you want to stop at any time just tell me. A witness statement can be added if the extra protection provided by it is desired parent/guardian.
APPENDIX D

PRINCIPAL PERMISSION
APPENDIX D

Principal Permission

September 28, 2015
Title of Study:  “Supporting Mathematical Explanation, Justification, and Argumentation through Multimedia: A Quantitative Study of Student Performance”
Principal Investigator: Bradley Morris
University: Kent State University
Co-Investigator: Keri L. Stoyle

To the Kent State University IRB,

As the principal of Leighton Elementary in the Aurora City School District, I am aware of the research procedures for the study. I give permission for the study to take place at Leighton Elementary and for the researcher to have contact with teacher and student data at this site (as described in the research protocol). My permission is contingent upon Aurora City School district permission and IRB approval.

________________________________________
Printed Name of School Principal
Paul M. Goodwin

________________________________________
Signature of School Principal
Paul M. Goodwin

9-29-15
Date

Your signature indicates agreement to participate in the study and you have the right to withdraw from participating at any time without penalty.
APPENDIX E

STUDENT MATHEMATICAL TASK #1
Appendix E

Student Mathematical Task #1

Fraction Mathematical Task (Treatment #1):
Julia and Tyler solved the following problem: \(\frac{7}{8} + \frac{9}{16}\). Julia said “I can add 7 to 9 to get 16 and add 8 and 16 to get 24. The answer is \(\frac{16}{24}\). Tyler said “I think the answer is more than one”. Who do you agree or disagree with and why?

Explain and justify your thinking.

**TASK: (#NF.1 & 2)**

- Remember to answer the math task by
- creating a **NEW BLOG POST (DO NOT COMMENT)**.
- **Title your BLOG POST** "Fraction Task #1 Unit 2 by Your First Name (and Student Number)". Example: "Fraction Task #1 Unit 2 by Snoopy K #28"
- While writing your response, check the following:
  - Punctuation & Capitalization
  - Complete Sentences
  - Details to explain and justify your thinking
  - Click "Publish"
- **AFTER you publish your POST:**
- Critique the reasoning of others by COMMENTING on their POST. Remember to do the following:
  - Punctuation & Capitalization
  - Complete Sentences
  - Lead with the Positive
    - Critically analyze by using EVIDENCE to support your ARGUMENT.
  - Respond (Critique) to AT LEAST 3 other student POSTS.
APPENDIX F

EXAMPLES OF TREATMENT TASK #1/ STUDENT A
Appendix F

Examples of Treatment Task #1/Student A

Student A

Julia and Tyler solved the following problem: $7/8 + 9/16$. Julia said “I can add 7 to 9 to get 16 and add 8 and 16 to get 24. The answer is 16/24. Tyler said “I think the answer is more than one”. Who do you agree or disagree with and why?

Explain and justify your thinking.

$7/8 = 14/16$ | $14/16 + 9/16 = 7/16$ or $23/16$ | I agree with Tyler for 2 reasons.

1: The sum is more than one, just like he said.

2: You don’t add the numerators unless you have a common denominator. Also, you never add the denominators like Julia did.

Examples of Student Argumentation on Student A Post

<table>
<thead>
<tr>
<th>Student</th>
<th>Comment (Argument)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Becky</td>
<td>“I like how you had two reasons and how you had a sentences too. “</td>
</tr>
<tr>
<td>Eve</td>
<td>“Hi I agree with Tyler too”</td>
</tr>
<tr>
<td>George</td>
<td>“I agree with Tyler too. I like how you said your thinking.”</td>
</tr>
<tr>
<td>Tim</td>
<td>“I agree with your thinking because you proved that Tyler was right in 2 ways! And, I like how you organized your work. :)”</td>
</tr>
<tr>
<td>Becky</td>
<td>“I agree with Tyler too but how did you get 16/8 and can you make it into a mixed number and that makes 2 wholes”</td>
</tr>
<tr>
<td>Scott</td>
<td>“I like how you did two reasons in the problem and I also like that you did you equation.”</td>
</tr>
</tbody>
</table>
Appendix G

EXAMPLES OF TREATMENT TASK #1/ STUDENT B
Appendix G

Examples of Treatment Task #1/Student B

Examples of Student Explanation and Justification (Treatment #1, Continued)

Student B

Julia and Tyler solved the following problem: 7/8 + 9/16. Julia said “I can add 7 to 9 to get 16 and add 8 and 16 to get 24. The answer is 16/24. Tyler said “I think the answer is more than one”. Who do you agree or disagree with and why? Explain and justify your thinking.

