

**Improving Math Fact Fluency using Online Resources in a Virtual Upper Elementary
Montessori Classroom**

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Abstract

Math fact fluency is a problem across the United States and it affects the success of many students. Math anxiety is a very real experience and considerations are to be made for this while also seeking to help students improve their math fact fluency. The research questions looked into math fact fluency after daily online practice in a upper elementary Montessori classroom, and tried to find out which online resources were the most preferred by participants. The population was 15 Montessori students in a 4-6th grade classroom that participated in daily 10-minute practice sessions using three different fact websites for six weeks. Surveys and timed assessments were administered weekly to determine student confidence growth, math fact fluency growth, and most-preferred website. Most students demonstrated an increase in math fact fluency and confidence by the end of the study. Multiplication.com was the favorite resource out of the three websites. This study shows that online resources can be effective for practicing math facts. Yet, the researcher also discusses the limitations imposed by the COVID-19 pandemic and how these affect the implementation of the Montessori educational experience. Many follow up questions and considerations are listed.

Keywords: math facts, Montessori, math anxiety, COVID-19, online math resources, math fluency, memorization, upper elementary

Introduction

In the spring of 2020, the global COVID-19 pandemic hit America and drastically changed our way of life. It altered the everyday functioning of families, jobs, and our economy, and its rippling effects are still felt a year later. One area of our society that was particularly altered was the schools and how education is serviced. Immediately, “school” was unrecognizable. Buildings were closed and children waited at home to learn how this would change, amongst the other waves of uncertainty that now suddenly existed in the other areas of their lives. In a matter of days, educators were forced to transition from their in-person environments with concrete materials and full classrooms to a new model of learning that existed online. Educators had to completely reformat “school” so that it could be accessed through technology and meet the needs of the children (emotionally, socially, and academically), all while still taking care of their own personal situations at home that were affected by the pandemic.

Montessori teachers were presented with an especially challenging situation: how does one take a model of learning, which focuses on the developmental needs of a child and implements concrete materials, and move it “online”? In amazing rigor and dedication, American teachers and other school workers came together to transform education, including those in the Montessori community. Though various schools had many different approaches to achieving this transformation, the general learning experience that does not occur in-person has been titled “distance learning”, and many schools are still implementing these changes a year later.

As the beginning of the 2020-2021 school year approached last summer, countless questions ran through educators’ heads: “Will the children be able to come back to school in person? Will it be safe for them? For the adults? Will they be able to use the shared Montessori

materials? What cleaning spray am I supposed to use? How many times do I have to wipe down the door handles each day?” After much deliberation, governing authorities helped schools determine whether distance learning, in-person learning, or a mixture of both (referred to as “hybrid learning”) would be safest and most appropriate for their community of learners.

In Minnesota, where my study took place, schools were able to decide which model of learning was most appropriate based on the number of positive cases per 10,000 people in the area. My school was fortunate to begin the year in hybrid learning instead of distance learning, but this came with its own flood of questions about logistics and timing. No matter how much we planned for hybrid, we were faced with the uncertainty of how long we would get to stay in hybrid: would we do this all year? Will we have to go to distance learning? Will it be possible to have completely in-person learning at all this year?

Amid all this planning and other obstacles thrown our way, I also was beginning to format my own research study for the first time. I often asked myself, “How in the world do I plan and implement a Montessori research study when the learning model could change at any time?” I had already identified multiplication math fact fluency¹ as an area of growth in my classroom that I wanted to address, and I was excited to create a study to meet this need. In the beginning stages of formatting this study, I envisioned children in my classroom using whatever math materials they preferred most to help them practice their math facts. I saw children using Montessori materials, such as the bead chains, finger charts, bead bars, and multiplication board with tiles. I also envisioned them coloring tables of multiples or recording factors; completing times tables on paper—either timed or at their leisure—some students could even use

¹ I am using the term “math fact fluency” to refer to a child’s ease and efficiency in giving the answer to a one-digit by one-digit multiplication problem (ex: 4 x 6). This is not limited to how well a child has *memorized* their math facts, but can also include how easily they can *find* the correct answer using helpful strategies.

recommended websites on the computer for practice time! I could teach them multiplication games that they could play with each other, either collaborative games or competitive games.

The possibilities were endless, and I was thrilled!

Unfortunately, as the year continued, my school moved to distance learning and most of the activities I had envisioned were suddenly unrealistic. I asked myself, “What activities can I realistically plan for my students that will be useful for them, but also realistic for me to provide during the stress of this school year?” Additionally, I had to make sure these activities I planned could be implemented in any of the three learning models so the study could continue if our school changed learning models during the study’s duration.

With all these unknowns, my study eventually shifted away from my ideal vision and I reluctantly, yet necessarily, adjusted it. I realized that for the study to have validity and effectiveness, the only real way I could imagine implementing it would be to use online websites to practice math facts. Again, this was far from the ideal and thrilling vision I originally held, but I had to be realistic with what I was capable of at the time and what would provide for a study that still held validity and, hopefully, effectiveness. Thus, the following study was designed. I discuss what was successful about this study in my Conclusions section, and in my Follow Up Considerations section, I contemplate the changes I would make if I were to implement a similar study in the future.

Literature Review

Significance of Mathematical Success in Daily Life

Mathematics play a significant role in a person's daily life. Practical applications arise constantly, whether one is keeping time during meal preparations, calculating how much to save from a paycheck, or determining the probability of a successful football play. Math builds upon itself throughout a person's life, from childhood into adulthood (Nelson et al., 2016). It is a very practical subject that also integrates all other subject areas. Frequently assumed to naturally integrate with science and geometry, math can be found in any subject area, including language, cultural studies, arts, physical education, and music. Math is even helpful while locating books in the library, thanks to the Dewey Decimal System!

Due to its practical nature, a country's and an individual's success both depend on mathematical success (National Mathematics Advisory Panel, 2008). Devlin (1998), Guedj (1998), and Dehaene (1997), all cited by Yanuarto (2018), compared math to a pyramid. The top of the pyramid refers to real-life applications, but the size of the top of the pyramid depends on the size of the base, which is the base knowledge a person has of mathematics. The more of the base knowledge they have with math, the wider scope they will have of real-world applications they can be successful with. The more foundational knowledge they have with math, the wider scope and success they will have of real-world applications. While math is certainly not a singular determining factor for a society's success, we can argue that an individual's and a society's mathematical understanding as a whole do significantly contribute to society's overall success.

With this in mind, let us take the United States as a sample. Nelson et al. (2016) cite several sources that suggest a problem in the United States, citing one in particular “that less than 40% of students are proficient in math” (Nelson et al., 2016). Additionally, Nelson et al. cite research supporting that students will fall behind in general academic progress without a solid mathematical understanding and that students need to have basic math skills mastered in order to support their continued growth in math education (Nelson et al., 2016). Looking at achievement gaps that already exist, it is also important to consider how other factors, including socioeconomic status, race, and gender, affect mathematical success (Paschall et al., 2018). Again, while math is not a singular factor that determines how successful a country will be, if its widespread application, impact on individual lives, and the achievement gaps that already exist are considered, it is only reasonable to assume that a country lacking in mathematical understanding will also lack in overall success.

Significance of Math Fact Fluency in Math Success

After examining how important math is in individual and corporate success, it is important to examine the basic concepts that will help support the rest of a person’s mathematical success. Recall the pyramid analogy offered by Devlin (1998), Guedj (1998), and Dehaene (1997) (all cited by Yanuarto [2018]). There are several factors at play in the base of the pyramid, and research shows that one of those factors is fluency in math facts. Math fact fluency (in terms of the four basic operations for digits 1-12) is a building block for mathematical success because complex operations require mastery of basic math facts (Nelson et al., 2016). In response to this, Minnesota includes mastery of basic math facts as part of the math standards. For example, note the following from the Minnesota State Math Standards (Minnesota Department of Education, 2008):

- 1.2.2: “Use number sentences involving addition and subtraction basic facts to represent and solve real-world and mathematical problems;...” (p. 5)
- 2.1.2: “Demonstrate mastery of addition and subtraction basic facts;...” (p. 6)
- 3.2.2: “Use number sentences involving multiplication and division basic facts and unknowns to represent and solve real-world and mathematical problems;...” (p. 10)
- 4.1.1: “Demonstrate mastery of multiplication and division basic facts;...” (p. 12)

These standards are geared toward lower-level ages, so it is clear that math fact fluency is a stepping stone to further mathematical success. Each of the standards listed above illustrate the value and importance that Minnesota places on math fact fluency according to relevant research.

To further expand on the significance of math fact fluency, consider multi-digit multiplication. In order to successfully multiply a three-digit by two-digit number, the child must successfully calculate 6 different multiplication math facts, remember to add a zero as a place holder in the second partial product, and then successfully calculate three or four more addition math facts. Even if a child knows the process well, if they do not have basic math facts mastered, the child will not get the correct answer. Gersten & Chard’s study (1999) suggests that the brain is limited in its ability and energy, and energy spent on calculating math facts is wasteful when working with complex operations. Unfortunately, multi-digit multiplication is a building block for even more complex math, such as calculating a 3D figure’s surface area or finding the LCM/GCF of two numbers. All of math builds upon itself, and the absence of basic fact fluency will severely impact a child’s ability to be successful in math.

Many children are affected by this truth daily, whether they are acutely aware of it or not. Math anxiety has become a term used to describe the varying degrees of anxious and unsure

feelings about math that many children experience when in a math class or completing math assignments. While research is unclear about math anxiety's effects on math fact fluency in elementary children, some studies suggest a negative correlation between the two. For example, Luttenberger et al.'s (2018) study showed evidence that the greater a child's math anxiety is, the lower their math fact fluency may be. A study performed by Van Mier et al. (2019) suggested an impact on gender when the results showed evidence of elementary-aged girls' math performances being more greatly affected by math anxiety than those of elementary-aged boys. The effects of math anxiety might not be bound to a child's school-aged years, either—due to decreased confidence and comfort with the subject area, math anxiety may consequently lead to altered choices in which secondary education courses to enroll in or which careers to steer toward or away from (Luttenberger et al., 2018). If a child's confidence in their math skills increases, the child will be likely to be more open-minded to a greater variety of secondary courses and career options as they approach adulthood.

Let us consider one tool typically used in classrooms that has been connected to math anxiety—timed tests. Timed tests are used by educators as an efficient way to quickly and accurately assess students' abilities to answer math fact problems. Unfortunately, research suggests that math anxiety can interfere with a child's ability to recall facts that they do know (therefore affecting their test score). Boaler (2014) reported a timed test study in which researchers found greater activity in the regions of the brain that have to do with fear—they also found *less* activity in the regions associated with problem solving. Additionally, Geist (2010) states that, "Teachers begin to focus on repetition and speed or 'timed tests' as important tools for improving mathematical prowess and skill which can undermine the child's natural thinking process and lead to a negative attitude toward mathematics" (p. 25). When used as a teaching

method and high-stakes assessment, timed tests can lead to anxious thoughts and feelings which can severely impact a child's ability to recall math facts, regardless of ability. Math anxiety can also lead students to have a negative perception of math and their abilities in the subject (Boaler, 2014).

Many educators argue that timed tests should not be used because it is not a successful learning tool for students. This is strongly related to the fact that timed tests do not encourage or increase a child's number sense, but rather, their memorization. Boaler et al. (2015) state that, "low achievers are often low achievers [...] because they don't use numbers flexibly—they have been set on the wrong path, often from an early age, of trying to memorize methods instead of interacting with numbers flexibly" (p. 2). If a child is able to engage with numbers in a flexible manner, their number sense will increase and they will show more success in mathematics, regardless of speed. After learning more about the research around math anxiety and timed testing, I took this research and these concerns into serious consideration, and I discuss the topic more in my Quantitative Data Collection section.

