FACT FLUENCY DEVELOPMENT: A COMPARISION OF FLASHCARDS AND FLUENCY GAMES

by

Kelly J. Sickle

An Abstract of a thesis submitted in partial fulfillment of the requirements for the degree of Education Specialist in the School of Teaching and Learning University of Central Missouri

August, 2018
ABSTRACT

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The purpose of this study was to compare the effects of math fluency games with the use of flashcards on the mathematics performance of first grade students. First grade students were given a pretest, which was a running record of the math fact addition progression. This interview showed where each of the students fell along the progression. Half of the students were randomly assigned to two groups and were given traditional, vertical flashcards. The other half were also randomly assigned to two groups and given visual flashcards and taught games to play based on their interview. The study lasted for six weeks. These four groups worked with their tools and with the teacher in small group once a week. Upon concluding the six week study, another running record interview was given to each of the students. This interview showed twelve of the fourteen students showed growth in their knowledge of addition math facts. The research did not show clear evidence that math fact fluency games increase the students’ knowledge of math facts more than students who just used traditional flashcards. The research did conclude that students who played the math fluency games were more engaged and vested in their learning.
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By
Kelly J Sickle

July, 2018

APPROVED:
Thesis Chair: Dr. Ann McCoy
Thesis Committee Member: Carol Dunn
Thesis Committee Member: Emily Combs
Thesis Committee Member: Marilyn Cannon

ACCEPTED:
Chair, School of Teaching and Learning: Dr. Ann McCoy
Director, Graduate Education and Research: Dr. Odin Jurkowski

UNIVERSITY OF CENTRAL MISSOURI
WARRENSBURG, MISSOURI
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CHAPTER 1
NATURE AND SCOPE OF THE STUDY

Statement of the Problem

Many students in today’s schools continue to be taught the same way their ancestors of the 1800’s were taught. They come to believe they should memorize math facts and use the standard algorithm, and that numbers are actually just the symbols that we see. Today’s world is drastically different from the covered wagons, horse drawn plows and one room school houses. We are in a world of technology, where most of our questions can be answered within seconds. “The need to understand and be able to use mathematics in everyday life and in the workplace has never been greater and will continue to increase [National Council of Teachers of Mathematics (NCTM), 2000, p. 4]. Mathematics is necessary for daily life, a part of cultural heritage, used in the workplace, and foundational for the scientific and technical community” (NCTM, 2000). Schools and educators need to update their teaching methods and give all students the education of today. Today’s world requires students to be able to problem solve, share their thinking, learn to agree and disagree with respect, and “recognize the value of studying mathematics and believe that they can learn mathematics” (NCTM, 2014, p. 8).

The biggest obstacle that stands in the way of these goals being met is that some educators don’t know any other way to teach mathematics than the way they were taught. Breaking this cycle will be imperative if school districts and employers want to see students and employees who have the skills necessary to compete in the 21st century. Fluency is a must in both reading and mathematics. While reading fluency seems to take center stage in most school districts and progress has been made in teaching students to be fluent readers, math fluency continues to be thought of as how fast someone gives an answer to a simple math fact. Students
are drilled on math facts, given ice cream parties for passing all the two-minute timed tests, and given a new set of flashcards all in hopes that the math facts will be mastered. Teachers have had many students “pass” their two-minute timed tests, only to be unable to solve multi-digit, multi-step problems. Teachers wonder why students don’t transfer their memorized math facts to solving problems or struggle with different mathematical concepts like least common denominator and distributive property. Memorizing math facts doesn’t transfer because students don’t know what they mean, they have little to no number sense, and don’t see numbers as a group of items.

**Background**

What does it mean to be fluent in math? Math fluency can be thought of in the same way as reading fluency as being fast, accurate, and flexible. Math fluency is key for student success across the grade levels. Computational fluency is defined by NCTM:

> Computational fluency refers to having efficient and accurate methods for computing. Students exhibit computational fluency when they demonstrate *flexibility* in the computational methods they choose, *understand* and can explain these methods, and produce accurate answers *efficiently*. The computational methods that a student uses should be based on mathematical ideas that the student understands well, including the structure of the base-ten number system, properties of multiplication and division, and number relationships (NCTM, 2000 p. 152).

The Common Core State Standards of Mathematics (CCSSM) document describes procedural fluency as “skill in carrying out procedures flexibly, accurately, efficiently and appropriately” (National Governors Association Center for Best Practices, 2010). This definition has caused many teachers to discuss what that means inside of a classroom. “Procedural fluency
is a critical component of mathematical proficiency. Procedural fluency is the ability to apply procedures accurately, efficiently and flexibly” (NCTM, 2000). What does flexible mean and how does a student represent that? If a student understands, what does that look like? How do I assess and grade efficiency?

Unlike simply answering a question correctly, assessing a student’s math fluency is not a simple matter. When teachers assess reading fluency, they work with them one on one listening to them read, ask them questions and evaluate their rate, accuracy and expression. Teachers need to use something similar to assess student’s mathematical fluency. Kling and Bay-Williams (2014) suggest that formative assessments including observations, interviews, performance tasks, and journaling should be used in an on-going way to determine students’ fluency. When people memorize facts, dates, or quotes, parts or all of the information can be forgotten thus interfering with the understanding. Students who memorize math facts without understanding not only use up a lot of working memory but they may not be accurate and have no way to tell if their computation even makes sense. However, “It is useful to hold some math facts in memory” (Boaler, 2015, p. 1).

Providing students with practice in math computation using different formats allows students to understand the concepts and procedures that are involved, which leads to students retaining many facts in their memory. Rutherford (2015, p. 1) stated that “Playing games encourages strategic mathematical thinking as students find different strategies for solving problems and deepen their understanding of numbers. When played repeatedly, games support students’ development of computational fluency. Games present opportunities for practice”. Games are good at “capturing attention, sustaining engagement, providing interesting contexts” all of which provide students the necessary practice they need in order be fluent in math facts.
(Sommerfeld 2018 p. 408) The use of flashcards and timed tests to determine if students were fluent with their math facts may have contributed to math anxiety which has now been recorded in students as young as 5 years old (Ramirez, et al., 2013) and timed tests may be a major cause of this debilitating, often life-long condition. But there is a second equally important reason that timed tests should not be used – they prompt many students to turn away from mathematics (Boaler, 2015). With the positive outcomes of computational fluency, and the negative outcomes of flashcards and timed tests, educators at all levels need to take note and proceed toward a more productive manner to achieve math fluency.

**Purpose of the Study**

The purpose of this study is to investigate if there is a difference in math fact fluency in students who study flashcards and those who use flashcards and math fluency games as well as how students will advance through the addition facts progression.

**Research Question**

What is the impact of including games to increase number sense on first graders’ fluency with math facts? This is the basis for this research project. Will there be a positive impact on student progression through the addition fluency who play games and study flashcards? How will it compare to students who only study flashcards?