I disagree because you can not add the denominator but you can add the numerator so I add and got 15/8.

<table>
<thead>
<tr>
<th>Student</th>
<th>Comment (Argument)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rose</td>
<td>“I like what you did but I got that Tyler is right who do you think is right”</td>
</tr>
<tr>
<td>June</td>
<td>“Who do you agree with and why?”</td>
</tr>
<tr>
<td>Student B</td>
<td>“I agree with Tyler”</td>
</tr>
<tr>
<td>Al</td>
<td>“Who do you agree with Tyler of Julia? But other than that you were right.”</td>
</tr>
<tr>
<td>Becky</td>
<td>“I agree with Tyler too but how did you get 16/8 and can you make it into a mixed number and that makes 2 wholes”</td>
</tr>
<tr>
<td>Student B</td>
<td>“I got more them 1 whole”</td>
</tr>
<tr>
<td>Daryle</td>
<td>“I agree that you can’t add the denominator but you can’t add the numerators either, unless you have a common</td>
</tr>
</tbody>
</table>
APPENDIX H

STUDENT MATHEMATICAL TASK #2
APPENDIX H

Student Mathematical Task #2

**TASK: (#NF.1 & 2)**

Alex is training for his school’s Jog-A-Thon and needs to run at least 1 mile per day. If Alex runs to his grandma’s house, which is \( \frac{3}{8} \) of a mile away, and then to his friend Justine’s house, which is \( \frac{1}{2} \) of a mile away, will he have trained enough for the day? Explain and justify your thinking.

- Remember to answer the math task by creating a **NEW BLOG POST** (DO NOT COMMENT).
- **Title your BLOG POST** "Jog-A-Thon Task #2 Unit 2 by Your First Name (and Student Number". Example: "Jog-A-Thon Task #2 Unit 2 by Snoopy K #28"
- While writing your response, check the following:
  - Punctuation & Capitalization
  - Complete Sentences
  - Details to explain and justify your thinking
  - Click "Publish"
- **AFTER you publish your POST:**
- Critique the reasoning of others by COMMENTING on their POST. Remember to do the following:
  - Punctuation & Capitalization
  - Complete Sentences
  - Lead with the Positive
    - Critically analyze by using EVIDENCE to support your ARGUMENT.
  - Respond (Critique) to AT LEAST 3 other student POSTS.
APPENDIX I

STUDENT MATHEMATICAL TASK #3
APPENDIX I

Student Mathematical Task #3

Sheamus was working on finding the better buy for cans of pumpkin for Thanksgiving dinner: 12 cans for $15 or 16 cans for $20. Which is the better buy, explain and justify your thinking.

- Remember to answer the math task by creating a NEW BLOG POST (DO NOT COMMENT).
- Title your BLOG POST "Better Buy Task #3 Unit 2 by Your First Name (and Student Number)". Example: "Better Buy Task #2 Unit 2 by Snoopy K #28"
- While writing your response, check the following:
  o Punctuation & Capitalization
  o Complete Sentences
  o Details to explain and justify your thinking
  o Click "Publish"
- AFTER you publish your POST:
- Critique the reasoning of others by COMMENTING on their POST. Remember to do the following:
  o Punctuation & Capitalization
  o Complete Sentences
  o Lead with the Positive
    - Critically analyze by using EVIDENCE to support your ARGUMENT.
  o Respond (Critique) to AT LEAST 3 other student POSTS.
REFERENCES


Rebecca, B., & Orton, R. (2011). The Original Impetus to Learn English Online: The ENFI Project at Gallaudet University


