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Math Fact Fluency Assessments and their Impact on Math Anxiety

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Abstract

This action research study investigated the impact math fact fluency assessments have on math anxiety in a central Iowa elementary school. The participants were 15 fourth-grade students who experienced different treatments for a duration of eight weeks. There were five students in each of the control, experimental, and mixed-strategy groups. The control group was given timed tests twice per week, the experimental group participated in one math fact interview per week, and the mixed-strategy group were given both a timed test and a math fact interview once per week. A math anxiety survey was administered before and after treatment, and the differences of math anxiety scores were compared within each group and between groups. The findings of this research showed significance in the differences of scores in the experimental group. No significance was found within either the control or mixed-strategy group. There was also no significance found between the control, experimental, and mixed-strategy groups.

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Math Fact Fluency Assessments and their Impact on Math Anxiety

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Abstract

This action research study investigated the impact math fact fluency assessments have on math anxiety in a central Iowa elementary school. The participants were 15 fourth-grade students who experienced different treatments for a duration of eight weeks. There were five students in each of the control, experimental, and mixed-strategy groups. The control group was given timed tests twice per week, the experimental group participated in one math fact interview per week, and the mixed-strategy group were given both a timed test and a math fact interview once per week. A math anxiety survey was administered before and after treatment, and the differences of math anxiety scores were compared within each group and between groups. The findings of this research showed significance in the differences of scores in the experimental group. No significance was found within either the control or mixed-strategy group. There was also no significance found between the control, experimental, and mixed-strategy groups.

Keywords: Math anxiety, timed testing, math fact interviews, math fact assessments, math fact fluency

Many students across the United States and the world experience math anxiety. According to Boaler (2012), math anxiety affects about 50 percent of the US population, and it affects more women than men. The Organization for Economic Co-operation and Development (OECD, 2013), specifically from their PISA 2012 report, found the following among 15-16-year old's from across the world:

> 59% of students reported that they often worry that it will be difficult for them in mathematics classes; 33% reported that they get very tense when they have to do mathematics homework; 31% that they get very nervous doing mathematics problems; 30% that they feel helpless when doing a mathematics problem, and 61% that they worry about getting poor grades in mathematics. (p. 100)

Math anxiety is a problem for many and teachers are needing to find ways to alleviate it. Math anxiety not only affects students when they are in elementary, middle, and high school, but it prevents students from taking courses in mathematics in college. Those affected by math anxiety are also less likely to take careers in mathematics. Math anxious people avoid mathematics (Ashcraft, 2002; Ramirez et al., 2013; & Scarpello, 2007).

It is important for students to develop math fact fluency. Math fact fluency is a foundational part of mathematics learning. Being fluent in math facts also can provide an easier path for students moving forward in more difficult mathematics courses. Thinking flexibly about numbers while also having automaticity is a stepping stone for students in mathematics (Bay-Williams, Kling, 2014; Bay-Williams, Kling, 2019; Boaler, 2014).

Measuring students' math fact fluency is highly important for both students, teachers, and parents as these assessment measures not only give a clear picture as to where students are at in their math fact fluency, but they also provide data and information for self-reflection and

continued growth in fact fluency. The most popularly used assessment to measure math fact fluency is timed testing (Boaler, 2012). Timed testing is an efficient way to measure math fact fluency, and it gives quick results. While timed testing is frequently used, research literature shows that it is connected to increased math anxiety among students (Beilock, 2008; Geist, 2010). Geist (2010) found, "the early use of high stress techniques like timed tests instead of more developmentally appropriate and interactive approaches lead to a high incidence of math anxiety" (p. 28).

If timed testing can increase higher incidences of math anxiety, other assessment measures should be considered when assessing math fact fluency. Bay-Williams and Kling (2014, 2019) present other alternatives for assessing math fact fluency, including math fact interviews. Math fact interviews can provide greater information on students' fluency levels (Bay-Williams, Kling 2014, 2019), but it is not yet clear if this kind of assessment invokes math anxiety in ways that timed testing does.

Purpose of the Study

The purpose of this study is to describe the levels of math anxiety in timed math fact testing versus math fact interviews among elementary students.