**Organization of remaining chapters**

This report will be organized into chapters. The next chapter, Chapter 2, will contain a Review of Literature and includes a summary of existing literature on math fact fluency. Chapter 3 will be the Methods. In this chapter, the research will be explained: who was involved, how the research was conducted, with specific items one can use in their classroom. The next chapter,
Chapter 4, will contain the results of the research. The final chapter will contain a discussion of the results of the research.
CHAPTER 2
REVIEW OF LITERATURE

Math fact fluency is a needed skill for students to be successful throughout their math career. Students who have computational fluency are more likely to develop a deeper understanding of procedural fluency, which helps with problem solving and more advanced mathematical areas. Students who are fluent in math facts also have a deeper understanding of math, numbers, and can explain their thinking process when solving problems. This study is designed to provide an alternative to memorizing math facts, and to use best practices that help students achieve math fact fluency.

Introduction

Mathematical fluency is often thought of as being able to solve the “standard algorithm” quickly. While it is important to be able to solve the standard algorithm, it is not the place to start, nor is it the only way students should be taught to solve problems. The standard algorithm is in a sense the opposite of being fluent. It is efficient, only if one understands what is being done to solve the problem. It does lead to accuracy, but often students don’t know if an answer is reasonable because they don’t have the number sense necessary to understand if the answer makes sense. Additionally and importantly, the algorithm is not flexible as there is only one way to solve the standard algorithm (Keiser, 2012).

The process of helping students become fluent cannot be rushed. Van de Walle (2001) states that students need several days to practice a strategy in order to internalize it. “Don’t expect to have a strategy introduced and understood with just one problem or one exposure” (Van deWalle, 2001, p. 174). Students learn math facts in a progression, and providing fact specific games, flashcards and interventions allow students to continue through those steps on
the continuum. Flashcard only practice doesn’t provide students with the conceptual, visual or hands on understanding needed to be fluent. Students who just use flashcards will not develop strategies that will help them be flexible when mathematical problems become more challenging. (Henry & Brown, 2008). Students should be provided math talk activities, games, and interventions based on their progress on the continuum. Teachers should provide daily opportunities to engage in number talks, story problems and games. Children become excited to participate in these types of activities, often looking at it as playing instead of learning (Bay-Williams & Kling, 2014). Students who are just required to memorize their math facts, don’t develop number sense or have strategies to use when solving mathematical problems (Henry & Brown, 2008). Students should practice building fact fluency. In first grade, fluency is about understanding addition and subtraction. “When given ongoing opportunities to practice for fluency with the foundation facts (+/-0, +/-1, +/-2, +/-10, doubles, making 10), first grade students develop a strong bank of known facts” (Math in Practice, 2016, p. 61). The activities that students participate in include a lot of modeling. During modeling, student have math manipulatives, such as counters and ten frames, rekenreks, and/or whiteboards for drawing pictures and equations. Using these tools, students develop their ability to visualize the math. Another practice is the use of flashcards, to build efficiency. The use of the traditional flashcards is beneficial for those students who have a deep conceptual knowledge of the math, but should not be used primarily for the purpose of building fluency. First grade students should be provided flashcards that have a visual representation of the equations. Visuals could include tally marks and ten frames. Short quizzes also help students see their growth in their fact knowledge. Teachers should monitor student progress through individual interviews and observation during practice. Students should also monitor their own progress. Teachers can perform a running
record, using a fact from each of the progression levels, as well as asking the student to explain the strategy they used to reach their answer. These individual interviews allow teachers to see each students’ ability to be efficient, accurate and flexible.

The remainder of this chapter is divided into three sections. The first section will answer the question, What is math fact fluency? Definitions and examples will be provided to help clarify what this term means in a classroom. The second section will focus on what students need to do in order to become fluent in mathematics. Number sense and math fact activities will be presented as examples of how to help students become fluent in their math facts. The final section of this chapter is how teachers should assess students to see if they have fluency. This part gives an alternative to the traditional timed tests that have been the primary assessment elementary teachers have been using to determine fact fluency.

**What is math fact fluency?**

Educators always want students to know their math facts. However, just knowing them doesn’t necessarily make a student fluent in math. Teachers who give timed tests and have had students study flashcards may not understand why students are unable to use math facts to solve a word problem. Curriculum teams may delete fluency from the curriculum, thinking that students can become proficient in math without knowing their math facts. With the release of Common Core, there is still a lot of resistance to how teachers can best help students become fluent. Educators in classrooms may be fearful to teach students in ways they are unfamiliar. Most teachers were taught to memorize facts and steps to algorithms and equations, and, therefore may not be fluent themselves. They may be afraid to teach something incorrectly, so they may stay with what they know and feel safe teaching.
Fluency is a goal for all students. They should be fluent in reading, writing and math. Fluency in reading is something that teachers can define and recognize: students reading at a pace that allows them to comprehend what they are reading with few errors. Students who write fluently can create sentences that make sense, have the proper conventions and few errors. Fluency in math is harder to define. Most people think that being fluent in math means you can answer the problem quickly, but in reality, there is more to being fluent in math than speed. When a student is fluent in math, they show that they are accurate, flexible and efficient in their strategies to solve problems. Students with math fluency show that they have number sense, which is a necessary component for becoming fluent.

Procedural fluency is the ability to apply procedures accurately, efficiently, and flexibility; to transfer procedures to different problems and contexts; to build or modify procedures from other procedures; and to recognize when one strategy or procedure is more appropriate to apply than another (NCTM, 2014). Computational fluency refers to having efficient and accurate methods for computing. Students exhibit computational fluency when they demonstrate flexibility on the computational methods they choose, understand and can explain these methods, and produce accurate answers efficiently (NCTM, 2014).

Students should be able to use what they know and apply it in many ways. When students invent and apply strategies, they develop a deeper understanding of addition and subtraction (Dixon, 2016). Solving math facts quickly allows for students to proceed through calculations required in solving multistep problems. While visuals and manipulatives are essential when learning the facts, knowing them quickly makes for more efficient problem solving. The key is understanding the concepts that lead to the procedures. For example, students knowing that the symbol “7” actually represents seven things is more beneficial than thinking that seven is “7”.
When one can manipulate seven items and add three items, the brain has physically, visually and conceptually grown in the understanding of $7 + 3$. This is a strategy one could apply in many mathematical problems. When students move through the progressions and reach a problem that asks them to make sense of $2n(7 + 3)$, a student who has number sense and fact fluency can visualize the problem, approach the problem in more than one way, and produce the solution accurately. Students who are given the opportunity to learn their math facts through hands-on activities, mathematical discourse, and increasing their number sense grow to be mathematical thinkers and problem solvers. Speed is not always in that equation.