Math Fact Automaticity via Constructivism and Technology in the Classroom

To support children's growth of math fact fluency, especially in an elementary classroom, Constructivist Theory is a practical approach. Constructivism is a theory that suggests that learning occurs through experiences, and individuals build their knowledge based off of these experiences (Western Governors University, 2020). Many teachers, interventionists, and researchers employ Constructivist Theory in their work, and this work can be tailored to include the improvement of student math fact fluency without limiting it to rote repetition. Constructive theory does not mean "rote repetition," and while unengaged rote memorization is not beneficial, there is a large amount of research supporting that repeated, methodical, and *engaging* practice

methods support the automation of math facts (Burns et al., 2014). Engagement affects the success of Constructivist methods (Poncy et al., 2010), and studies have shown that if students are properly engaged, Constructivist methods improve fluency (Burns et al., 2014). The repeated practice of math facts, in a variety of ways, with a variety of materials, using a variety of strategies, can build the foundations for valuable Constructive experiences.

Technology is another practical approach to developing a child's math fact automaticity. It has become a typical element in nearly every classroom throughout the country (Lynch, 2013) and has evolved tremendously in a short period of time. Classroom technology began with overhead projectors and teacher computers, but now a vast array of resources are available to teachers and students alike. SmartBoards are now used for taking attendance, delivering lessons, giving directions, and many other daily tasks. Computers and tablets are now available for student use, often including a computer lab. Many schools of varying ages even have classes centered around the use of computers. Musti-Rao et al. (2015) reference the use of one-to-one devices with applications for students to practice differentiated skill sets, and devices are used to offer support to many children who receive services for special needs, whether they be emotional, academic, or social needs.

Now that students' learning environments have been transferred home due to COVID-19 restrictions, technology is more abundant than ever in their learning experiences. In a full distance learning model, lessons are delivered completely online through video calls and pre-recorded videos, attendance is taken and work is submitted through online classroom websites, and virtual resources are used in place of physical materials or paper submissions. In a hybrid model, many of these elements are still in place. Just like when an educator shows children how to navigate the physical classroom space at the beginning of a typical school year, educators have

had to teach children how to navigate these resources in order to help them be successful in the current context. Children have also explored their own ways for how to use this technology to their benefit, including sending emails to teachers and peers, texting friends a question about homework, or video chatting with classmates to work on an assignment together.

Due to the prevalence of technology in the educational setting, whether virtual or in-person, it is used to improve automaticity in math skills. Particularly, many schools employ the use of devices with applications or websites to have students practice their math facts (Musti-Rao et al., 2015). Research exists to support that Computer-Assisted Instruction or Intervention (CAI) is a useful tool for increasing math fact fluency (Berrett & Carter, 2017; Hawkins et al., 2017), referring to computer-based resources that help students practice math facts. These resources come in a variety of formats (Hawkins et al., 2017), including direct practice, timed tests, programs with “levels” or skill-focuses, and games (individual or multi-player). Digital math fact resources are extremely valuable now during distance learning and hybrid models since standard Montessori materials and other physical materials and methods are not as easily accessible.

In conclusion, there is a large amount of research supporting the repeated practice of math facts, especially with the use of technology. Constructivist Theory supports the constant exposure to these facts in order to improve automaticity and to help focus student efforts on more complex operations rather than basic math skills. Putting an emphasis on math fact mastery will not only allow a child to be more confident and successful in their math studies, but it will support their educational experience in their secondary and post-secondary years and will open a great deal more of opportunities to them as an adult. One simply cannot succeed well without an understanding of math, and the development of math fact fluency can ultimately impact the quality of living that a person has throughout their entire life.

Purpose and Research Questions

Math facts play a significant role in a child's success in mathematics and can even impact their long-term success into adulthood. I chose to study math fact fluency due to personal interest, its relevance in the classroom, and the research that supports focusing on math facts explicitly during the school day. In the context of our current school year, where children are shifting between full on-site, hybrid, and distance learning models and families have different needs and accessibility, daily math fact practice looks very different than I envisioned it occurring during a typical year. Postponing my vision of a study that implements the several Montessori math materials designed to help with math fact fluency², I chose to develop a study for this year that focused around technology that would be accessible in all three learning models and would result in the most consistent and reliable data. Thus, the following research questions were developed to reflect the context of our current school year.

Main research question:

What improvement in student math fact fluency is made after daily practice of math facts in a virtual upper elementary Montessori classroom setting?

Secondary question:

What online tools for practicing math facts are most preferred by students in an upper elementary Montessori classroom?

² My original vision for my study is discussed in the Introduction and Furthering the Study sections.

Montessori Connections

Regular practice of math facts is strongly supported by the Montessori philosophy and pedagogy. First, Montessori mathematics builds upon itself. If a child is not ready for a more advanced topic, the child does not move on to the more advanced work until they have a firm grasp on the current topic or show an expressed interest in the advanced topic. The pedagogy was designed this way so the child can appropriately develop his or her skills at their current level, which will prepared them for the more advanced task. Maria Montessori wrote in *The Secret of Childhood* (1966, p. 186) that, “A child’s desire to work represents a vital instinct since he cannot organize his personality without working: *a man builds himself through working.*” The phrase “*builds himself*” suggests that there must be a foundation that is being built upon, and if that foundation is not firm, the rest of the “building” will not stand. Almost all of my students understand what multiplication means, but they do not have a firm grasp on their basic math facts. How can my students successfully move on to more advanced topics if their foundation of basic math facts is not sound? Currently, my students struggle very much to consistently be successful with more advanced topics simply because of math fact errors that are made during the process. As I consider this I visualize my students attempting to build a structure by putting up vertical planks first—of course the planks will not stand if the foundation is not firm! At the very least, concurrent practice of math facts alongside the more advanced topics can be a helpful option to help support my students as they continue the process of “building” their mathematical skills.

Next, Montessori knew the importance of offering relevant skills to the child in order to pique their interest, give them a setting to practice such skills, and prepare them for the next task

that they will embark on (Montessori, 2007, p. 8). As she noted in *The Secret of Childhood* (1966),

...when because of favorable circumstances work flows naturally from an inner impulse, it assumes an entirely different character, even in adults. When this happens, work becomes fascinating and irresistible and raises a man above his diverted self. Examples of this may be found in the toils of an inventor, the discoveries of explorers, and the paintings of an artist. (p. 186)

Relevance supports interest, and interest activates the imagination and engrosses the child in a way that is not accessed through disengaged motions. Though her method was developed over 100 years ago, the principle of relevance applies greatly to the study of math facts. As discussed earlier, the relevance of these skills is undoubted. I will actually be doing my students a great injustice if I do not have them practicing such a relevant topic. Montessori observed that children learn best through ways that are relevant and familiar to them, and modern children (in general) are exceptionally fluent and comfortable with the use of computers and other technology, so it is reasonable to use these materials to support children in their math fact fluency. Websites used via computers are a great tool for practicing such a relevant topic, especially in the context of our COVID-19 school year.

Finally, through her observations, Montessori discovered that repetition is a necessary component in a child's learning experience and it became a core part of the Montessori pedagogy (Montessori, 1966, p. 119-120; 1995, p. 167; 1998, p. 92-93). Materials found in Children's House and Elementary classrooms are designed to allow repetitive practice, and several of these materials are specifically geared toward practicing math facts. For example, the bead chains are an opportunity for the child to practice counting by numbers and eventually can be used to

further develop math fact fluency. Additionally, starting in classrooms as early as Children's House, various tile boards can be found for practicing any math facts, including addition, subtraction, multiplication, and division. While math fact fluency can be confused with rote memorization, these Montessori materials (among others) demonstrate how this process can be differentiated to meet student needs and can be approached in many different ways.

In conclusion, repetitive math fact fluency practice holds an extremely relevant place in an upper elementary Montessori classroom. Repetition allows the child to develop a deep understanding and mastery of a skill, and several Montessori materials reflect the significance of practicing math fact fluency skills. In the setting of a COVID-19 school year when students are learning at home several days per week, providing modern means to practice such skills (such as websites via computers) invites children to practice math fact skills in a familiar and engaging manner. Dr. Montessori demands that educators "follow the child", and though this study takes a unique approach to accomplishing this demand, this study is designed to seek out the most effective way to follow my students' needs in math fact fluency within our current learning context.

Methodology

Participants and Setting

The individuals who participated in my research study are my own students from Minnesota who attend a public Montessori school in our Elementary 2 classroom (E2) —fourth through sixth grade). In total, 23 students are enrolled in my class and 16 students participated at the onset of the study. Of the 16 participants, one student was enrolled in distance learning and joined the study via video calls. One other student began the study, but due to overwhelm with distance learning work, chose to withdraw their participation from the study. This resulted in a final participation of 15 students. The grade levels of the participants were relatively balanced with fifth grade having the highest participation and fourth grade having the lowest (see Table 1 for a breakdown of participation by grade).

Table 1

Number of Participating Children in Each Grade

4th Grade	4
5th Grade	6
6th Grade	5
Total	15

As the classroom teacher, I had identified an overall pattern in my E2 classroom which was that students did not have high fluency with their math facts. This was true for the incoming fourth graders all the way up to the veteran sixth graders. Several challenges existed in math success due to a lack of fluency in math facts—often times, the students would lose their place in the math process simply because of having to calculate basic math operations. Though I

encouraged children to take advantage of the various materials to practice their skills during choice work time, these were rarely selected in comparison to other available choice works that captured the children's attention.

Table 2

The Three Learning Models of MN Schools during the 2020-2021 COVID School Year

Learning Models	Number of COVID cases/10,000 people	Number of on-site school days per week	Daily schedule and format of lessons
Distance Learning	50+	0	Virtual lessons with optional office hour
Hybrid Learning	20-50	2	Off-site days: distance learning style On-site days: full on-site learning style
Full On-Site Learning	Less than 20	5	Small group lessons, work time, recess/lunch, afternoon work time, in-person specials

The pattern of low math fact fluency arose each year in my classroom, but with the onset of the COVID-19 pandemic, the format of learning was suddenly transformed and became very fluid. The specifics of our school's learning setting changed periodically throughout the 2020-2021 school year (during which my study occurred) due to shifts in learning models to meet COVID-19 safety measures. There were three learning models that our school would shift between based on how prevalent COVID cases were in our city and school community: these three models were called distance learning, hybrid, and full on-site (or full in-person). Each

learning model determined the type and frequency of teacher interaction that students had during their learning experience.

These three learning models looked very different from each other and are explained below (for an overview of each model, see Table 2). When COVID cases were less than 20 cases/10,000 people, our school was allowed to be fully on-site, which meant that all students attended school every day, every week, just like in a typical school year. Students had a regular daily schedule (including a two-hour morning work cycle, recess and lunch, about one hour of afternoon work time, and then specials lessons), and they received their regular daily lessons during their work time. However, lesson groups were split in half to accommodate spacing requirements for COVID safety. When COVID cases were more than 50 cases/10,000 people, our school needed to be in distance learning. This meant that each grade level had a video call with their teacher every morning for their lesson, and a virtual “office hour” video call was available or required later in the day if students had questions or missing work to finish.

Finally, when COVID cases were between 20-50 cases/10,000 people, our school shifted into hybrid learning, which was a combination of the on-site and distance learning models. When the school was in the hybrid model, students were split into two groups referred to as Group A and Group B. All students attended school every week, but Group A students attended school on-site on Mondays and Tuesdays, and Group B students attended school on-site on Thursdays and Fridays (Wednesdays were reserved as teacher prep days, so no students attended school on-site on those days). When students were on-site, they would follow a similar schedule to the full on-site schedule. On the days when students were not attending on-site school (referred to as “off-site” days), they stayed home and completed distance learning work per directions or pre-recorded lessons posted onto a virtual classroom. Teachers were then available in the afternoons

for an optional “office hour” video call with students at home when the on-site students were out of the room for specials. Since Wednesdays were reserved as teacher prep days, students followed the same routine as their other “off-site” days, with the addition of a mandatory virtual morning class meeting to connect with each other and discuss important topics.