Research Questions

The following research questions will guide this study:

1. Do timed tests increase math anxiety among elementary students?
2. Do timed tests decrease math anxiety among elementary students?
3. Do math fact interviews increase math anxiety among elementary students?
4. Do math fact interviews decrease math anxiety among elementary students?

Definition of Terms

For the purpose of this study, the following definitions will be used. Unless otherwise noted, the definitions are those of the author.

Math anxiety- "A feeling of tension, apprehension, or fear that interferes with math performance" (Ashcraft, 2002, p. 181).

Math fact fluency- "...the ability to apply procedures accurately, efficiently, and flexibly; to transfer procedures to different problems and contexts; to build or modify procedures from other procedures; and to recognize when one strategy or procedure is more appropriate to apply than another" (NCTM, 2014, n.p.).

Math fact interviews- An untimed assessment tool used to measure math fact fluency. The interview occurs in a one-on-one setting with a student. The student solves a set of math fact problems while the teacher annotates. The teacher may ask, "How did you figure it out?"

Timed tests- An assessment tool used to measure efficiency and accuracy of math facts. Consists of multiple math fact problems. Students are expected to solve as many problems as they can within a time constraint.

Working memory- "consists of temporary memory stores with associated mechanisms for rehearsing stored information and a mechanism of central or executive attention that regulates the contents of the active portion of memory" (Engle, 2002, p. 19).

Literature Review

Math Fact Fluency

The National Council of Teachers of Mathematics published a position on math fact fluency in 2014. They noted:

> Procedural fluency is the ability to apply procedures accurately, efficiently, and flexibly; to transfer procedures to different problems and contexts; to build or modify procedures from other procedures; and to recognize when one strategy or procedure is more appropriate to apply than another. (n.p.)

Bay-Williams and Kling (2014, 2019) describe math fact fluency as having four major components: accuracy, efficiency, appropriate strategy use, and flexibility. Procedural fluency involves the learning of multiple procedures, not just one. Bay-Williams and Kling (2019) mentioned, "Strategy selection, adaptation, and transference are critical to both procedural fluency and mathematical proficiency and must be a significant part of students' experiences with the operations right from the beginning, with learning basic facts" (p. 3). Math fact fluency requires higher-order thinking as students think flexibly and choose appropriate strategies, along with accuracy and efficiency.

Developing fact mastery is an important part in a student's foundational math learning experience (Bay-Williams & Kling, 2019). Fact mastery has been historically developed through many different methods including flash cards, timed tests, games, online tools, repetition, and the teaching of multiple strategies. Research studies have pushed many towards thinking that strategy-focused instruction is the best way to encourage and develop math fact fluency (Bay-Williams & Kling, 2019; Boaler, 2014; Henry & Brown, 2008; Woodward, 2006). Bay-Williams and Kling (2019) stated that "activities and assessments traditionally associated with learning basic facts (such as drill, flash cards, and timed testing) exclusively focus on students' accuracy and part of efficiency (speed), neglecting strategy development" (p. 4).

Bay-Williams and Kling (2019) believe that instead, substantial and enjoyable practice in math facts is needed to develop mastery. They have presented multiple formative assessment

tools that assess students' math fact fluency other than timed testing. Math fact interviews, math fact running records, use of observation, untimed math fact quizzes, and journal prompts are all valid ways of collecting data on students' math fact fluency. For example, when conducting math fact interviews with 38 beginning first-graders, Bay-Williams and Kling (2014) found that the children's self-reported strategies aligned with what the interviewer was able to observe 97 percent of the time. Ashlock (2006) calls interviewing an effective way of collecting information about a student's mathematical abilities. Further, he mentioned, "They are a way to gain both quantitative and qualitative data about an individual" (Ashlock, 2006, p. 23). The emphasis is moving towards assessments that measure strategy-use and flexibility, rather than solely memorization and speed.

Boaler (2014) emphasizes the development of number sense as a means of developing automaticity with math facts. She defines number sense as "the ability to work flexibly with numbers, decomposing and regrouping them with confidence" (p. 471). Boaler (2014) believes that this development of number sense can be done through an increased use of number talks, a pedagogical tool that increases the strategies used to solve basic procedural math problems while also encouraging mental math. When Boaler (2014) used number talks with struggling seventh and eighth grade students, the students reported that the number talks "completely changed their views of math" (p. 472).