**How do students become fluent?**

Educators have been asking that question for years. For all of those years, teachers may have been thinking that if students memorize those math facts, then they are fluent. Using flashcards and timed tests paved the way to that sense of fluency. The research tells us that fluency is so much more, so getting students fluent requires so much more than flashcards. When we ask students to tell us what they think of when we say $5 + 3$, we want them to draw 5 circles and 3 circles or some sort of picture, not just the number sentence $5 + 3$. Getting students to be visual in math leads them to fluency. Students who develop a deep number sense, are able to show both computational and procedural fluency. Tondevolde (n. d.) describes a series of steps in the progression to fluency:

- **Subitizing** – the ability to tell how many without counting
- **Verbal counting** – being able to count numbers in sequence
- **Object counting** – attaching a number sequence to objects
- **Cardinality** – understanding the last number word you say tells you how many when counting objects
• Spatial relationships – using visuals to look at how quantities relate to each other
• 1 & 2 More and Less – instantly tell you much is one more or less or 2 more or less
• Benchmarks of 5 & 10 – understanding how numbers relate to 5 & 10; instantly know how a number relates to 5 or 10.
• Part-part-whole – understanding that the whole can be broken into parts and how parts come together to make a whole

Assisting students through this progression isn’t as daunting as it looks and can be done in as little as 30 minutes a day (Institute of Education Sciences, 2009). Dividing those 30 minutes into 10-minute increments allows for many activities to occur that helps students reach fluency. One of these ten-minute segments should be designated as a math talk. Many activities can occur during this time: Oral counting, counting around, subitizing (can use dot cards, dominoes, ten frames, rekenreks), Splat, guess my number, number talks, number strings, anything that gets students thinking about numbers, and talking about them. These talks should be based on a visual picture of an amount. During the questioning, an educator asks students how many they see and how they see it. They then ask others who saw the amount the same way or in a different way, allowing 2-3 students share their thinking. Students who listen to all these different ways one visual representation is viewed, develops a greater understanding of numbers. A teacher can also ask how many there would be if there was one or two or ten more/less. These math talks just included many of these elements of progression in just 10 minutes a day. The next 10 minutes to reaching fluent students is a class solved word problem. Each grade is responsible for helping students master several different types of real world problems. Giving students a lesson or two each quarter will not give the students the practice they need to master those problems. A word problem a day opens up the opportunity for all students to learn more than one strategy to solve
those problems. Student discourse during the solving of these problems is imperative. These word problems can lead students toward procedural and computational fluency as they work with the numbers that are grade appropriate. The final 10-minute segment is fluency practice. Fluency practice can have many different looks. Flashcards can be a part of that practice, but should not be the only thing students have access to on their road to math fact fluency. Fluency practice can be partner or group math fact games as well as small group instruction with a teacher based on the needs of the group. Individual and partner flashcard study can also lead students to math fluency.

**Assessing Math Fact Fluency**

Many teachers were taught to be fast thinkers when it comes to math facts. As students, teacher may have been drilled with flashcards or had to think and write quickly on two-minute timed tests. Boaler (2015) says all of this can lead to math anxiety and the ever-present belief that many adults have of “I’m not good at math.” While the previously mentioned activities are easy to administer, grade, and give a score to, those assessments don’t tell the truth of a student’s fluency. When grading a two-minute timed test, a student might get stuck on one problem, but know many more. A teacher can’t tell that when grading the test. A student has the ability to count on quickly, but has trouble writing, another incident in which the teacher wouldn’t know by grading a two-minute timed test. Timed tests can cause a lot of anxiety, many times without the teacher ever being aware of that student’s feelings. Dr. Nicki Newton has done research to find the best way to assess students’ fact fluency. (Newton, 2015) Just as it is a best practice to listen to each student read, it is a best practice to interview each student individually to assess their math fact fluency. Math running records give a teacher a lot of information about each students’ road to fluency. Addition Running Record Recording Sheet is where teachers asked
students one math fact, written horizontally, from each of the progressions of facts during the first step. Teachers code how the student answered: automatic, wrong operation, self-corrected, attempted self-correction, counted all, finger counted on, counted on in head, prolonged thinking time, didn’t know (Newton, 2015). Teachers can then give a coded score, which in turn tells the teacher where each student is in the fluency progression. The code tells the teacher if the student: doesn’t’ know, used counting strategies, mental math, using known factions, or just automatic recall (Newton). This helps teachers design games, small group activities, and visual and non-visual flashcards that each student needs to master the fact families, one step at a time. The next step of the running record is called an Addition Flexibility Assessment. This is a set of 10 questions based on the sets of math facts. This is a way to dig deeper in each students’ thinking. Teachers take notes, which should lead teachers to know how to set up small group, or whole class instruction. The final part of the running record is Mathematical Disposition interview, which consists of four questions, that lets the teacher know how each student feels about math.

The information that is gathered in this math fluency running record tells the teacher where each student falls in their journey toward mathematical fluency. Students are scored as automatic, knowledge of math facts using strategies, and unknown. With this data, a teacher can give each student small group instruction, activities, and visual flashcards according to the level they are on. This individualized instruction allows each student to practice on the math facts they haven’t mastered, giving them the ability to continue to show growth and mastery. Without this information, teachers give all students the same flashcards and activities.
CHAPTER 3
METHODS

Students who have math fact fluency are equipped to solving problems and being able to explain their thinking process through those problems. This study is designed to compare traditional fluency routines to recent research-based fluency routines in elementary children. This chapter will discuss the method used for this study.

Setting

The setting for this research was in a first-grade classroom in a school that is part of a large suburban district. The first-grade classroom used in this study included 19 students in a school of approximately 490 students from preschool through fifth grade. There are approximately 15,000 students in the entire school district.

Participants

The participants in this study were the first-grade students from the regular education classroom. There were 19 students in the classroom. The parents of these students attended an informational meeting that explained the research study. Parents who were unable to attend were sent the information via email. Parents were required to sign permission that their student could participate. Seventeen of the parents signed consent. The students, ranging in ages from six to seven years of age, were presented with the research information, and asked if they wanted to students gave permission to be a participant. The majority of the students are from low-income families. There were six female and eight male participants. The ethnicity of the students included nine Caucasians, three Hispanics, and two African Americans. All of these students had good attendance. One of the students was deemed “high risk” in all academic areas due to
childhood diagnosis of Chiari Syndrome and having a permanent shunt in place. At the time of this study, none of the participants had academic IEPs.

**Measurement**

The tool used to assess student fluency was a pre- and post-test fluency interview. The addition running record was the same for both the pre- and post-test interviews. The interviews are from Math Running Records in Action: A Framework for Assessing Basic Fact Fluency in Grades K-5 (Newton, 2015). This running record has very specific math facts for students, questions that determine student thinking as they are answering math facts, as well as general questions about the thoughts and feelings about mathematics. This running record also allows teachers to code their answers which will give them a direction on how to assist students in their growing knowledge of math facts. The three parts of the interview take anywhere from seven to thirteen minutes. While the interviews are time consuming, in the eyes of educators, the information is very specific for each student, and gives detailed direction that the educator can use for the benefit of each student.