The pattern of learning models experienced by our school throughout the 2020-2021 school year ended up being hybrid learning, distance learning, hybrid learning again, and then full on-site learning. Whenever a shift occurred, our school had two or three “no learning” days in which students did not have to complete any school work, for the purpose of allowing staff to make preparations for the upcoming learning model. Since state guidelines were released during the winter that limited the amount of students who could fully return on-site at one time, our E2 students shifted between each learning model at a slightly different time than the other grade levels in the school (see Table 3 for an overview of the E2 learning models throughout the year). Our 7-8th grade program (referred to as “ErdKinder” in the Montessori community) remained in distance learning throughout the school year, until a February shift to hybrid learning and finally an April shift to full on-site learning.

Table 3

Overview of the E2 Learning Models Experienced during the 2020-2021 COVID School Year

Months of the School Year	Learning Model Experienced by E2 Students
September-November	Hybrid Learning
December-beginning of January	Distance Learning
Middle of January-middle of February	Hybrid Learning
End of February-June	Full On-Site Learning

Procedure

As mentioned in my Introduction, this study did not take the shape that I originally envisioned it would. Many factors were different from the original vision due to ever-changing COVID-19 procedures and restrictions. My priority was to follow these procedures and restrictions to keep the children safe and make the study accessible to families during an already-challenging school year. Additionally, while having the privilege to work in a Montessori school where we have more freedom to meet the individual needs of children, I still am held accountable by the structure that I must respond to in my public setting. Students take state tests at the end of each year as accountability measures; they are tested three times each year using a screening program; and the results of these tests impact our school and myself as an educator. Whether or not I care for these tests, my students must take them (at least at this point in time), and I am held accountable for the results. Fluency of math facts plays an important role in a student's success on such assessments. I must respond to these structures as a public school teacher. I must also respond to the structures that I am accountable to as a student—for example, I must create a final research study to complete my Montessori graduate program, regardless of the pandemic and less-than-ideal circumstances. It is my responsibility to take into consideration the factors that I cannot control and then, considering what I can control, create the best math facts research study that I can create at this time.

One of the beautiful features of Montessori education is that it does not fit a cookie-cutter model. The Montessori method was designed to meet the developmental needs of the child and was designed to be flexible in order to meet such individual needs. If the method is flexible, then I argue that I can propose a research study implementing certain Montessori features yet looking different from the traditional perspective of Montessori education, in order to meet the needs

of students in the current learning context (the COVID-19 pandemic and distance/hybrid learning models). The practical purpose of an action research study is to ask, “Based on existing research and considering possible risks, if I try *this*, will it have a positive impact on *my* students?” If it does not have a positive impact, then I have helpful data and conclusions to show that it didn’t work, and I will continue to change my approach to find how I can help the children learn better in the future. I wrestled with the final design of this study and acknowledge that it is not what I (or many other Montessori educators) would have chosen in a different context. In light of this, I explore what the study could look like in the future in my Follow Up Considerations section.

My study was specifically and carefully designed to be research-based while still meeting the needs of students and families during a challenging school year. To shape my study, I referenced research from several different sources that included participants who are fourth through sixth grade students. Many studies implemented short, daily practice sessions and results showed improvements from this repetition (Berrett & Carter, 2017; Plass et al., 2013; Schutte et al., 2015; Woudstra, 2017). The length of studies also varied from six weeks to one single session (Plass et al., 2013; Poncy et al., 2010; Schutte et al., 2015; Woudstra, 2017). Therefore, I chose to host daily and concurrent practice sessions that lasted 10-15 minutes over the course of six weeks, with the pre-assessment also occurring the Friday before practice sessions began (technically resulting in a study that involved seven weeks total).

Additionally, several of my sources showed evidence that computer-assisted instruction (CAI) is an effective tool to use for improving math fact fluency (also referred to as computer-based instruction [CBI]). Berrett & Carter’s study (2017) implemented the Timez Attack computer program. Plass et al. (2013) hosted an after-school study that used a game called

FactorReactor and had students play the game on Xbox consoles. Woudstra (2017) employed the use of the free *XtraMath* internet-based program with the students in her study. All of these sources showed growth that was related to the use of CAI.

Inspired by this research, I chose to use a variety of Computer-Based Instruction (CBI) programs with which the students would practice. Poncy et al.'s study (2010) supports the use of rotating intervention programs to address student preferences, engagement, and varying skills. After perusing several online resources that the students could practice with throughout the study, I narrowed it down to the *XtraMath* program, multiplication flashcards on *FactMonster.com*, and games found on *Multiplication.com*. These three varying programs all offered students immediate feedback on their answers and allowed students to engage with math facts in three very different manners. For example, *XtraMath* focuses on a variety of math facts 1-9. *FactMonster.com* has seven different levels of math fact flashcards, so we focused on the first three levels. These levels included: Level 1, which focused on multiplying numbers 1-4 by numbers 1-4; Level 2, which focused on multiplying numbers 1-4 by numbers 1-9 (an emphasis on lower number math facts), and Level 3, which focused on multiplying numbers 1-9 by numbers 1-9 (an emphasis on higher number math facts). See Table 4 for a breakdown of each of the levels on *FactMonster.com*. Finally, the *Multiplication.com* games provided ways for the students to practice math facts in an engaging manner with a greater purpose than simple repetition (Berrett & Carter, 2017; Plass et al., 2013). Our daily practice sessions occurred at the same time each day and families were instructed not to use these programs outside of our practice sessions for the duration of the study (Berrett & Carter, 2017), for the sake of protecting the validity of the research results. Practice sessions did not occur on no-school days or transition days for changing models.

Table 4*FactMonster.com Multiplication Flashcard Levels*

Level Name	Focus of Level
Level 1	Numbers 1-4 x Numbers 1-4
Level 2	Numbers 1-4 x Numbers 1-9 (emphasis on lower number facts)
Level 3	Numbers 1-4 x Numbers 1-9 (emphasis on higher number facts)

In my Literature Review, I discussed Constructive Theory and how it relates to math fact fluency. Constructivism refers to learning that occurs by building upon one's previous experiences. While math facts are often memorized through rote memorization (often "learned" via rote memorization), there are many other ways for students to engage with math facts, and this can be done through Constructivist strategies. For example, if a child is struggling to learn their 8's math facts but already knows their 4's facts, the child can multiply each 4's fact by 2—bonus points if the child uses Montessori bead bars to make this connection and find the answer! Ideally, after continued practice, the child would start to become more fluent in their math facts, in the sense of being able to recall the answer more quickly than having to follow a process to find the answer. Eventually, habitual practice leads to memorization. Consider the variety of ways that children are taught reading. While we want our students to be able to deconstruct words, know the meaning of words in a context, and use spelling rules to figure out which letters to use, we also want children to simply recognize as many words as possible to make reading easier for them. Therefore, we have students practice sight words in a variety of ways. If we want children to have greater automaticity with their sight words (which benefit their

reading abilities), why wouldn't we want the same for them regarding their math facts (which benefit their mathematical abilities)? I argue that after sufficient *learning* opportunities are provided, there is a point that *automaticity* of math facts is the most beneficial for a child.

Due to the complicated and unexpected nature of the changing learning modes to accommodate safety measure for COVID-19, this study was intentionally designed to be simple and to require the least amount of work for families while students were participating at home, while still meeting accountability measures to ensure the accuracy of the study's results. My study ended up occurring during hybrid and full on-site learning models. When students were on-site in either model, they used our classroom computers to access the websites. In order to accommodate for the hybrid model, participating students were to video call into the classroom, so the students on-site and off-site could all practice at the same time. On the one day of the week that all students were distance learning, the time remained the same and all participating students joined a video call. The student who was enrolled in distance learning for the entirety of the study joined all practice sessions via the daily video call. See Table 5 for an outline of my final research design.

Table 5*Final Research Design*

Number of Participants	15
Grade Level(s) of Participants	4-6th
Length of Study	7 weeks
Frequency of Practice Sessions	Daily
Length of Practice Sessions	10-15 min
Resources Used for Practice Sessions	XtraMath, FactMonster, and Multiplication.com Games
Quantitative Data	1-min. Math Facts Assessment (number correct out of 100)
Qualitative Data	Confidence Survey (Final Survey includes preferred website)
Frequency of Assessment and Survey	Weekly
Distance Learner Accommodations	Attend all practice sessions virtually

Quantitative Data Collection

In my Literature Review, I discussed the relationship between math anxiety and timed tests. We recall that a time limit on providing math fact answers can lead to stress, interfering with a child's ability to remember or find the correct answer regardless of mathematical ability. Many educators argue that number sense, or being able to work with numbers flexibly, is more important than memorizing math facts. Learning math facts instead of memorizing them is key, and this is consistent with Constructivist Theory and Montessori pedagogical practices.

As I was creating and transforming this study throughout the ever-changing COVID-19 learning setting, I was faced with another predicament: I needed a simple quantitative data tool to gather information about my students' ability to give the correct answer to a math fact answer, in a reasonable amount of time. Considering my students are upper elementary (4-6th grade) and

eventually need to simply know their facts, was it appropriate to use timed tests in some capacity? Not to use them as a learning tool (that's what the daily practice sessions were for), but if I used timed tests as a once-per-week, low-pressure tool and provided my students with emotional support during the process, would it reduce the risk of math anxiety and provide the data I needed to gather? Taking into consideration all of the factors discussed, I decided to try it.

Amazingly, I did find several sources that support the practice of regularly administering one-minute paper assessments (including pre- and post-assessments) to determine student growth, so I chose to administer such assessments before my study began and then at the end of each week of the study, resulting in seven assessments total (Berrett & Carter, 2017; McTiernan et al., 2016; Schutte et al., 2015; Woudstra, 2017). These one-minute paper assessments had 100 math facts on them and were created using an online resource (Berrett & Carter [2017] implemented such online-created resources in their study), which were then administered and graded by me. I graded how many math facts students answered correctly in one minute, and then I recorded these on a spreadsheet that I kept online (Appendices E-K for the Weekly Assessments and Appendix L for the assessment raw data). Each participating student was assigned a random number 1-16 before the study began, so I recorded their data next to their corresponding number on my spreadsheet. The student who chose not to complete the study was assigned #2, so that number does not appear in my data.

The manner in which I applied timed tests in my classroom for this study was done in a way that considers the very real needs of the students regarding timed tests, while also assessing the children in some capacity. To address the research, concerns around timed testing, and the possibility of anxiety, I was very purposeful with the language I used with the children. Before beginning our tests each week, I tried to put the students at ease by saying something to the

effect of, “I do NOT expect you to complete all 100 of these math facts in one minute. We are going to see how many you can do correctly. No pressure! Just do your best at a comfortable pace. Each week we will take a timed test and see if you can get more facts done each time.” I assured the children that their results did not determine whether they are “good” or “bad” at math and would not affect their progress reports. Additionally, immediately before starting our test each week I would remind the children to take a deep breath. We did this breath as a whole group together each week, and as the weeks went on, I noticed more children taking initiative by sitting up straight and taking breaths on their own before beginning the test. We practice mindful breathing in our room every day, so it was encouraging to see them apply it to these timed tests.

Qualitative Data Collection

My process for collecting qualitative data was very similar to that of quantitative data. I created a survey that I administered to the students every week immediately before they completed their weekly assessment (seven surveys total). The survey was identical for the first six weeks and asked one question: “How confident do you feel about your multiplication math facts?” Beneath the question were four possible responses that students could circle, accompanied by an emoji that expresses the emotion they may feel in that confidence level. I corresponded each response with a number so I could record it next to the student’s assigned number in my online spreadsheet. The seventh and final survey was two-sided, with the original survey on the front and an extra question on the back asking students to circle their favorite website that they used during the study. The answers for the second question on this final survey were also corresponded to a number, for the purpose of recording the students’ preferences (Appendices C & D for the Weekly and Final Surveys).