However, the most popular tool for assessing math fact fluency in the United States is timed testing (Boaler, 2012). Many school districts require timed testing as a measure of math fact fluency at least once per term, but many teachers often use them weekly as an assessment tool. The frequent use of timed testing has caused many children to believe that mathematics is a performance subject and that memorizing math facts is the most important part of math (Boaler,

2014). Boaler (2014) noted, “Students also suffer from one of the most damaging myths that pervades U.S. math classrooms: the belief that good math performance is fast math performance” (p. 471). Many schools require timed testing because that is the way it has always been done, and “they simply do not know how else to assess fact mastery” (Bay-Williams, Kling, 2019, p. 10).

While some researchers believe timed testing should be eliminated as an assessment tool, others believe it is still a valid way of increasing fact fluency. Woodward (2006) in his research tested 58 fourth-grade students in their multiplication facts. For one group, the teacher only used timed testing for their students’ development of facts. The other group used an integrated approach of both timed testing and strategy-focused instruction. The findings found an increase in the mean for both groups in the pretest to post-test scores. However, Woodward (2006) found that Cohen's d analyses favored the integrated approach group in the development of automaticity in multiplication facts. Woodward noted that if fact development was solely for the purpose of developing the foundation for traditional algorithms, then timed testing could strictly be used. Because there is an increased emphasis on number sense development in order to estimate or use more mental math, strategy-focused instruction along with timed test drills is the best approach for students to succeed in both number sense and traditional algorithms.

In contrast, Henry and Brown (2008) conducted research on the memorization of facts at the first-grade level. In their study across nine different elementary schools in California, they found that increased use of timed tests negatively predicted the memorization of basic math facts. They found the following:

> Teachers reported frequent use of worksheets, flash cards and timed tests, focusing variously on memorization, derived-fact strategies, and accuracy with counting. It seems that many of the participating teachers held a belief that repetition using counting would

> eventually lead to derived-fact strategies and memorization. This belief was not supported by student achievement findings. In fact, none of these three ubiquitous practice activities was found to provide a substantial contribution to memorization or fluency with the facts. Perhaps the most startling finding for teachers is that frequent use of timed tests seemed to actually work against student memorization and Basic Facts Competence. (p.178)

Rather, Henry and Brown (2008) suggest use of derived-fact strategies along with retrieval from long-term memory.

Math Anxiety

Math anxiety is unsurprisingly connected to lower performance in school. Beilock and Willingham (2014) found, "Students with a high degree of math anxiety perform worse in math from elementary school through college, relative to their less math-anxious counterparts" (p. 29). Ashcraft (2002), in his studies found that math anxious people avoid math, take fewer math courses, receive lower grades in math, espouse negative attitudes towards math, and have negative self-perceptions about their own math ability. However, Ashcraft (2002) concluded that math anxiety is weakly related to overall intelligence. A meta-analysis on mathematics anxiety was conducted by Hembree (1990) and included 151 studies. When finding any correlations between mathematics anxiety and IQ among the studies included, he found there was only a small correlation between math anxiety and overall intelligence (-0.17).

Math anxiety is also becoming more evident in younger and younger children. Ramirez et al. (2013) conducted a study with 154 first and second graders. The participants were given a measure of math achievement and working memory, and then a few days later were given a measure of math anxiety. The researchers found that first and second graders experienced levels

of math anxiety. However, math anxiety did not correlate with grade level, reading level, or parental income. They did find that there was a negative relationship between math anxiety and math achievement when the students had higher working memory. Ramirez et al (2013) hypothesized that students with higher working memory "are most impacted by math anxiety because worries about the situation deplete or interfere with the cognitive resources that support their math performance" (p. 194).

Math anxiety can prompt students with higher working memory to do two things at once: solve their math problem and deal with their worries about math. Because of this, they have less working memory to devote to their math problems because the anxiety blocks the working memory (Beilock & Willingham, 2014). Ashcraft (2002) also found this to be true when testing participants with math anxiety and the ability to solve one- and two-column addition tasks, half involving carrying. Students with higher levels of math anxiety made more mistakes in their addition with higher-load conditions than students with lower levels of math anxiety. However, when there were lower-load conditions, the same number of mistakes were made for both groups of low and high anxiety levels. Ashcraft also found that there are small gender differences in levels of math anxiety. Higher levels of math anxiety are found in women, rather than men (Ashcraft, 2002).