**Procedures**

A student was called to do the interview one on one with the teacher. The first part of the interview, Addition Running Records, consists of twelve addition problems, written horizontally. There is one problem from each of the following math fact progressions:

- Adding 0
- Adding within 10
- Adding doubles plus 1
- Adding by compensating
- Adding 1
- Making 10
- Adding doubles plus 2
- Adding 10 to a number
- Adding within 5
- Adding doubles
- Adding higher facts
Students were shown a table with math facts on it and given as much time as needed to answer one problem at a time. (See Appendix A.) Starting in the first column at the top, students were directed to answer the first problem. Observing the student, their answer could be assessed in several different ways:

- **Automatic**-they knew the answer automatically
- **Wrong operation**-their answer coincided with the same numbers used in a different operation
- **Self-corrected**-they gave the wrong answer, then corrected themselves
- **Attempted self-correction**-they tried to correct the answer, but still gave the wrong answer
- **Counted all**-they were able to come up with the answer by counting out the first number on their fingers, then counting out the second number on their fingers, then counting all of them again
- **Finger counted on**-students started at one of the addends, then counted on the second addend using their fingers.
- **Counted on in head**-students started with one addend, then looked up, or bobbed their head the next addend to determine answer
- **Prolonged thinking time**-students took longer than usual to come up with an answer
- **Didn’t know**-gave wrong answer

Answers are coded on the scoring sheet next to the corresponding math fact. (See Appendix B.) A student is then directed to answer the next fact until the student has answered
the math facts. Students who incorrectly answered three problems in a row didn’t have to proceed through the remaining facts.

The second part of the interview is the Addition Flexibility Assessment. (See Appendix C.) Students were asked each question as listed on the assessment, so each interview was consistent. Answers that the students gave for each section were noted in that section. Students who were not able to answer three questions in a row didn’t have to answer the remaining questions. This part of the assessment took as long as each student needed.

The final part of the interview consisted of four questions about their thoughts and feelings about math and math facts. (See Appendix D.) Notes from students’ answers were logged on their interview sheet.

At the conclusion of each interview, students would return to their seat while an additional column of coding by the researcher occurred. On the Addition Running Record Sheet, there was a final column where each math fact was coded according to how the student determined the answer. The code consisted of numbers 0 through 4 with “0” indicating that the student doesn’t know the answer, “1” indicating that the student used a counting strategy, “2” indicating that the student used mental math to solve the problem, “3” meaning that the student used other facts, or compensation, to help solve the math fact, and “4” meaning automatically recalling the answer.

Upon completion of the interviews, students were divided into two groups. Each group was determined by a random drawing. One group was labeled the Regular Fluency Group. The other was the Control Fluency group. Analysis of these random groups took place to ensure a sense of equality. Similar numbers of female and male participants were placed in each group. Each group also consisted of students of all abilities, based on the pretest interview. Students
who were not given permission to be a part of the study were included in the groups due to needing to be a part of the classroom and not having other adult supervision available. Data from these students was not collected for the study. Within each group there were two subgroups based on the results of their interview. Students in the Regular Fluency Group had a group of students who didn’t answer the first one or two math facts with automaticity. This was Fluency Group A and there were three students in this group. The second Regular Fluency Group consisted of students who were automatic in the first two math facts but not in the third or fourth fact. This was Fluency Group B and there were four students in this group. The Control Group was divided similarly according their which math facts they new automatically. The Control Group A consisted of three students who were not automatic in the first two math facts. The Control Group B consisted of four students who were automatic with the first two math facts, but not the third or fourth.

Each day there was scheduled a fluency block of 10 minutes. Each group followed a rotation of activities:

Fluency Group A:

- **Monday**-Study visual flashcards at their desks by themselves See Appendix E
- **Tuesday**-Students played games with a partner. The games were developed based on the math facts that they needed to study.
- **Wednesday**-Students met with the teacher to work on games and mastering the math fact that they were working on.
- **Thursday**-Students worked on a computer program Happy Numbers
- **Friday**-Students worked on computer program Ten Frame Mania
Fluency Group B:

- **Monday**- Study visual flashcards at their desks by themselves
- **Tuesday**- Students played games with a partner. The games were developed based on the math facts that they needed to study.
- **Wednesday**- Students worked on computer program Ten Frame Mania
- **Thursday**- Students worked on a computer program Happy Numbers
- **Friday**- Students met with the teacher to work on games and mastering the math fact that they were working on.

Control Group A:

- **Monday**- Students met with teacher to study flashcards based on the math fact that they were not automatic on.
- **Tuesday**- Students studied traditional flashcards at their desks by themselves
- **Wednesday**- Students studied traditional flashcards with a partner
- **Thursday**- Students worked on a computer program Fact Dash
- **Friday**- Students worked on a computer program Fact Dash or Basketball Math

Control Group B:

- **Monday**- Students studied traditional flashcards at their desks by themselves
- **Tuesday**- Students met with teacher to study flashcards based on the math fact that they were not automatic on.
- **Wednesday**- Students studied traditional flashcards with a partner
- **Thursday**- Students worked on a computer program Fact Dash
- **Friday**- Students worked on a computer program Fact Dash or Basketball Math
The Regular Fluency Groups participated in non-traditional games and used non-traditional activities to learn their math facts. These included visual flashcards, small group activities, partner games, and online math tools, Happy Numbers and Ten Frame Mania.

Visual flashcards included a horizontal math fact along with a number path, ten frame or picture that students would use to help them solve the fact, and give them a mental image of what the math fact meant were used with the students in Fluency Groups A and B.

Small group time with a teacher included games that were designed for students to understand the math fact. Clothespin Add 1 was a hands on game where the students rolled a dice, put that many clothespins on one side of a piece of paper, then added 1 to the other side. Students were able to see that +1 means that it is the next number when you count. Being able to flip the paper also showed students the commutative property. This game was also adapted to the students who were working on +0 facts. They could physically and visually see that adding zero means that the amount stays the same. Walk the Number Line was another small group activity in which there was a piece of tape place on the floor. Students were given number cards from zero to ten to place in order on the number line. One of the students chose a number card from zero to ten and stood on that number. The teacher then told them to add zero, one or two, depending on the individual group needs, and the student then took that many steps. This physical game allowed them to have a kinesthetic feel to math facts. The teacher also wrote the math fact on a white board so they could make the connection. I Have Who Has was another game played with students during small group activities. Students were each given several traditional flashcards based on the math fact that they were working on. One person in the group would pick a card and give the math fact and the answer. The students with a flashcard that had the same answer would say that they had a math fact with the same answer. That student would
then pick another flashcard, state the fact and the answer, looking for another student with the same answer. These three games were used with each of the Fluency Groups, and adjusted based on the math facts they were working on.