Data Results & Analysis

Quantitative Results

The following data represent the quantitative results gathered about student math fact fluency throughout my research study. These results were gathered from the weekly one-minute, 100-math-fact assessments administered on Fridays (Appendices E-K for Weekly Assessments). Knowing the research around timed testing that I referred to earlier (Boaler, 2014; Boaler et al., 2015; Geist, 2010), timed testing can certainly cause anxiety and also affect the final scores of the timed tests. Therefore, I sought to alleviate their fears by reminding them of my realistic expectations, including: going at a comfortable pace during the test; selecting which problems they want to complete in whichever order they prefer; and remembering that the test is to see where they are at now so we can see how much they get better at their math facts over time. The tests are *not* used to decide if the students are “good” or “bad” at math, and I assured the children that the results of these timed tests would have no effect on their progress reports. Right before they took their test each week, I also told them to “take a breath”, which helps oxygen get to the brain, calming the mind and body. There were times I could visibly see some of my students relax after taking a breath. This was the goal—to help the children relax while taking these timed tests so they could be as successful as possible on them. With this context in mind, I will discuss the number of correct facts per minute that students scored on their weekly assessments, compare pre- and post-assessment scores, and analyze percentage growths made by individuals and grade levels. Some of the students surprised me by showing excitement about completing the weekly assessment, and they were enthusiastic about seeing how many math facts per minute they could complete as compared to the previous week.

Student Correct-Facts-per-Minute Scores

Each of the 15 participating students completed a one-minute, 100-fact paper assessment at the end of each week to measure what growth, if any, was occurring from our daily, 10-minute practice sessions. Figure 1 shows the results of the pre- and post-assessments in terms of math facts answered correctly per minute (Appendix L for raw weekly assessment results). Each student was assigned a number, and the student assigned to the number 2 withdrew from the study partway through. Of the 15 students who completed my study, 11 students showed growth and two students showed regression. The final two students have missing data. Student 3 did not complete the pre-assessment and Student 5 did not complete the post-assessment. These two students' scores were not included in the group analyses found below, but both students' weekly scores demonstrated growth. Student 3 got a score of 30 in Week 2 and a score of 43 in Week 7. Student 5 got a score of 13 in Week 1 and a score of 27 in Week 5 (the final assessment they completed—see Table 6 for these students' raw assessment data). This results in a final count of 13 student scores.

Figure 1

Individual Pre-Assessment and Post-Assessment Scores after the seven-week study

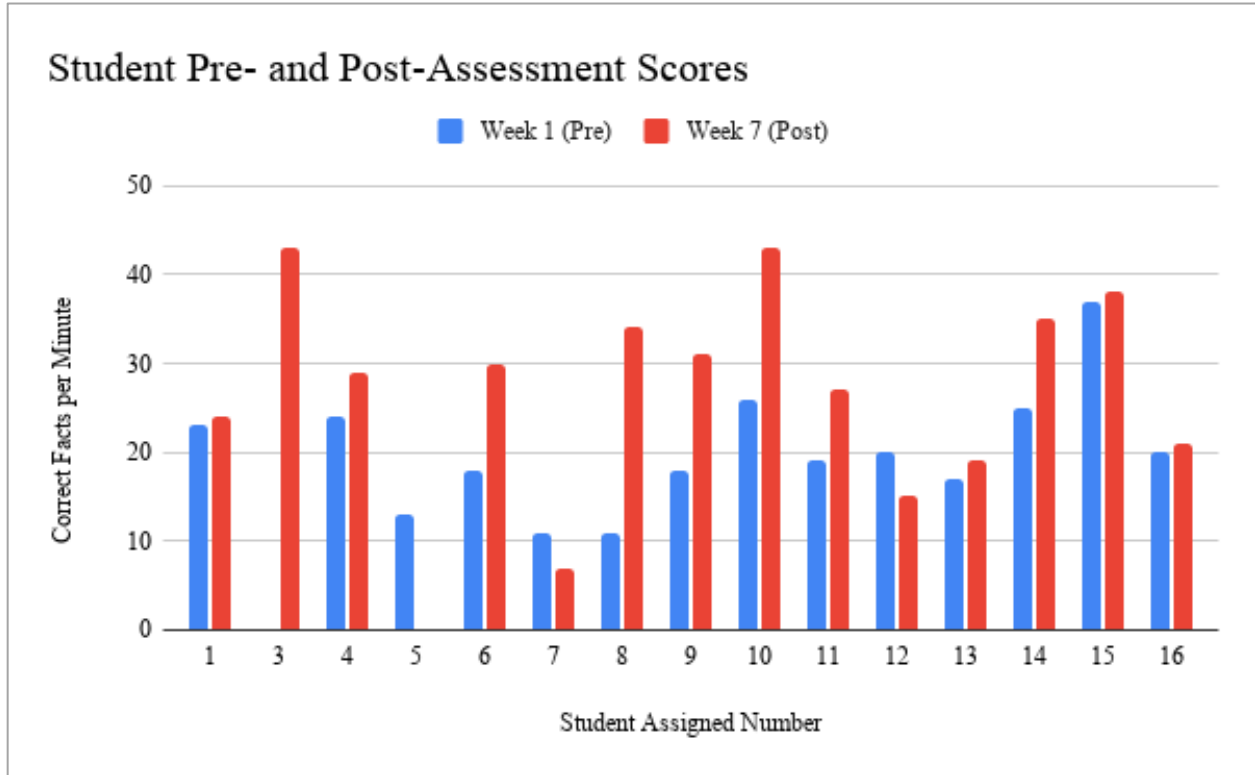


Table 6

Raw Assessment Scores for Students 3 & 5 (both have missing data from pre- or post-assessments)

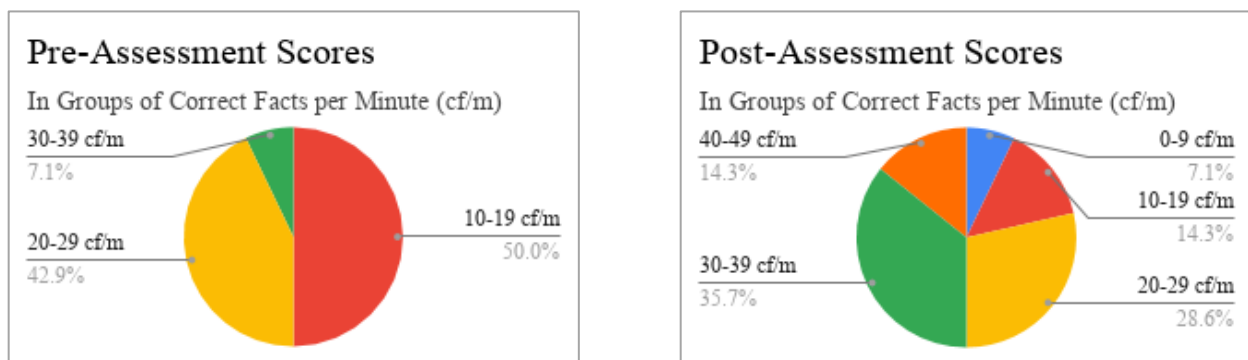
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Student 3	/	30	27	33	40	36	43
Student 5	13	22	/	31	27	/	/

As I observed the scores from the pre- and post-assessments, I noticed all of them scored between 0 and 50 correct math facts per minute out of 100 total math facts. I also noticed trends,

such as several scores being between 10-19 correct math facts per minute in the pre-assessment, or many more scores being between 30-39 correct math facts per minute in the post-assessment. Thus, I organized the scores into five different 10-point groups: 0-9, 10-19, 20-29, 30-39, and 40-49. Organizing the data in these groupings within a pie chart allowed me to have a birds-eye view of the general trends that showed up in the pre- and post-assessment scores. Figures 2 and 3 represent the percentage that each 10-point grouping made up of the participating students.

Figures 2 & 3

Groups of Pre-Assessment and Post-Assessment Scores



In the pre-assessments, all of the students scored between 10 and 39 correct facts per minute, so the 0-9 and 40-49 groups do not appear in Figure 2. In the post-assessment, scores varied further in both directions, thus entering the 0-9 range and the 40-49 range. In the post-assessment, 7.1% of the class scored 0-9, and 14.3% of the class scored 40-49. The 10-19 range decreased from 50.0% to 14.3% of the group; the 20-29 range decreased from 42.9% to 28.6%; and the 30-39 range increased from 7.1% to 35.7%. See Table 7 for the number and percent of scores that fall into each range.

Table 7

Number and Percent of Scores in Each 10-Point Grouping Range in Correct Facts/Minute (cf/m)

Ranges of Scores	Number (#) of Pre-Assessment Scores in Each Range	Percent (%) of Pre-Assessment Scores in Each Range	Number (#) of Post-Assessment Scores in Each Range	Percent (%) of Post-Assessment Scores in Each Range
0-9 cf/m	0	0%	1	7.1%
10-19 cf/m	7	50%	2	14.3%
20-29 cf/m	6	42.9%	4	28.6%
30-39 cf/m	1	7.1%	5	35.7%
40-49 cf/m	0	0%	2	14.3%

Student Percentage Growths

The following figures observe the percentage of growth that each student demonstrated in their weekly assessments throughout the study. The percentage growth was calculated by subtracting each student's pre-assessment score from their post-assessment score, and then dividing that difference by the student's pre-assessment score. As noted in the Qualitative Results section, specifically in Figures 7 & 8, the students felt increasingly confident throughout the study and this was reflected in most of their percentage growths.

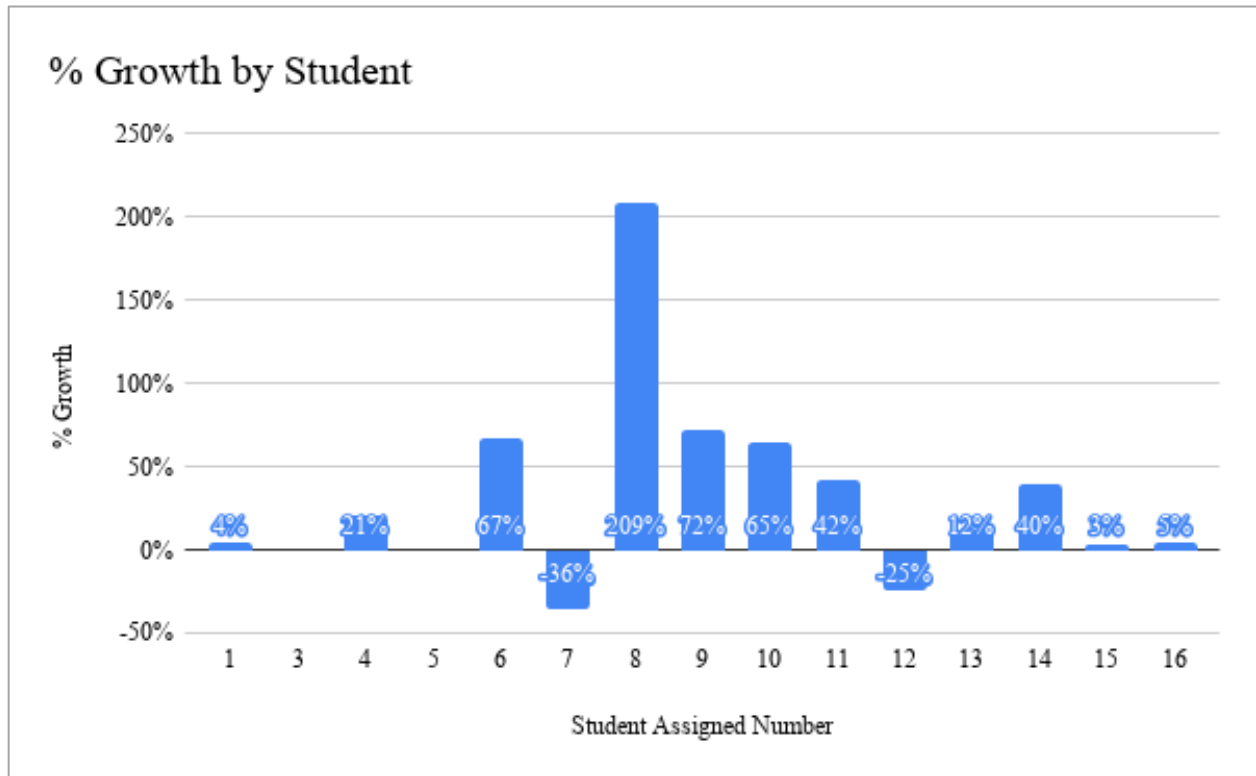
Figure 4*Individual Student Percentage Growths*

Figure 4 represents the percentage growth made by each student in the class. As clearly demonstrated again by this figure, two students made regressions and the other 11 students made growth. This figure makes the extreme growths apparent, such as one student's growth of 209% and another student's regression of -36%. There is one other regression (-25%), and the other ten students made positive growths ranging from 3% to 72%.