Timed Testing and Math Anxiety

Boaler (2014) asked teachers of second and fourth grade students to write reflections after taking timed math fact tests. One-quarter of each class shared feelings of anxiety after taking the tests. The anxiety did not correlate with test success as some of the high scoring students had the highest levels of anxiety. Students used words such as "pressured" and "nervous." Other students felt "mad" and "terrible at math." Boaler (2014) wrote, "Some

students cope with the pressure created by timed tests, but for a significant number of high and low achievers, timed tests create fear, stress, and anxiety" (p. 470).

Research completed by Beilock (2008) found that the mathematical performance of students who have higher working memory will decrease in stressful situations. Beilock and her colleagues in their initial study were able to create a high-stakes testing environment in their laboratory and tested different groups according to low- or high-pressure environments along with low or high working memory problems. Their research found that performance decreased when individuals solved the higher working memory problems in a high-pressure situation. Later, they did a study that identified individuals as lower or higher in working memory. Interestingly, Beilock found that individuals in higher working memory outperformed those with lower working memory when the pressure was low. However, when the pressure of the situation increased, those with higher working memory underperformed the lower working memory group (Beilock, 2008). If stress impedes working memory, which is the area of the brain that holds math facts, then timed tests could very well be causing these blocks for many of the higher working memory students in classrooms (Boaler, 2012).

Faust, Ashcraft, and Fleck (1996) conducted research on math anxiety associated with timed performance on simple and complex addition problems. Their first two experiments focused on anxiety with timed performance on the problems, but then in a third experiment they removed the timed dimension. They found when there was an untimed factor to the experiment, more high anxious math students did better on their performance of the math task. Commenting on the timed vs. untimed aspect of their experiment they said, "...while the math problems on a performance test will still arouse the anxiety reaction, relieving subjects of the normal time pressure should enable them to display their competence in a less contaminated fashion" (p. 53).

It is important to note that prior experiences in math often dictate later attitudes towards mathematics. Geist (2010) specifically articulated about the experience of timed testing by saying, “The early use of high stress techniques like timed tests instead of more developmentally appropriate and interactive approaches lead to a high incidence of math anxiety” (p. 28). Geist (2010) further noted that mathematics itself is not the stem of math anxiety, but rather the experiences children have in math classrooms, along with the way mathematics is presented by teachers, may be the root cause.

Math Fact Interviews and Math Anxiety

Bay-Williams and Kling (2014) said, “To assess basic fact fluency, all four tenets of fluency (flexibility, appropriate strategy use, efficiency, and accuracy) must be addressed. Additionally, assessments must provide data on which facts students know from memory” (p. 490). Unfortunately, timed tests do not effectively address all four tenets of fluency. Timed tests can address efficiency and accuracy, but they do not show how students are using flexibility in their thinking along with choosing appropriate strategies to solve. Additionally, Bay-Williams and Kling (2019) noted that a student could pick only the facts they know on a timed fact assessment, such as all the 5’s and 2’s facts, while ignoring more difficult derived facts such as the 7’s and 8’s. While this student’s “test score” may be high, it does not reflect that the student consistently avoids certain sets of derived facts. While timed testing can be an effective tool for formative assessment when integrated with strategy development (Woodward, 2006), it may not be the best tool in assessing all four tenets of fluency.

One assessment tool that Bay-Williams and Kling (2014, 2019) present as an alternative to timed testing is a math fact interview. A math fact interview can be conducted in-the-moment during strategy practice or game play, or it can be conducted more formally in a one-on-one

environment. Math fact interviews require more time and careful planning on the part of the teacher, but they can provide very descriptive information and data on all four tenets of fluency for an individual student. In a one-on-one formal interview, a teacher or specialist sits with a student and presents the student a set of math facts. If the teacher wants to formally assess mastery on all multiplication facts sets, a blend of both foundational and derived facts is required. While the student is solving, the teacher is asking, "How did you figure it out?" The teacher is noting automaticity, accuracy, strategy selection, and also overall flexibility.