Once a week, students played with one or two people in a hands-on game that corresponded with the math fact they were working on. Students who needed practice with +0 and +1 played Zero Spinner and Bump +1. Zero Spinner consisted on a dice and a spinner that had four sections: +0, +1, +1, and no turn. There was also a game board with the numbers zero through seven. Students would roll the dice then spin the spinner. They would add to the number rolled and use a marker on that number on the gameboard. Bump +1 is similar, except you add one to the number rolled and you can bump a player off the gameboard if there is a marker there. For those students who were working on facts within five and ten, they played Greg Tang Limbo. (See Appendix G.)

Happy Numbers is a fee-based on-line computer program that the building principal purchased for the entire building. It is a progressive program that gives each student a pretest, then places them in the instruction group based on their results. The activities on this program are visual and hands on. Students progress through a series of problems, and advance to the next level after they have mastered that skill. Students who are working on +1, practice making two parts, adding that amount, and other fluency activities until they have few errors. It is a colorful, user friendly, program.

Ten Frame Mania is a free app or online game. This game is a visual game of learning what each number really means in the sense of quantity. They learn to add one, add, five or ten, and learn the relationships of each number to another.
The Control Fluency groups participated in flashcard study individually and with partners. They also worked in a small group with the teacher using only the traditional vertical flashcards. Their online programs were Fact Dash and Basketball Math.

Traditional flashcards were vertical math facts on a card without the answer or anything to help them figure out the answer.

For the small group rotation, the students would sit at the table with the teacher and play Up You Go, Down You Go. Each child would be shown a bigger version of the traditional vertical flashcard. The student would have to figure it out. If they answered correctly, they would stand up or sit down depending on their previous position. If they answered incorrectly, they would remain in their sitting or standing position.

Fact Dash is a math fact fluency program that is an online program based on timed tests. A student can pick an operation, and different number ranges, set an amount of time, then answer as many vertical problems as one can in the time allotted. If an answer is incorrect, it will show you the math fact at the end without the correct answer. Students can continue to play this game, adding more or taking away time for each practice session.

Basketball Math is similar to Fact Dash, just with a basketball theme. The computer sets the time, the user answers the problems. If the answer is correct, then the basketball goes through the hoop. If not, then it doesn’t score the points. After the time expires, students watch a short clip showing the basketball player playing.

After three weeks of these rotations, a “Just Know it” quiz was given in a small group setting. See Appendix F. Each student received a list of eleven math facts written horizontally based on the set of math facts they were studying. They were allowed to take as much time as needed to answer all the problems. While the students were answering the questions, notes were
taken as to how each student solved the problems. Were they counting on their fingers, were they counting on, using mental math or just automatic with their answers. This formative assessment was given to see if students were able to advance in the math fact progression, or if more practice was needed. Students in the Regular Fluency Groups were given new visual flashcards, and the Control Fluency group was given new traditional flashcards if they moved to the next level of progression. The Regular Fluency Groups were shown new games to play as well.

At the end of the six-week study, students were then given the same three part interview as they had prior to the study taking place.

**Consideration of Ethical Concern**

Students were randomly divided into the two fluency groups. They were not aware of which group they were in. Each running record was done individually, with the results being kept confidential. Only the investigator had access to the results as they were kept in a filing cabinet only accessible to the investigator.

Upon completion of the six-week study, all students were then involved in the activities of the fluency group: visual flashcards, small group instruction, partner games, and on-line fluency games.

**Data Analysis**

The pre-test and post-test were scored according to the running record codes. Results from the pre-test were used to design interventions for each student to help them progress through the math fact progressions. Results from the post-test were also used to help each individual student advance through the progressions. Pre-test and post-test results were compared to see the pros and cons to the use of traditional flashcards versus the number sense based activities with the goal of each student developing math fact fluency.
CHAPTER 4
RESULTS

This research was conducted to compare the outcome of students’ use of traditional flashcards and timed computer-based math drills to the use of visual flashcards, small group instruction and math games toward mastery of math facts. This chapter will focus on the results of the study designed to answer the question, “What is the impact of including games to increase number sense on first graders’ fluency with math facts? Results obtained from the pre-test and post-test in order will be shared.

Pretest Results

Each student in the study was given a pretest and a posttest to determine where they placed in the progression of addition math facts. The results from the pretest are in Table 1. The majority of the students fell in the plus 0, with none of the students scoring above the fourth stage of the progression, adding within 10. The posttest results are in Table 2. The results of the posttest show a decrease of students in the first two stages of the progression, and students advancing to the seventh stage, adding doubles plus 1. The posttest was given six weeks after the pretest. Figure 1 shows how the control group scored on the pretest compared to the posttest. Figure 2 shows the results of the fluency group scored on the pretest and posttest. Both of the Figures 1 and 2, show a decrease in the number of students in the plus zero stage of the addition fluency and an increase of students moving positively through the progression.
Table 1

*Baseline Interview/Math Fact Progression*

<table>
<thead>
<tr>
<th>Addition Level</th>
<th>Number of students</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0</td>
<td>6</td>
<td>43%</td>
</tr>
<tr>
<td>+1</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>+ within 5</td>
<td>3</td>
<td>21%</td>
</tr>
<tr>
<td>+ within 10</td>
<td>4</td>
<td>29%</td>
</tr>
<tr>
<td>Make 10</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ doubles</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ double +1</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ double + 2</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ higher numbers</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ with compensation</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ 10</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 1 shows the results from the pretest interview of 14 first grade students. It indicates the majority of the students are on the basic level of adding 0 to a number. The next highest percentage is with students who are able to add fluently with numbers within 10 (i.e. 3 + 6, 4 + 3, etc.).
Pretest and Posttest Data

Students involved in this study were given two individual interviews. The second interview occurred after working with their flashcards and fluency group for six weeks.

**Figure 1.** Control group – Comparing pretest to posttest data.

Figure 1 is a comparison of the pretest and the posttest results of the control group. The control group consisted of seven first-grade students. These students engaged in traditional flashcard study and computer-based math fact practice in the traditional flashcard format. It indicates that the majority of the students began with little to no understanding of math fact fluency. After six weeks of study, it shows significant growth in the progression of math facts.
Figure 2. Fluency group – Comparing pretest to posttest data.

Figure 2 is a comparison of pretest and posttest results for the fluency group. This group consisted of seven first grade students. These students were involved in the study of math facts with the use of visual flashcards, math games based on their understanding, and small group instruction to help them increase their understanding of math fact strategies and computer games using visuals. The results of the posttest show a positive growth of the students involved after the six week study.
Table 2

*Posttest interview/Math Fact progression*

<table>
<thead>
<tr>
<th>Addition Level</th>
<th>Number of students</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>+1</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ within 5</td>
<td>5</td>
<td>36%</td>
</tr>
<tr>
<td>+ within 10</td>
<td>4</td>
<td>29%</td>
</tr>
<tr>
<td>Make 10</td>
<td>2</td>
<td>14%</td>
</tr>
<tr>
<td>+ doubles</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>+ double +1</td>
<td>1</td>
<td>7%</td>
</tr>
<tr>
<td>+ double + 2</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ higher numbers</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ with compensation</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>+ 10</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 2 shows the posttest results of all 14 students involved in the study. The results show significant growth with all but one student involved. Now the highest percentage of students were able to add numbers within 5 (3 + 2, etc.) and the second highest group is adding numbers within 10. The pretest results show that students highest fluency score was numbers within 10. After six weeks, students progressed several steps with the highest results being three steps higher on the progression, at adding doubles +1.