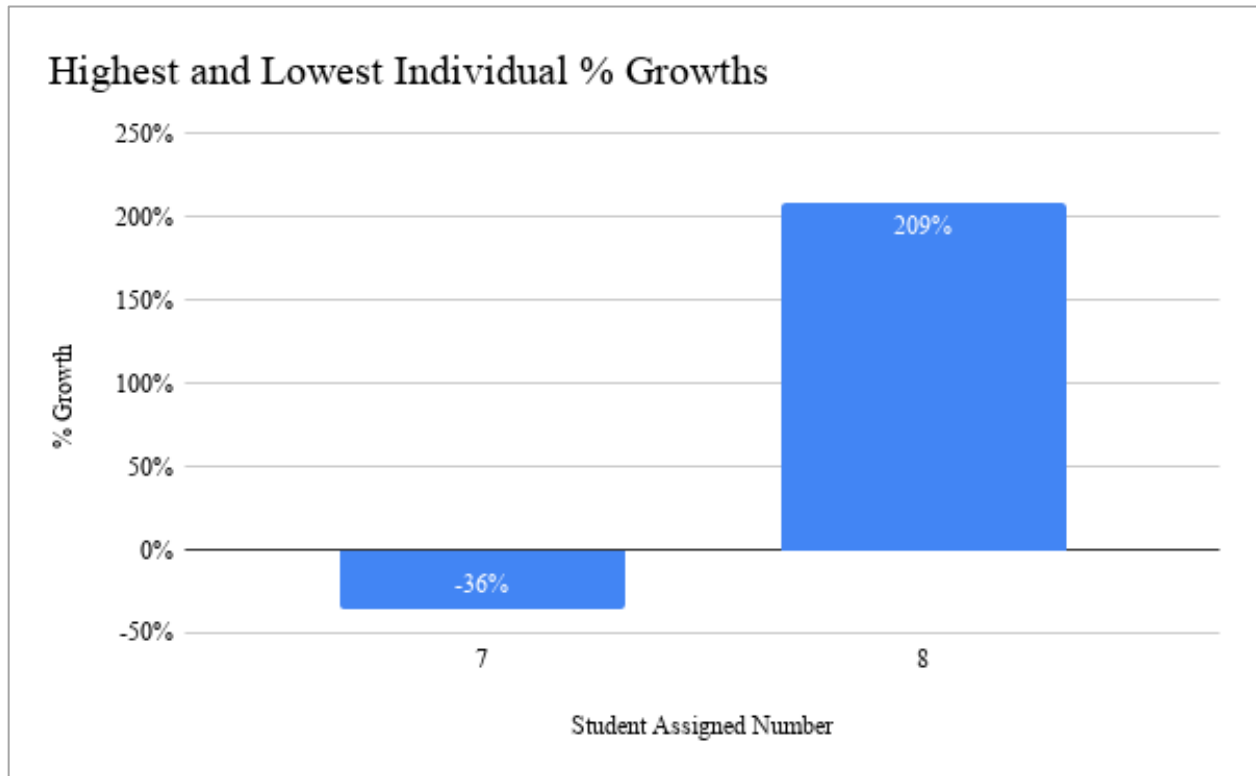
Figure 5*Highest and Lowest Individual Percentage Growths*

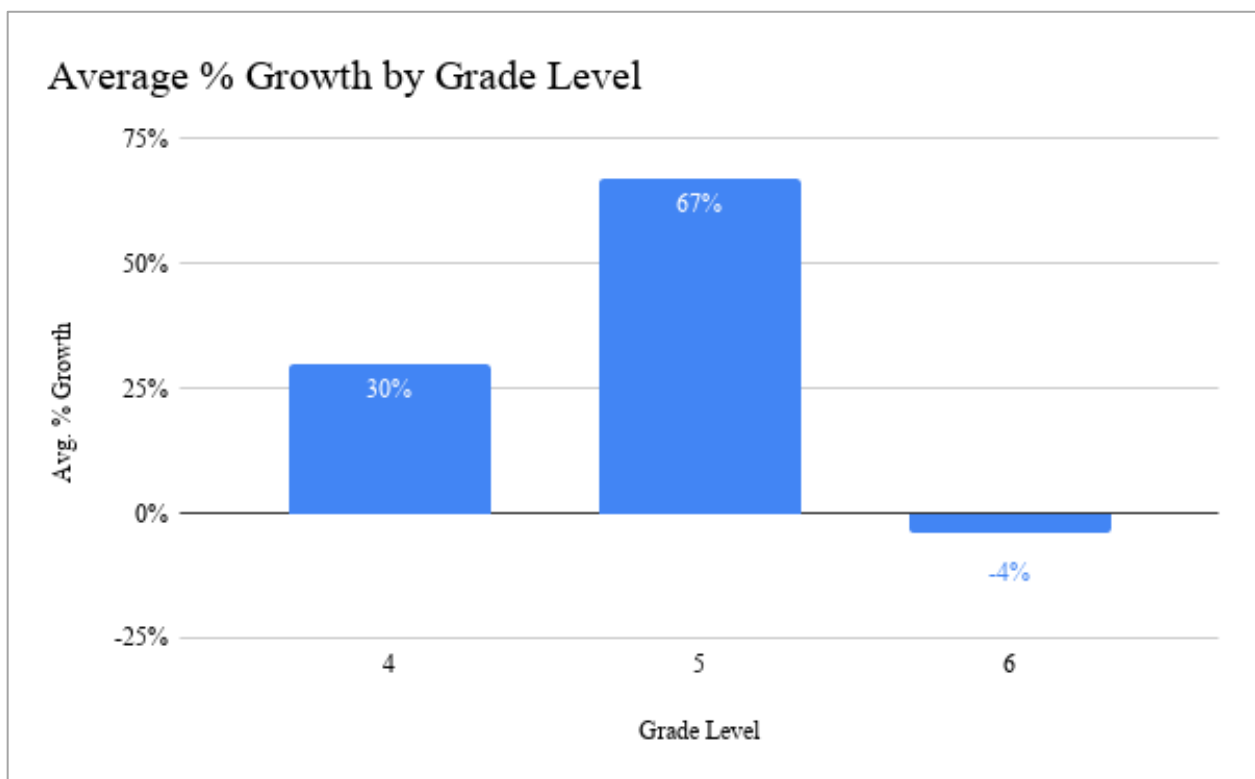
Figure 5 magnifies the growth rates to compare the highest and lowest percentages. Again, the highest percentage growth was 209%, and the lowest percentage growth (regression) was -36%. This figure represents the wide range of progress that the students made throughout the study. Interestingly, I know these students well and the regression in particular stands out to me. Student 7's results were not at all what I expected, especially considering that I know this child enjoys math and is generally successful. This student may be an example of a method that simply did not work for them; something for me to note. Student 8's results were exciting and encouraging to see—this student generally does not show very much confidence in math, and they showed the most growth! This may be an example of a method that worked well for them. However, this is one child who has exhibited some anxiety around math, so I would still be

cautious with the implementation of timed tests with this child in the future, if I were to implement them again.

Below, Figure 6 demonstrates the average percentage growth made by each grade level. Fourth grade is represented by the left bar and sixth grade is represented by the right bar. The fifth graders showed the highest average percentage of growth (67%) and the sixth graders showed the lowest average percentage of growth (-4%).

Figure 6

Average Percentage Growths by Grade Level



Qualitative Results

While multiplication math fact fluency is incredibly important, the students' confidence in their ability to accurately calculate these math facts is equally important. The following

figures examine the results of Week 1 and Week 7's surveys. Figures 9 & 10, the final figures in the Qualitative Results section, also denote the preferred practice website that students indicated on their Week 7 surveys (Appendices M & N for raw weekly survey results). As mentioned in the Quantitative Results section, many students showed increased confidence in their surveys. Regardless of the amount of correct facts per minute that each student completed on the weekly assessments, it is extremely important to me that the students in my class feel that they can succeed with math fact fluency and therefore have increased confidence in their math skills.

It was enjoyable to see the children's confidence visibly increase each week when we took the surveys and assessments. Each time that we were about to take the weekly assessment, I reviewed my expectations with them and reminded them to take a breath. Toward the end of the study, there was a lighter chatter in the room among the students as I passed out the assessments, and I watched some of the children sit up straight and take a deep, slow breath as I had taught them. To see them using the strategies I taught them for managing any possible test anxiety, and to hear their excitement about trying to get a better score each week, was a sweet and encouraging reminder that they were a group of children simply practicing their math facts.

Student Confidence Levels

Figures 7 & 8 compare the percent of how many students indicated which confidence level in Weeks 1 and 7. Figure 7 shows the confidence levels that students reported in their Week 1 Survey (before taking any assessments or participating in any practice sessions). There were four different confidence levels (each associated with a numerical value) indicated on each week's survey that the child would choose to reflect their current confidence level in their math facts (Appendix C & Pg. 1 of Appendix D for Weekly Surveys):

- “1. I’m lost.”;
- “2. I’m not feeling very confident...”;
- “3. I feel good!”; and
- “4. I’ve totally got this!”

The same two students who did not complete the pre- and post-assessments did not complete the pre- and post-surveys as well (Student 3 did not complete the pre-survey and Student 5 did not complete the post-survey). Student 3 answered all 3’s and 3.5’s for the rest of their surveys (Weeks 2-7; a score of “3.5” meant that the student wrote the number “3.5” on their paper between the “I feel good!” section and the “I’ve totally got this!” section). Student 5 answered 3, 2, 3, and 3 for their surveys (Weeks 1-4). Therefore, these two students’ scores are not included in Figures 8 or 9 (see Table 8 for these students’ raw survey data). For the remaining 13 students, 0 of the students answered “I feel lost”. The largest portion of the group answered “I feel good!” (six students—46.2%); the next largest portion answered “I’m not feeling very confident...” (four students—30.8%); and the smallest portion represented in this figure answered “I’ve totally got this!” (three students—23.1%).