The math fact interview is not a timed assessment, but automaticity can be noted by how much time the student takes to solve the fact (e.g. one dot recorded for every 3 seconds the student takes to solve). This untimed assessment could decrease math anxiety levels for math anxious students as it is a less stressful environment. However, there currently has been no research on math fact interviews connected to levels of math anxiety.

Conclusion

Math anxiety is a major concern, and it can start as young as first grade (Ramirez et al., 2013). Further, it is known that math anxiety does not come from math itself, but can be developed from the math experiences that children have in their schooling (Geist, 2010). Timed testing as a tool for assessing math facts can be one link to students experiencing math anxiety (Boaler, 2012, 2014). There are conflicting studies on the effectiveness of timed facts as an assessment that increases fact achievement (Henry & Brown, 2008; Woodward, 2006).

Alternatively, other tools for assessment have emerged such as math fact interviews. There is currently no research on math fact interviews in connection with math anxiety. This research could benefit teachers as they choose the best ways to assess fact development among their students while also decreasing math anxiety in their classrooms.

Methods

Participants

The research participants were 15 fourth grade students attending a K-12 private school in the Midwest during the 2021-2022 school year. Participants included nine female and six male students with a mean age of 9.5 years. Five students made up the timed testing group, five students made up the mixed-strategy group, and five students made up the math fact interview group. The students came from similar socio-economic backgrounds, mostly being upper middle-class families.

There are three sections of 25, 25, and 26 students at the fourth-grade level of the participating school. The participants were chosen from their classes as students who struggled with their multiplication and division math facts. A two-minute timed test fact screener administered at the beginning of the year indicated that the participants were not yet proficient in their multiplication and division facts. Further data such as observations and timed test scores were collected throughout the first semester of school that also showed the participants struggled in their math fact fluency.

Materials

A math anxiety survey was used to quantify students' levels of math anxiety (See Appendix A). The survey was created by the researcher, but modified from SEMA, the Scale for Early Mathematics Anxiety (Wu et al., 2012). SEMA was created for use with second and third grade students. SEMA is a reliable scale as it showed both internal consistency and split-half reliability. The internal consistency of SEMA was 0.870 (Cronbach's α), and the split-half reliability was 0.774 (Wu et al., 2012, p.7). The rating scale was adjusted to meet the needs of the researcher's environment. This included slightly changing the mathematics questions in

section one of the form to be aligned to fourth grade-level content. Further, the scale was adjusted for use in a large group setting, rather than in a one-on-one interview. The first section of the questionnaire assessed students' math anxiety related to completing math problems, and the second section assessed students' math anxiety related to social and testing situations that require the use of math. The survey was pilot tested by the researcher with twenty-six participants in the fifth grade. The pilot went well, and the survey did not need to be adjusted or changed. The participants provided positive feedback and had no confusion throughout the survey experience.

Math fact interview screeners for both multiplication and division developed by the Iowa Heartland AEA (See Appendix B and C), separated into 3 sets of math facts, were used as the math fact assessments for the experimental group and mixed strategy group. The first set assessed 0s, 1s, 2s, 5s, and 10s math facts; the second set assessed 3s, 4s, and 6s math facts; and the third set assessed 7s, 8s, and 9s math facts. One set of math facts was used for each math fact interview. The protocols for the screener were used as noted in the instructions for the screener such as asking students how they solved the fact along with coding the results on the form.

A 2-minute, 60-question, mixed-math facts assessment (See Appendix D and E) was used for the control group and mixed strategy group. The math facts on the timed test ranged from 0s-12s facts. There were four different forms (two multiplication and two division) of the timed test assessment that were cyclically used throughout the intervention.

Design

This quasi-experimental study measured the levels of math anxiety in students who struggled with math fact fluency between two different interventions, math fact interviews and timed testing. One group of fourth grade students made up the control group, while one group

made up the mixed strategy group, and a final group made up the experimental group. The independent variable was the method of intervention used, and the dependent variable was the level of math anxiety measured using the math anxiety survey.