The pretest interview showed that most of the students fell into the Adding Zero area of the progression. The posttest showed that most of the students were in the Adding Within Five
area of the progression. This shows an increase of three steps on the progression after six weeks of study.

Fluency is much more than answering math facts quickly. It is the ability to understand and use the concepts learned in solving other math problems. The second part of the interview consisted of 10 questions. These questions allow the teacher to see how each student understands the different type of math facts.

The following tables will show how students progressed in their understanding of mathematic concepts.

Figure 3. Flexibility interview pretest – 140 questions.

Figure 3 shows most of the students have no understanding of the meaning behind each group of math facts. Few students were able to explain how they solved a math fact, which is
evident in the minimal number of students who used a strategy or already understood the concepts they were questioned about.

**Figure 4.** Flexibility interview posttest for the entire class - 140 questions.

Figure 4 shows significant growth in the number of students who have some strategic understanding of the meaning behind each group of math facts. More students were able to explain how they solved a math fact, especially in the first four categories of the progression.

Table 3 categorizes the 140 responses from the pretest and posttest to show those demonstrating concept understanding, use of a strategy, or demonstrating no understanding.
Table 3

*Results of the Fluency Interview Questions-140 Questions total*

<table>
<thead>
<tr>
<th></th>
<th>Concept Developed</th>
<th>Strategy Use</th>
<th>No Understanding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>8</td>
<td>25</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>6%</td>
<td>18%</td>
<td>76%</td>
</tr>
<tr>
<td>Posttest</td>
<td>27</td>
<td>54</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>19%</td>
<td>39%</td>
<td>42%</td>
</tr>
</tbody>
</table>
This study was designed to investigate the impact of including games to increase number sense on first graders’ fluency with math facts. There was a pretest interview given to each student prior to the beginning of the study and a posttest interview given at the end of the six-week study. Students were placed into one of four groups based the results of the interview. Half of the students were placed in two groups that were given traditional flashcards, vertically written math facts, based on the fact set indicated at their pretest interview. The other half of the students were placed in two groups that were given visual flashcards, horizontally written math facts with a picture to match the math fact, also based on the fact set indicated at their pretest interview. It was determined that there was growth in math fact fluency in both groups after the post-test interview was given.

**Discussion of Pretest and Posttest Results**

When comparing the results from the two interviews, it is obvious that there was significant change in the number of math facts students grew to know after six week of math fact study. Prior to working with math facts, 10 of the 14 students were not proficient in the math facts that should have been mastered during their kindergarten year, +0, +1, +2 facts within 5. The other 4 students in the study were proficient with those math facts and were tested to be in the set of adding within 10. Students within both groups worked with math facts flashcards and participated in small group instruction for six weeks. The posttest interview showed significant gains in the student knowledge of math facts. 6 of the 14 students were proficient in the math facts of adding within 5. 6 students showed growth in the first grade facts of adding within 10, and 2 students grew to higher facts adding up to 20.
Another part of the interview consisted of asking students about their knowledge of strategies when solving math facts. Each student was asked ten questions. The questions asked students about how they think when solving addition math facts. Students were scored as understanding each concept, using a strategy to solve the math facts, or no understanding of how to solve the fact. During the pretest, there were eight of the 140 questions asked that students understood the concept. 25 of the 140 questions, students were able to explain a strategy they used to solve the math facts. Leaving 107 questions asked with no understanding of how to get the answer. The post test revealed significant growth. Students who scored as understanding each concept grew from 8 questions to 27. 24 of the 140 questions asked during the pretest, a strategy was used to describe the answer, and during the posttest there were 54 questions answered with a description of a strategy use. That left 59 questions during the post test that couldn’t be answered. This six-week study showed a thirteen point growth in students who developed an understanding to the concept behind math facts, and a 21 point growth in students who developed a strategy to solve math facts. The decrease in no understanding was very significant, going from 76% questions with no understanding of the concepts related to math facts, to 46%. That indicates more than half of the questions had students who had an understanding of the concepts behind the math facts.

In the third part of the interview, students were asked how they felt about math, and what they would do if they got stuck on a problem they were trying to solve. The seven members of the control group all stated that they liked math during the first interview, with one indicating that he “loved it”. Six of the seven children from the fluency group indicated that they liked math, with one student shrugging their shoulders, meaning that she didn’t know if she liked it or not. At the end of the study, these students were again asked if they liked math. Six of the seven
in the control group answered that they liked math, and one was hesitant, and didn’t really know if he liked the subject. The seven members of the group all stated that they liked math, with one stating that it was “his favorite.”

Students in each group were also asked what they would do if they “got stuck” when trying to solve a math problem. The interview prior to the study revealed that students had different plans for their struggles. Within the control group, three students said they would ask the teacher for help. Two of them would use their fingers, and two of them would use the counting on strategy. The seven members of the fluency group also provided their thinking. Four of that group would count with their fingers, two of them would add for all their problems they got stuck on, and one student stated that they would continue to think.

Upon the conclusion of the study, these students were again asked what they would do if they got stuck solving a math problem. Students were more aware of strategies they could use to solve problems, and seemed to have a better plan. Four of the students in the control group had a strategy they would use. One would write down the problem and use a ten frame, another would ask for help or use a rekenrek. A third student would use a number line or count on, and another would use their hands to count. Two of the students in the control group would count on, and one would just “try my best.” These students grew in their knowledge of strategies, not during their fluency time, but during the math lessons. These students showed more confidence in their ability to solve a problem.

Students in the fluency group were also asked this question at the conclusion of the study. These students also showed that they had a better knowledge of ways to solve problems. Three of the students stated that they would count on. Two of the students said they would use their fingers, with one of those students stating that they would “keep trying”. Another student stated
his strategy of counting on, but also added that he would draw a picture or use a math tool to help him solve the problem. Another student said they would redo the problem if they got stuck. These students also showed that they had a deeper knowledge of math, and that they had more “tools” in their schema to use to help them when solving problems.

Each group had students of different mathematical knowledge. The next paragraphs will discuss some of the students involved in this study.