Table 8

Raw Survey Scores for Students 3 & 5 (both have missing data from pre- or post-assessments)

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Student 3	/	3	3	3	3.5	3.5	3
Student 5	3	2	3	3	/	/	/

Figures 7 & 8

Student Confidence Levels Reported in Week 1 and in Week 7

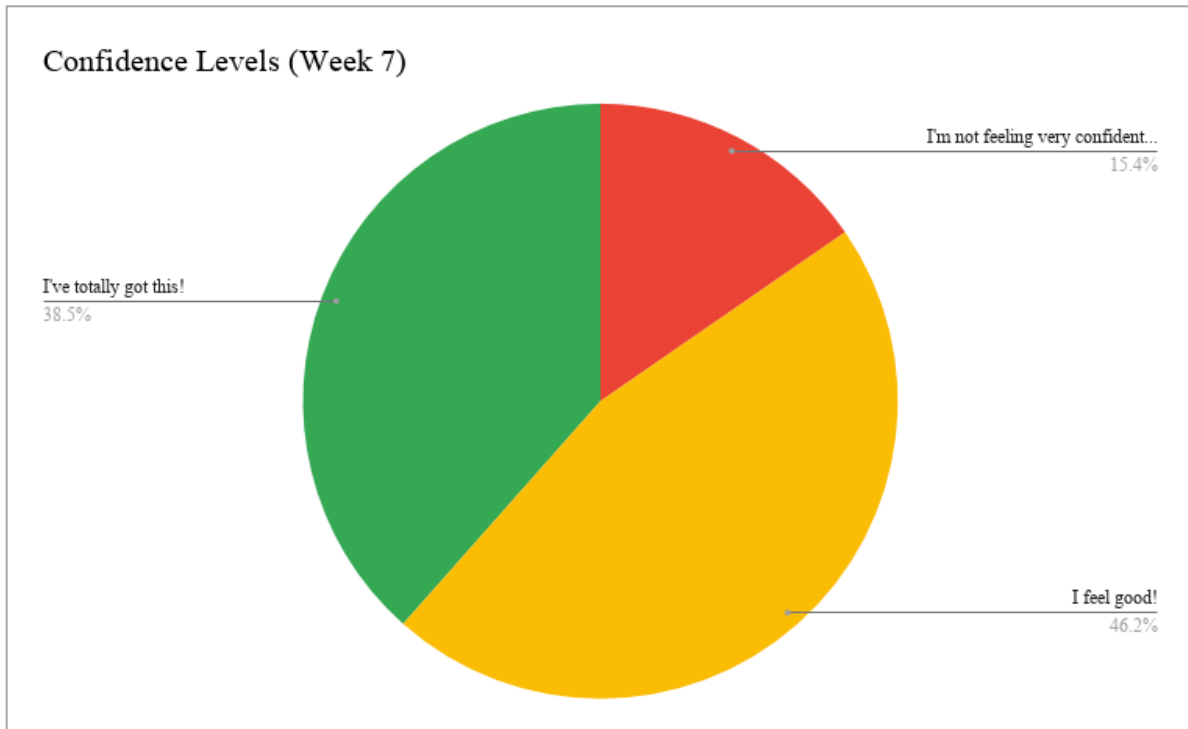
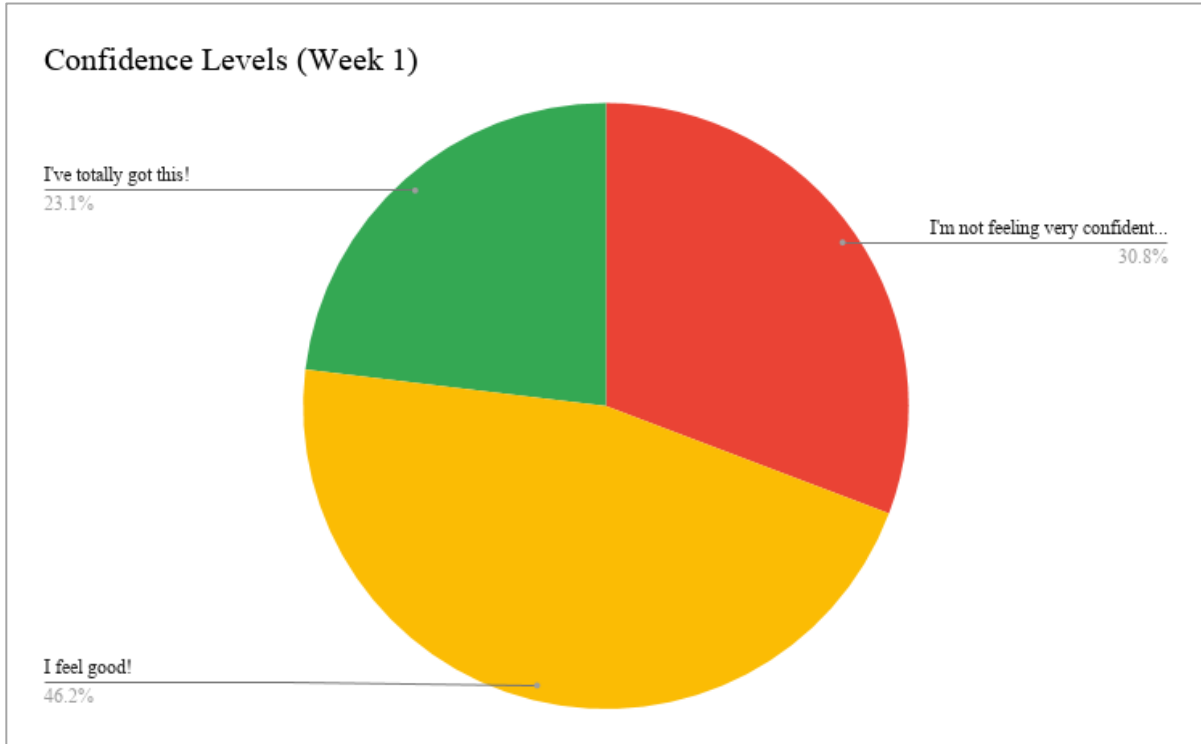


Figure 8 shows the confidence levels that students reported in their Week 7 Survey (without participating in a practice session and before taking the post-assessment). Once again, out of 13 students, 0 answered “I feel lost”. The answer that was most given remained “I feel good!” (six students—46.2%), though some of the students who gave this response changed. The next most common response was “I’ve totally got this!” (five students—38.5%), and the least common response represented on this figure was “I’m not feeling very confident...” (two students—15.4%). See Table 9 for the number and percent of responses for each confidence level indicated on the pre- and post-surveys.

Table 9

Number and Percent of Responses in Each Confidence Level (not including Students 3 & 5)

Confidence Levels	Number (#) of Pre-Survey Responses in Each Level	Percent (%) of Pre-Survey Responses in Each Level	Number (#) of Post-Survey Responses in Each Level	Percent (%) of Post-Survey Responses in Each Level
1. I’m lost.	0	0%	0	0%
2. I’m not feeling very confident...	4	30.8%	2	15.4%
3. I feel good!	6	46.2%	6	46.2%
4. I’ve totally got this!	3	23.1%	5	38.5%

Student Website Preferences

Finally, Figures 9 & 10 examine the websites that the students indicated they preferred on their Week 7 Surveys. Figure 9 looks at how many students preferred each website and Figure 10 looks at the percentage of the class that preferred each website.

Figure 9

Websites Most Preferred by Students by the end of the study

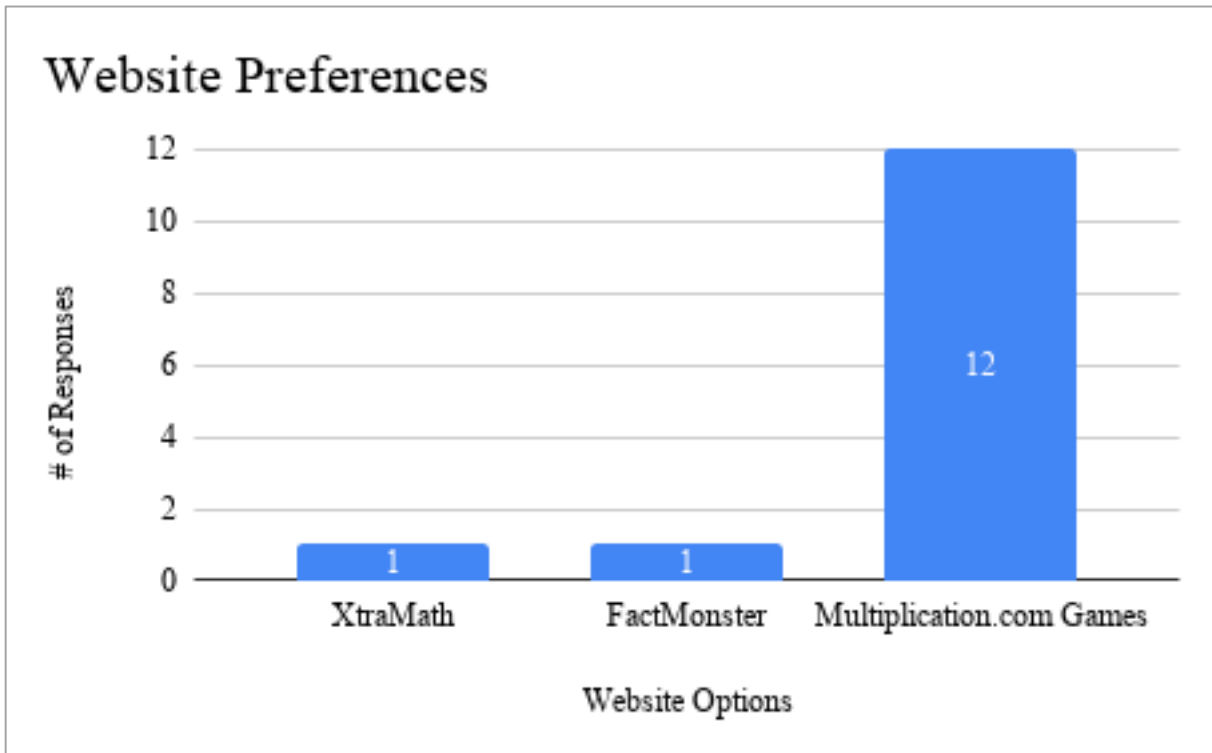
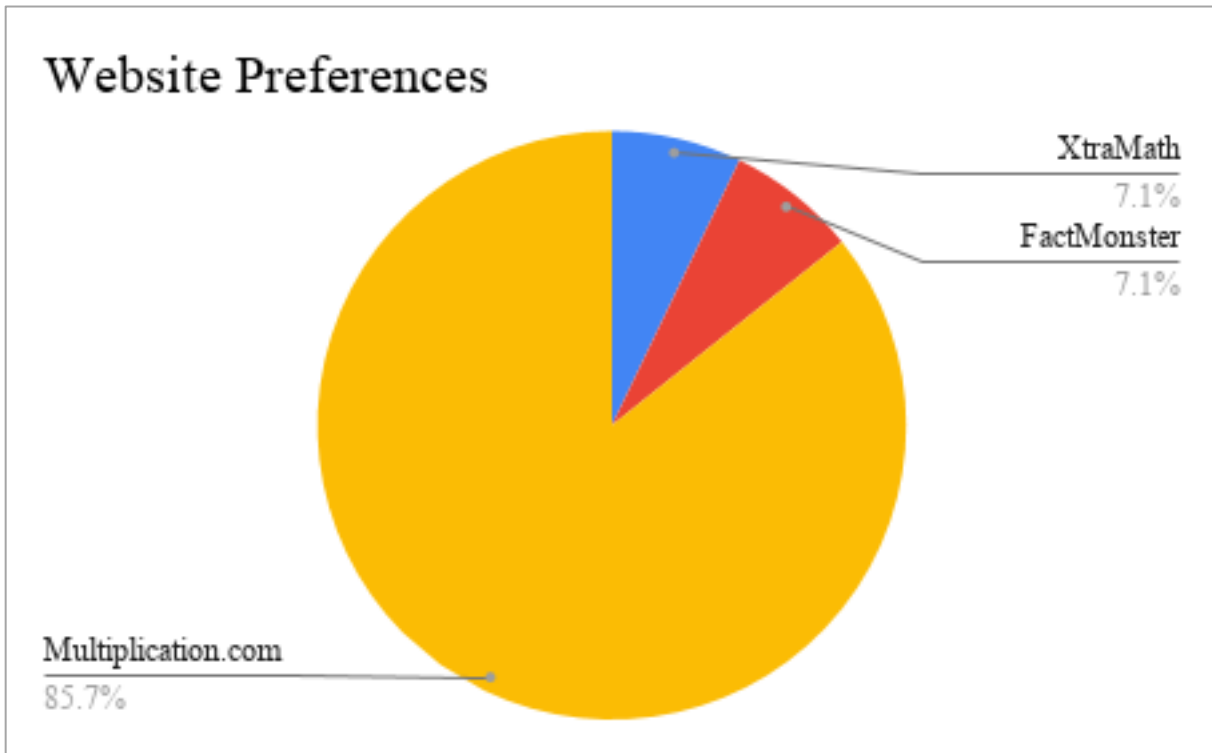


Figure 9 represents the number of students who preferred each of the three websites used during the study practice sessions. Since the post-survey response for this question did not have a corresponding pre-survey response and Student 5 did complete the Week 7 survey, I included their preference in this figure. One student preferred XtraMath and one other student preferred FactMonster; all of the 12 other students preferred the games on Multiplication.com games. Figure 10 shows the percentage comparisons represented by the difference preferences. In observing the figure below, 85.7% of the students preferred the games on Multiplication.com.