Procedure

During the beginning of the first week of the study, all seventy-six students from all three classes completed the math anxiety survey. They completed the survey as individual classes during their normal math instruction time. Data was specifically analyzed for the struggling math fact students. In weeks one through eight of the study, the interventions were administered for all three groups of students.

The control group completed the 2-minute, 60-question timed math fact tests twice-per-week as an entire class. After they completed the timed fact tests, they self-checked their scores and charted their scores on a bar graph. They also submitted their scores on a Google Form so that the researcher was able to receive all the data from their timed test. This was a process that they had done previously in the school year, but rather biweekly. The only change was that they now completed the timed tests more frequently.

The experimental group did not complete any timed tests during the intervention time. Rather, the five students who struggled in their math fact fluency, participated in a math fact interview with the researcher in a one-on-one setting once per week. The math fact interview screener was used by the researcher with the student. The student solved one of the three sets of either all multiplication or all division problems in an untimed setting and were asked occasionally how they found the answer. The researcher also noted the participant's answer as having the answer memorized, whether or not the student used a direct model or counting, and what derived fact the student may have used to solve the problem. The researcher also noted

when the student took longer than 3 seconds. The researcher and the participant then together analyzed which facts the participant could continue to work and improve on.

The third group experienced both methods of timed testing and math fact interviewing. The entire class completed the 2-minute, 60 question timed math fact test one time per week. The class also self-checked their answers, charted their score in a bar graph, and submitted their test score on a Google Form. Additionally, the five students who struggled in their math fact fluency participated in a weekly math fact interview. The same protocols were used with these five students as the students who completed the math fact interview in the experimental group.

During the end of week eight, the math anxiety survey was administered again to all three sections of students during their normal math instruction time.

At the completion of the eight weeks, data was analyzed from the pre-test and post-test for math anxiety levels in each of the groups. The total score of both the pretest and posttest for the math anxiety survey was calculated for all three groups of students. Then, the difference between the pretest and posttest scores was calculated. Students who had positive growth in their pretest to posttest scores experienced an increase in their levels of math anxiety, whereas students whose scores had negative growth experienced a decrease in their levels of math anxiety.

Results

Data Analysis

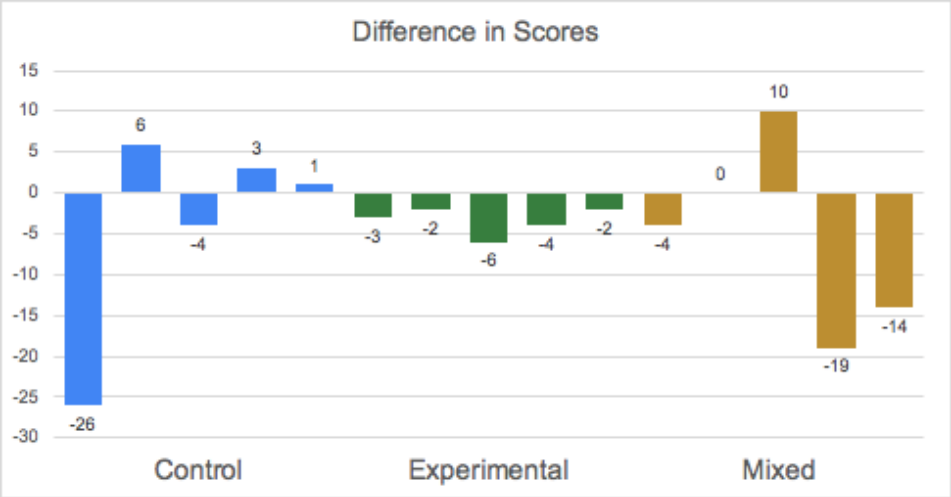
The main purpose of this study was to see if timed tests increase or decrease math anxiety among elementary students as well as if math fact interviews increase or decrease math anxiety among elementary students. The independent variable was the method of intervention used, and the dependent variable was the increase or decrease in the level of math anxiety measured using

the math anxiety survey. The control group experienced timed testing twice per week. The experimental group experienced no timed testing and weekly math fact interviews. The mixed strategy group experienced both timed testing and math fact interviews. A t-test was conducted on each of the control, experimental, and mixed methods groups to determine if there was any significance in the difference between the pre and post test scores from the math anxiety survey. Additionally, an ANOVA test was conducted to determine if there was any significant difference in means between the three groups. An alpha level of 0.05 was used for all statistical tests.