Student A was a student of higher mathematical knowledge, who was in the control group. She used her traditional flashcards for individual study, partner study and small group time. She worked with the same vertical math facts on the computer. This student showed an understanding of the first three sets of math facts, +0, +1 and add within 5. She could use a strategy to answer the remaining math facts. She had a conceptual understanding of the same math facts she was fluent in, and could explain her strategy on the other eight questions asked. This student would ask during the course of the six-week study, when she could take part in the games, small group discussions, and computer program that used visuals and conceptual ideas to build fluency. The posttest interview showed that this high achieving student did not make any growth on her math fact fluency. She remained proficient in the same math facts, and used the same strategies she used during the pretest.

Student B was a student of lower mathematical knowledge who was in the control group. She was not proficient in any of the math facts, including the +0, +1, and adding within 5 that were taught in kindergarten. During the pretest interview, she couldn’t explain any strategies that she would use to answer the basic math facts. During the six weeks she tool studied her math facts flashcards by herself, with a partner and during small group time. During the posttest interview, she showed proficiency in +0 and +1 as well as during her interview questions, she
could explain her understanding of the concepts of adding zero and one to any number. The remaining math facts questions were answered in the same manner as during the pretest. One could infer, that this student recalled this information from her previous kindergarten teaching, and the exposure reopened her schema. This student showed growth in the math facts and strategies that she was exposed to during the previous year.

Student C was a student of higher mathematical knowledge who was in the fluency group. He was proficient in the kindergarten math facts of +0, +1 and adding within 5 during his pretest interview. He could explain the concepts of adding zero and adding one to any number during this pretest. He had a very basic strategy of counting all the items in the remaining 8 types of math fact questions. He participated in the six-week study, where he was able to study visual flashcards, play mathematical games with a partner, and participate in small group instruction where concepts were introduced and practiced with teacher assistance. Questions were asked and explained during the small group instruction. This student showed significant growth after the six-week study. He showed proficiency in seven areas: +0, +1, add with in 5, add within 10, making 10, adding doubles and doubles plus 1. His strategy knowledge also increased in eight of the ten questions. He went from a basic counting all strategy to using a counting on strategy, a doubles, and a doubles +1 strategy. This student grew in his ability to be flexible, fast and accurate in many of the math facts, including ones that were not formally introduced during small group.

Student D was a student of average mathematical knowledge who was in the fluency group. He was proficient in the kindergarten math facts of +0, +1, and adding within five during his pretest interview. He could explain the concept of adding 0 to any number, but didn’t have any conceptual knowledge of the other math facts, even the ones he was able to answer with
proficiency. This student also participated in the same fluency type activities. He was given the post test interview, where he grew in his knowledge of strategies. He was able to answer the same kindergarten facts with accuracy, then showed an increase of knowledge in the next five math fact questions. He went from no knowledge of adding within 10, making ten, doubles, doubles plus 1 and doubles plus 2, to being able to use more mental math strategy use when solving those facts. He was also able to use a strategy on eight of the ten interview questions. This student took the strategy practice that was used during small group and transferred it to many other types of math facts.

**Limitations**

One of the limitations in the study was the amount of time allocated for the study. For ethical reasons, a six-week study was done, as to avoid neglecting the students in the control group. Another limitation was the small group of the students that were in the study. With five students in the class not able to participate, this left a smaller number of students available for the study. All students in the class were involved in math talks, which addressed strategy use. These math talks involved both groups, which could have influenced the control group in answering the interview questions. Addressing these limitations could improve this study.

**Recommendations for Future Research**

The results of this study suggest the need for further research in this area, First, replicating this study with a larger group of students would provide support for the findings of the study. Engaging more students in a study would enable a larger amount of data as well as see the effects of fluency games on a wider variety of students. Waiting until after the six week study to start math talks could show a truer knowledge of strategy growth from those students in the fluency group. Small group instruction was part of this research, and one could also eliminate
that part or add in more small group instruction times with each group, both of which may affect how quickly students progress through the math facts. There were no whole group lessons on fluency during this six week study. One might also incorporate that into a future research question.

Conclusions and Implications

The data is not conclusive. The pretest for the control group showed five of the seven students able to solve the addition facts within five and two adding within ten. The post test for this group shows everyone grew in their knowledge of their math facts. The fluency group started with five students able to add within five and two within ten. Six of the seven students showed growth in their math fact knowledge.

The use of strategies also grew across both groups. Prior to the study of math facts, only 24% of the problems were answered by students who could explain their strategies. After six weeks, 58% of the problems were able to be solved using a strategy. The majority of the kindergarten facts, +0, +1, +2 within five, were able to be explained. Both the control group and fluency groups showed growth in general math fact knowledge and strategy understanding.

One thing that showed a difference during the two groups during the six-week study was the amount of engagement. The fluency group showed more eagerness to get started, stay on task and use the visuals available to them. The control group often asked when they could play the games with each other and on the computer. During small group, students in the control group became less interested as the weeks went by.

While the numbers don’t give solid evidence that games help increase number sense in first grade math fact fluency, this was only a six-week study. Upon concluding the six-week study, all nineteen students began participating in the fluency group regiment. The interviews
were given three more times over the course of seven months. Students engaging in this process began using higher level strategies to solve their math facts, and more levels became automatic for all students. Engagement and interest didn’t wane with the games online or with partners. As students grew in their math fact knowledge, a deeper understanding also became evident. Fewer students were using the counting all strategies and began describing their counting in and compensation strategies. These two strategies are higher level thinking skills, as noted in Math Running Records in Action (Newton 2015). Another added bonus to this format is the knowledge the teacher gained by hosting small groups and individual interviews. This allowed for more individualized instruction for each student.

In conclusion, math fact fluency practice should involve many formats. Students should not be expected to all learn in the same manner. Teachers who interview their students gain a deeper knowledge of each student, which allows them to address each student’s individual needs. Providing small group instruction, games, computer programs and visual tools for students to use has been shown to support an increase in mathematics content knowledge. In addition, use of these tools leads to a deeper understanding that will transfer to other mathematical areas, hence the increase in strategy use and understanding.
REFERENCES


## ADDITION RUNNING RECORD

<table>
<thead>
<tr>
<th>Student Page</th>
</tr>
</thead>
</table>
| 0 + 1        | 5 + 6  
| 2 + 1        | 7 + 5  
| 3 + 2        | 4 + 8  
| 2 + 6        | 7 + 8  
| 4 + 6        | 8 + 9  
| 7 + 7        | 10 + 4 |
**APPENDIX B**