Figure 10

Percentages of Websites Most Preferred by Students by the end of the study



Conclusion of Research

To conclude the findings of my research project, most students demonstrated improvement in their math fact fluency and their confidence levels toward math facts. After a seven-week study that included six weeks of brief, daily practice sessions, students showed an average post-assessment score of 28 correct facts per minute and an average percentage growth of 36.8%. Therefore, certain math fact websites can be a good resource to use to improve student math fact fluency, even if used briefly each day for six weeks. The three different resources gave children a selection to choose from for further independent practice, but Multiplication.com was the most preferred resource by a large margin.

Additionally, my students show more confidence throughout the day and during lessons as math facts arise. With all but two students indicating that they at least feel “good” about their math facts confidence, the atmosphere is energized with assurance and certainty that they are capable of being successful with their math facts. Some students have mentioned that they are remembering facts quicker, and occasionally I see a student choose to use their optional computer time to practice their facts on Multiplication.com. Now that we have been more aware of math facts practice in the room, some students are even pulling out more of the Montessori materials on their own, such as the bead chains.

Follow Up Considerations

This study took place during the COVID school year of 2020-2021 and schools were transitioning between full on-site, hybrid, and distance learning. While I made every effort to reduce the additional requirements for participation in this study, it was inevitable to have some added responsibility for participating families and students. Since families were already having to manage large amounts of paperwork, schedules, and video calls, the additional work for participating in this study may have caused some families to choose not to participate, resulting in smaller amounts of data. Additionally, the safety requirements and changing modes of learning forced me to simplify the use of practice materials to online resources only, as discussed earlier in my paper. Finally, the stressors of the COVID school year and the lack of routine at certain points of the school year (and particularly the study) may have affected the students’ math fact fluency, growth, and confidence levels.

In addition to the above considerations, several questions arose while I was carrying out the study and reflecting on its results. I have very few answers, if any, but posing these questions help me contemplate various aspects of my study, what I could possibly do differently in the

future, and what could possibly be changed to prevent certain situations from occurring in the first place. To start, I learned to clarify “math fact fluency” as being able to efficiently get the math fact answer instead of unintentionally limiting it to the idea of automatically knowing the answer. If my students struggle to develop automaticity with their math facts, I want them to be fluent with various strategies for finding these facts. It can be argued that being able to explain how to get the math fact answer is more important than the actual answer, an idea consistent with the Montessori philosophy of “process over product.” However, it can also be argued that math is worthless if one is not eventually and fluently able to get the correct math fact answer. If the process is habitually correct, then with practice, the correct math fact should be the result of it. Could both the process and the correct math fact answer be equally as important?

Various questions arose regarding how the activities and assessments could look in the future (which is also discussed in the *Furthering the Study* section below). First of all, the most preferred resource by far was *Multiplication.com Games*, many of which provided immediate feedback—the website also had a variety of fun and engaging games. What could this tell me about how my students like to practice their math facts? Considering that all of my resources included immediate feedback, it likely wasn’t that feature. The games had fantastic, video-game-like components that likely reminded my students of the games they play at home with friends. Since the games are somewhat familiar in that manner, it makes sense that they would be the most preferred option over the drill-like feel of *XtraMath* or *FactMonster*. The game setup might also reduce any stress the students may have felt during the straightforward practice formats of *XtraMath* and *FactMonster*. This leads me to wonder how I can make games in my classroom that are similar to those found on *Multiplication.com*. Regarding the weekly assessments in my

study and the reality of state tests and regular screening tests, I wonder if there is a way to accurately assess student math fact fluency without incurring anxiety.

I also wonder about upper elementary children not knowing their math facts in the first place and the effects of the learning models produced during the COVID-19 pandemic. How do I service students who have been home for an entire year? I am not only considering my current students, but also those who will be in my class in the future. Additionally, what are the best methods for supporting 5th and 6th graders who still don't know their math facts? Whether one is looking at the Montessori curriculum, the Minnesota State Standards, or the Common Core State Standards, children are expected to know their math facts fluently (meaning that they have easy access to the right answer) by the time they are in 5th grade. The practice of these facts begins in the early years of education, and the upper elementary years require fluency so students can exert their mental energy on complex math practices. How are students motivated to learn their math facts, and what can be done to prevent needing to do such an intensive study with all of my students in the future? Ideally, the students coming into my class in 4th grade would be relatively fluent with their math facts so they are prepared to work at a more complex level and transition into more interest-driven, real-life applications.

This leads into my next set of ponderings, with some considerations for the younger levels. It is my pleasure to serve my students according to their diverse academic abilities; however, are there practices that can be done in the younger levels to develop such an important skill before coming to 4th grade? There are several materials in Children's House and lower elementary classrooms that are specifically designed for memorizing math facts, including the finger charts, strip board, multiplication board, and various games. Additionally, the Montessori method traditionally teaches multiplication before subtraction. There is certainly value in this

process, for example, by teaching multiplication as repeated addition. However, I wonder if this is truly the best method for teaching math facts, especially when fact families are considered. Are we doing a disservice to our students by not teaching addition/subtraction and multiplication/division fact families? One example that comes to mind is when I teach my 6th graders addition and subtraction of integers: it is clear that they don't know their fact families when they learn addition and subtraction of integers, and this knowledge would be tremendously useful!

A final thought in regards to becoming more fluent with math facts in the younger years relates to language development. Around the age of five years old, children consciously acquire new vocabulary and memorize effortlessly words and numbers. For example, it is common for a six-year-old to be able to list 10 different types of dinosaurs without knowing any in-depth information about each dinosaur. The young child is capable of vast memorization. I would like to see this potential taken advantage of for memorizing math facts.

Furthering the Study

I have several considerations for how this study could be continued and expanded in the future. As discussed earlier, this study originated with the idea of using any materials possible to practice math facts, whether that included websites, Montessori classroom materials, other physical resources, or any other variety of practice tools and strategies. The goal was for every participating child to find at least one resource that they enjoyed using to practice their math facts. This is very much a Montessori approach—follow the child's interests and preferences to help them accomplish the goal at hand. Some of the resources that could be included in a future study are the bead bars, the bead chains, the multiplication boards, the stamp game, and even the peg board, amongst many others that can be varied to fit the needs of multiplication math fact

practice. Factor charts and blank multiplication charts can be printed off and set on shelves, along with paper times tables. Even blank white boards with dry-erase markers can be used to practice basic math facts.

Additionally, students could work with each other to challenge each other, support each other, complete a work together, and create games out of math facts. In the study completed by Plass et al. (2013), there were no major differences between collaborative, competitive, or individual practice done by the students, so students could potentially use each other as resources without it negatively affecting their skills. Whole-group practice games could even be offered. As always, students would have the freedom to choose which kind of practice (individual, collaborative, or competitive) they would like to engage in each day.

I wondered in my Follow Up Considerations section how else I could assess my students' math fact fluency without implementing the traditional one-minute timed tests, which tend to lead to anxious thoughts and feelings. A very simple adjustment that could potentially reduce anxiety would be to shift the mindset from the amount of correct facts the children can get per minute to the amount of time it takes them to complete 100 math facts. This way, they can more easily go at their own pace, but there is still a measure of how efficiently they can access the answer to each math fact problem. Beyond simple math fact practice, students could also be given the results of their weekly test scores, including how quickly they completed the 100 facts and how many of those facts were accurate. This could easily lead into several other math lessons, such as various types of graphs, converting units of measure (for example, minutes to seconds), percents, and even ratios (correct facts per minute compared to number of seconds it took to complete the assessment).

As I strongly iterated in my Introduction and reinforced throughout my paper, this study was designed to meet COVID-19 restrictions and distance/hybrid learning circumstances. Taking the study in the current setting, these are a few examples of how I would change or expand the study. As I finish writing this research paper, I am enjoying the benefits of COVID-19 parameters being loosened and am watching the world around me continue its slow but certain recovery from the pandemic. Therefore, I look forward to the opportunity to implement many of the considerations listed above to find the best ways for my students to practice their math facts, in order to support their success in mathematics, both in the coming year and far into their futures.

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Appendix A

IRB Approval Document

Date: 1-5-2021

IRB #: IRB-FY2020-237
Title: O'Connell Improving Math Fact Fluency using Online Resources in a Virtual Upper Elementary Montessori Classroom
Creation Date: 12-6-2020
End Date:
Status: Approved
Principal Investigator: Kateri Carver
Review Board: UW Institutional Review Board
Sponsor:

Study History


Submission Type	Initial	Review Type	Exempt	Decision	Exempt
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Key Study Contacts

Member Kateri Carver	Role Principal Investigator	Contact kateri.carver@uwrf.edu
Member Amy O'Connell	Role Primary Contact	Contact Amy.o'connell@my.uwrf.edu

Appendix B

Parent Informed Consent Form, Pg. 1

 <p>UNIVERSITY OF WISCONSIN River Falls GLOBAL. INNOVATIVE. EXCELLENT.</p>		
<p>Informed Consent for Research Participation</p>		
<p>IRB # <u>IRB-FY2020-237</u></p>		<p>IRB Approval Date <u>01-05-2021</u></p>
<p>Study Title: Improving Math Fact Fluency using Online Resources in a Virtual Upper Elementary Montessori Classroom</p>		
Researcher Names	Department	Contact Information
Amy O'Connell	TED	Amy.oconnell@my.uwrf.edu
<p>I am asking you to participate in my research study. Participation is voluntary and you may request that your child stop participating in the study at any time. If you choose not to participate or stop participating, there will be no negative consequences to you or your child. Participating will not change anything about your relationship with the researcher. Participating or not participating will not change any services you receive from Ms. Amy O'Connell.</p>		
<p><u>Overview of the Research</u></p>		
<p>Purpose of the Study</p>	<p>My goal is to study the improvement of multiplication math fact fluency in my classroom using online resources daily. Primary Question: What improvement in student math fact fluency is made after daily practice of math facts in a virtual upper elementary Montessori classroom setting? Secondary Question: What online tools for practicing math facts are most preferred by students in an upper elementary Montessori classroom?</p>	
<p>What my child will be asked to do</p>	<p>Participants are going to be asked to:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Do a pre-assessment. <input type="checkbox"/> Do math fact practice online with provided websites each school day for about 10 minutes during a synchronously scheduled time. <input type="checkbox"/> Do a one-question weekly survey about their confidence in their math facts. <input type="checkbox"/> Return their documents weekly. <input type="checkbox"/> Do a post-assessment and two-question final survey. 	
<p>Amount of time it will take your child to participate</p>	<ul style="list-style-type: none"> <input type="checkbox"/> Daily synchronous 10-minute practice (approximate) <input type="checkbox"/> Weekly 1-minute survey and 1-minute assessment during lessons 	
<p>Risks to you if you choose to have your child to participate</p>	<p>The risks for this study are minimal:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Timed assessments and/or timed practice tools may trigger anxiety for some participants. <input type="checkbox"/> Participants who have low math fact fluency may experience diminished confidence. <input type="checkbox"/> Files and data will be kept in a password-protected online database that is accessible to our Head of School or Assistant Head of School under extreme circumstances. <input type="checkbox"/> During a distance learning model, packets with confidential study information (i.e. timed test scores and surveys) could potentially be accessed by other staff members or an intruder under very unlikely circumstances. 	
<p>What we will do to reduce the risks?</p>	<ul style="list-style-type: none"> <input type="checkbox"/> Students will be told that their test scores and surveys related to this study will have no bearing on their progress reports and that I am the 	

Parent Informed Consent Form, Pg. 2

	<p>only person who will know how each of them did on their practice sessions and tests.</p> <ul style="list-style-type: none"> <input type="checkbox"/> The online database is only accessible by me except under extreme circumstances. <input type="checkbox"/> I will be the only individual handling the outgoing or returning packets.
Benefits to you, your child, or others if you choose to have your child participate	<p>Potential Benefits:</p> <ul style="list-style-type: none"> <input type="checkbox"/> Participants will likely improve their math fact fluency. <input type="checkbox"/> Improved math fact fluency may increase a participant's confidence in math and their abilities to solve more complex math problems. <input type="checkbox"/> Participants will have access to a variety of free online resources that they will become very familiar with for regularly practicing their math facts.
Compensation	<p>Your child will not be compensated for participating in this study. However, I will host a one-time virtual celebration for children who choose to participate in the study. We will have a math facts competition and the top 3 winners will have a new book of their choice ordered for them.</p>
If I don't want my child to participate in the study are there other options for my child to get these services?	<p>If your child chooses not to participate in the study, they are still welcome and encouraged to practice math facts regularly, whether using online resources or other methods.</p>
<u>Confidentiality and Data Protection</u>	
Who will see my child's answers/information?	<p>Non-identifying information will be compiled and presented in my Master's paper that will be kept in the archives of UW-River Falls. Depending on the outcome, it is possible that this data may be used in a conference presentation or a published paper. However, there will be no identifying student information shared in these contexts.</p>
Where will my child's answers/information be stored?	<p>At the end of the study, all of the paper documents will be shredded. The non-identifying data in any electronic files will be kept in a password-protected online area.</p>
How will my child's answers/information be protected?	<p>Your child will receive a random number from 1-24. This number will be pre-written on your child's assessments and surveys so that their name will not be written on their forms. In their weekly packet, your child will receive their assessment and survey for that week inside of a white sealable envelope with my name on it. When your child has completed their assessment and survey for that week, they will place those materials back into the white sealable envelope, seal it, and return it inside of their weekly packet to me.</p>
Mandated Reporting Requirements	<p>We are mandated reporters and if we suspect a child or vulnerable adult is being abused or neglected, we are required by law to report this information to local child protection or adult protection agencies or to the police.</p>
<u>Protection of Human Research Subjects</u>	
If I have questions about this research I should contact:	<p>Kateri Carver: kateri.carver@uwrf.edu</p>
If I have questions or want to complain about my rights or how my child was treated as a research participant I should contact:	<p>Institutional Review Board Chair University of Wisconsin River Falls 410 S. Third St. River Falls, WI 54022 715-425-0629 irb@uwrf.edu</p>

Parent Informed Consent Form, Pg. 3

Signatures:

_____ I **agree** to have my child to participate in this study and understand I may remove my child from the study at any time.

_____ I **do not agree** to have my child to participate in this study.

*

Printed Name of Participant

If participant is a minor or requires a Legally Authorized Representative:

*

Printed Name of Parent, Guardian or Legally Authorized Representative

*

Signature of Parent, Guardian or Legally Authorized Representative

Date

Appendix C

Weekly Survey (Weeks 1-6)

Amy O'Connell
IRB #IRB-FY2020-237
O'Connell.Instrument.1.Survey.Weekly
Student Code: 1

Weekly Survey

How confident do you feel about your multiplication math facts? (circle one)

1. I'm lost.



2. I'm not feeling very confident....



3. I feel good!



4. I've totally got this!



Appendix D

Final Survey (Week 7), Pg. 1

Amy O'Connell
IRB #IRB-FY2020-237
O'Connell.Instrument.2.Survey.Final
Student Code: 1

End Survey

How confident do you feel about your multiplication math facts? (circle one)

1. I'm lost.



2. I'm not feeling very confident....



3. I feel good!



4. I've totally got this!



Final Survey (Week 7), Pg. 2

Amy O'Connell
IRB #IRB-FY2020-237
O'Connell.Instrument.2.Survey.Final
Student Code: 1

Circle the name of your favorite program to use:

1. XtraMath



2. FactMonster



3. Multiplication.com Games





Appendix E

Week 1 Assessment

Name :	Amy O'Connell IBB #IBB-FY2020-237	Score :	
Teacher :	O'Connell.Instrument.3.Assessment.Weekly.1 Student Code: 5	Date :	

1 Minute Drill

$\begin{array}{r} 7 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 1 \\ \hline \end{array}$
$\begin{array}{r} 2 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 4 \\ \hline \end{array}$
$\begin{array}{r} 7 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 1 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 2 \\ \hline \end{array}$
$\begin{array}{r} 8 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 8 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 2 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 7 \\ \hline \end{array}$
$\begin{array}{r} 9 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 6 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 4 \\ \hline \end{array}$



Appendix F

Week 2 Assessment

Name :	Amy O'Connell IRB #IRB-FY2020-237 O'Connell.Instrument.3.Assessment.Weekly.2	Score :	<u> </u>
Teacher :	Student Code: 1	Date :	<u> </u>

1 Minute Drill

$\begin{array}{r} 10 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 4 \\ \hline \end{array}$
$\begin{array}{r} 2 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 8 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 1 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 6 \\ \hline \end{array}$
$\begin{array}{r} 3 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$
$\begin{array}{r} 6 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 1 \\ \hline \end{array}$
$\begin{array}{r} 4 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 7 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 10 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 9 \\ \hline \end{array}$
$\begin{array}{r} 3 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 3 \\ \hline \end{array}$



Appendix G

Week 3 Assessment

Name :	Amy O'Connell IRB #IRB-FY2020-237 O'Connell.Instrument.3.Assessment.Weekly.3	Score :	<u> </u>
Teacher :	Student Code: 7	Date :	<u> </u>

1 Minute Drill

$\begin{array}{r} 4 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 4 \\ \hline \end{array}$
$\begin{array}{r} 4 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 6 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 2 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 6 \\ \hline \end{array}$
$\begin{array}{r} 9 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 5 \\ \hline \end{array}$
$\begin{array}{r} 8 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 2 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$
$\begin{array}{r} 4 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 6 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 2 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 1 \\ \hline \end{array}$



Appendix H

Week 4 Assessment

Name :	Amy O'Connell <u>IRB #IRB-FY2020-237</u>	Score :	<u> </u>
Teacher :	O'Connell.Instrument.3.Assessment.Weekly.4 <u>Student Code: 1</u>	Date :	<u> </u>

1 Minute Drill

$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 5 \\ \hline \end{array}$
$\begin{array}{r} 7 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 9 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 8 \\ \hline \end{array}$
$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 2 \\ \hline \end{array}$
$\begin{array}{r} 9 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 6 \\ \hline \end{array}$
$\begin{array}{r} 6 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 6 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 4 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$
$\begin{array}{r} 7 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 1 \\ \hline \end{array}$
$\begin{array}{r} 9 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 4 \\ \hline \end{array}$



Appendix I

Week 5 Assessment

Name :	Amy O'Connell IRB #IRB-FY2020-237	Score :	<u> </u>
Teacher :	O'Connell.Instrument.3.Assessment.Weekly.5 Student Code: 10	Date :	<u> </u>

1 Minute Drill

$\begin{array}{r} 7 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 8 \\ \hline \end{array}$
$\begin{array}{r} 3 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 10 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 2 \\ \hline \end{array}$
$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 5 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 5 \\ \hline \end{array}$
$\begin{array}{r} 9 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 9 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 1 \\ \hline \end{array}$
$\begin{array}{r} 8 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 2 \\ \hline \end{array}$
$\begin{array}{r} 7 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 9 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 5 \\ \hline \end{array}$



Appendix J

Week 6 Assessment

Name :	Amy O'Connell IRB #IRB-FY2020-237	Score :	<u> </u>
	O'Connell.Instrument.3.Assessment.Weekly.6		
Teacher :	Student Code: 5	Date :	<u> </u>

1 Minute Drill

$\begin{array}{r} 7 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 10 \\ \hline \end{array}$
$\begin{array}{r} 7 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 6 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 4 \\ \hline \end{array}$
$\begin{array}{r} 7 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 9 \\ \hline \end{array}$
$\begin{array}{r} 10 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 2 \\ \hline \end{array}$
$\begin{array}{r} 4 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 10 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 6 \\ \hline \end{array}$
$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 10 \\ \hline \end{array}$
$\begin{array}{r} 10 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 4 \\ \hline \end{array}$



Appendix K

Week 7 Assessment

Name :	Amy O'Connell IRB #IRB-FY2020-237 O'Connell.Instrument.3.Assessment.Weekly.7	Score :	<u> </u>
Teacher :	Student Code: 5	Date :	<u> </u>

1 Minute Drill

$\begin{array}{r} 10 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 6 \\ \hline \end{array}$
$\begin{array}{r} 6 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 8 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 10 \\ \hline \end{array}$
$\begin{array}{r} 4 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 5 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 5 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 1 \\ \hline \end{array}$
$\begin{array}{r} 2 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 4 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 5 \\ \hline \end{array}$
$\begin{array}{r} 9 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 9 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 9 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 3 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 6 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 6 \\ \hline \end{array}$	$\begin{array}{r} 2 \\ \times 2 \\ \hline \end{array}$	$\begin{array}{r} 8 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 10 \\ \times 3 \\ \hline \end{array}$
$\begin{array}{r} 1 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 9 \\ \times 1 \\ \hline \end{array}$	$\begin{array}{r} 7 \\ \times 10 \\ \hline \end{array}$	$\begin{array}{r} 1 \\ \times 7 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 5 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 4 \\ \hline \end{array}$	$\begin{array}{r} 3 \\ \times 8 \\ \hline \end{array}$	$\begin{array}{r} 5 \\ \times 8 \\ \hline \end{array}$

Appendix L*Raw Data for Weekly Assessments*

	Week 1 (Pre)	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7 (Post)
1	23	30	37	/	22	30	24
3	/	30	27	33	40	36	43
4	24	27	22	19	27	26	29
5	13	22	/	31	27	/	/
6	18	24	14	23	29	33	30
7	11	/	9	5	/	13	7
8	11	26	/	21	30	35	34
9	18	26	23	28	35	35	31
10	26	36	/	37	28	36	43
11	19	31	50	28	/	29	27
12	20	19	17	21	24	24	15
13	17	11	20	5	10	25	19
14	25	30	25	34	28	40	35
15	37	38	50	36	40	40	38
16	20	20	30	18	13	24	21

Appendix M*Raw Data for Weekly Surveys*

	Week 1 (Pre)	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7 (Question #1)
1	2	2	3	/	3	3	3
3	/	3	3	3	3.5	3.5	3
4	4	3	3	3	3	3	3
5	3	2	3	3	/	/	/
6	2	2	2	3	2	3	2
7	3	/	3	3	/	3	3
8	3	3	/	2.5	2.5	3	4
9	3	2	3	3	2	2	3
10	2	3	3	3	/	3	3
11	4	3	3	4	/	3	4
12	3	3	3	3	3	3	4
13	2	2	2	2	2	2	2
14	3	3	3	3	3	3	4
15	3	3	2	3	2.5	3	3
16	4	4	4	4	4	4	4

Appendix N*Raw Data for Question 2 on Final Survey (Website Preference)*

	Week 7 (Question #2) Numerical Answer	Week 7 (Question #2) Website Name Answer
1	3	Multiplication.com Games
3	3	Multiplication.com Games
4	3	Multiplication.com Games
5	/	/
6	3	Multiplication.com Games
7	1	XtraMath
8	2	FactMonster
9	3	Multiplication.com Games
10	3	Multiplication.com Games
11	3	Multiplication.com Games
12	3	Multiplication.com Games
13	3	Multiplication.com Games
14	3	Multiplication.com Games
15	3	Multiplication.com Games
16	3	Multiplication.com Games