**Part 1: Addition Running Record Recording Sheet**

<table>
<thead>
<tr>
<th>Strategy Levels and Accuracy</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 + 1 a wo se asc ca foe coh ph dl</td>
<td>A0 = adding 0</td>
</tr>
<tr>
<td>2 + 1 a wo se asc ca foe coh ph dl</td>
<td>A1 = adding 1</td>
</tr>
<tr>
<td>3 + 2 a wo se asc ca foe coh ph dl</td>
<td>A\text{w}5 = adding within 5</td>
</tr>
<tr>
<td>2 + 6 a wo se asc ca foe coh ph dl</td>
<td>A\text{w}10 = adding within 10</td>
</tr>
<tr>
<td>4 + 6 a wo se asc ca foe coh ph dl</td>
<td>A\text{M}10 = adding doubles</td>
</tr>
<tr>
<td>7 + 7 a wo se asc ca foe coh ph dl</td>
<td>A\text{D} = adding doubles plus 1</td>
</tr>
<tr>
<td>5 + 6 a wo se asc ca foe coh ph dl</td>
<td>A\text{D}1 = adding doubles plus 2</td>
</tr>
<tr>
<td>7 + 5 a wo se asc ca foe coh ph dl</td>
<td>A\text{D}2 = adding higher facts</td>
</tr>
<tr>
<td>4 + 8 a wo se asc ca foe coh ph dl</td>
<td>A\text{H}3\text{F} = adding by compensating</td>
</tr>
<tr>
<td>7 + 8 a wo se asc ca foe coh ph dl</td>
<td>A\text{H}3\text{F} = adding by compensating</td>
</tr>
<tr>
<td>8 + 9 a wo se asc ca foe coh ph dl</td>
<td>A\text{H}3\text{F} = adding by compensating</td>
</tr>
<tr>
<td>10 + 4 a wo se asc ca foe coh ph dl</td>
<td>A10 = adding 10 to a number</td>
</tr>
</tbody>
</table>

**Codes:**

a = automatic
wo = wrong operation
se = self-corrected
asc = attempted self-correction
c = counted all
coa = finger counted on
coh = counted on in head
ph = prolonged thinking time
dk = didn't know

**Comments:**

0 – doesn’t know
1 – counting strategies
2 – mental math/solving in head
3 – using known facts and strategies like doubles, make ten
4 – automatic recall
Teacher: We are now going to administer Part II of the Running Record. In this part of the Running Record we are going to talk about what strategies you use when you are solving basic subtraction facts. I am going to tell you a problem and then ask you to tell me how you think about it. I am also going to ask you about some different types of facts. Take your time as you answer and tell me what you are thinking as you see and do the math. I am going to take notes so I can remember everything that happened during this Running Record.

<table>
<thead>
<tr>
<th>Zero Facts</th>
<th>+1 Facts</th>
<th>Adding within 10 Facts</th>
<th>Make ten facts</th>
<th>Doubles Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 + 0</td>
<td>4 + 1</td>
<td>2 + 2</td>
<td>What does 3 + 7 make?</td>
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<tr>
<td>5 + 0</td>
<td>10 + 1</td>
<td>6 + 3</td>
<td>What about 5 + 5?</td>
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<tr>
<td>A0</td>
<td>A1</td>
<td>Aw10</td>
<td>What kind of facts are these?</td>
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**Doubles + 1**

If a friend did not know how to solve 6 + 7, what would you tell them to do?

What about 4 + 5?

**Doubles + 2**

If a friend did not know how to solve these facts, what would you tell them to do?

3 + 5
6 + 8

**Higher/Higher facts**

What do you do when you see problems like 5 + 9 or 7 + 4? What strategy do you use to solve these problems?

**Compensation**

If a friend did not know how to solve 9 + 7 what would you tell them to do?

What about if they could not solve 8 + 5, what would you tell them to do?

**Add 10**

What do you do when you add 10 and a number?

10 + 2
10 + 8

Comments/Notes about gestures, behaviors, remarks.
<table>
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<th>Part 3</th>
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<tbody>
<tr>
<td>Mathematical Disposition: Quick Interview</td>
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<tr>
<td>Do you like math?</td>
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<td>Rectangular Snip</td>
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<tr>
<td>What facts are easy? Which facts do you just know? (Point to the benchmark problems.)</td>
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<tr>
<td>What facts are tricky? Do you use any strategies on the tricky problems?</td>
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<td>What do you do when you get stuck?</td>
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### APPENDIX E

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Scaffolded and visual flashcards found at [www.guided-math-adventures.com](http://www.guided-math-adventures.com)
APPENDIX F

_________ just know it.... .

0 + 3 = ___
8 + 0 = ___
7 + 0 = ___
0 + 2 = ___
0 + 0 = ___
1 + 0 = ___
6 + 0 = ___
0 + 5 = ___
4 + 0 = ___
0 + 9 = ___
10 + 0 = ___

_________ just know it.... .

2 + 3 = ___
7 + 2 = ___
3 + 6 = ___
2 + 4 = ___
5 + 3 = ___
4 + 2 = ___
6 + 4 = ___
4 + 5 = ___
4 + 3 = ___
2 + 5 = ___
1 + 9 = ___
**MATH LIMBO™**

Take turns: Roll. Cross out 1-2 numbers on your triangle that either add or subtract to equal the number rolled. Players take turns back and forth, rolling and eliminating numbers on their triangle. If a player rolls and no numbers can be eliminated, the turn is over and opponent rolls again. Winner: Player to eliminate all his/her numbers first.

Example: Player rolls 8

Other Possibilities:
1 & 7, 3 & 5, 8, 9 & 1, 10 & 2
Full Review
8/29/2017
Protocol Number: 859

Dear Kelly Sickle:

Your research project, 'The Effects of Math Games on Elementary Fact Fluency', was approved by the University of Central Missouri Human Subjects Review Committee on 8/29/2017. You may collect data for this project until 8/29/2018. Your informed consent is also approved until 8/29/2018.

**If an adverse event (such as harm to a research participant) occurs during your project, you must IMMEDIATELY stop the research unless stopping the research would cause more harm to the participant.** If an adverse event occurs during your project, notify the committee IMMEDIATELY at researchreview@ucmo.edu.

The following will help to guide you. Please refer to this letter often during your project.

- If you wish to make changes to your study, submit an “Amendment” through Blackboard under the “Amendment and Renewals” tab. **You may not implement changes to your study without prior approval of the UCM Human Subjects Review Committee.**

- If the nature or status of the risks of participating in this research project change, submit an "Amendment" through Blackboard under the “Amendment and Renewals” tab. **You may not implement changes to your study without prior approval of the UCM Human Subjects Review Committee.**
• If you are nearing the expiration date for collecting data for this project (8/29/2018) and you have not finished collecting data:

1. submit your project application via Blackboard under the “Amendment and Renewals” tab (include any revisions and/or amendments approved since you submitted your application initially)

   AND

2. submit a “Renewal Report” through Blackboard under the “Final/Renewal Report” tab.

• When you have completed your collection of data, please submit the “Final Report” found on Blackboard under the “Final/Renewal Report” tab.

If you have any questions, please feel free to contact me at researchreview@ucmo.edu.

Sincerely,

Kathy Schnakenberg

Program Administrator/Research Compliance Officer

Office of Sponsored Programs and Research Integrity

University of Central Missouri

cc: mccoy@ucmo.edu