Findings

Figure 1

Summary of Data



The summary of data found in Figure 1 reveals that ten out of the fifteen students did experience a decrease in math anxiety according to their results from the math anxiety survey. Four students had an increase in math anxiety and one student experienced neither an increase or decrease in score. The experimental group all experienced a decrease in their math anxiety whereas the control and mixed strategy groups experienced varied increases and decreases. It is

interesting to note that more extreme decreases in math anxiety did occur in both the control and mixed strategy groups. However, when determining the Interquartile Range (IQR) for each set of data within each group, all the data points fell within the upper and lower limits.

Table 1

Differences in Math Anxiety Survey Scores (Control Group)

Student	Pre-Test Total	Post-Test Total	Difference
Student A	41	15	-26
Student B	19	25	6
Student C	16	12	-4
Student D	9	12	3
Student E	14	15	1
Average	19.8	15.8	-4
SD	12.40	5.36	12.83

Table 2

T-Test on Control Group Scores

Group	N	Mean	SD of Differences	t	df	p-value
Control (Timed Testing)	5	-4	12.36	0.70	4	0.52

A paired sample t-test was conducted on the pretest to post-test scores from the control group in order to determine any significance in the differences between scores. As seen in Tables 1 and 2, the t-test revealed that there was no significance in the differences between the pretest scores (M = 19.8, SD = 12.398) and the post-test scores (M = 15.8, SD = 5.357), $t(4) = 0.70$, p = 0.52. These results suggest that the timed testing treatment did not make a significant difference in math anxiety levels among the students in the control group.

Table 3

Differences in Math Anxiety Survey Scores (Experimental Group)

Student	Pre-Test Total	Post-Test Total	Difference
Student F	33	30	-3
Student G	19	17	-2
Student H	24	18	-6
Student I	24	20	-4
Student J	37	35	-2
Average	27.4	24	-3.4
SD	7.37	8.03	1.67

Table 4

T-Test on Experimental Group Scores

Group Type	N	Mean	SD of Differences	t	df	p-value
Experimental Group	5	-3.4	1.67	4.54	4	0.01

A paired sample t-test was conducted on the pretest to post-test scores from the experimental group in order to determine any significance in the differences between scores. As seen in Tables 3 and 4, the t-test revealed that there was significance in the differences between the pretest scores (M = 27.4, SD = 7.369 and the post-test scores (M = 24, SD = 8.031), $t(4)$ = 4.54, p = 0.01. These results suggest that the math interview treatment did make a significant difference in math anxiety levels among the students in the experimental group

Table 5

Differences in Math Anxiety Survey Scores (Mixed Strategy Group)

Student	Pre-Test Total	Post-Test Total	Difference
Student K	12	8	-4
Student L	27	27	0
Student M	11	21	10
Student N	33	14	-19
Student O	55	41	-14
Average	27.6	22.2	-5.4
SD	18.02	12.72	11.48

Table 6

T-Test on Mixed Strategy Group Scores

Group Type	N	Mean	SD of Differences	t	df	p-value
Mixed Strategy Group	5	-5.4	11.48	1.05	4	0.35

A paired sample t-test was conducted on the pretest to post-test scores from the mixed strategy group in order to determine any significance in the differences between scores. As seen in Tables 5 and 6, the t-test revealed that there was no significance in the differences between the pretest scores (M = 27.6, SD = 18.022) and the post-test scores (M = 22.2, SD = 12.716), $t(4)$ = 1.05, p = 0.35. These results suggest that the mixed strategy treatment of both timed testing and math interviews did not make a significant difference in math anxiety levels among the students in the mixed strategy group.

Table 7

Summary Table of Differences of Math Anxiety Scores

SUMMARY				
Groups	*Count*	*Sum*	*Average*	*Variance*
Control	5	-20	-4	164.5
Experimental	5	-17	-3.4	2.8
Mixed Strategy	5	-27	-5.4	131.8

Table 8

ANOVA Test on Differences of Math Anxiety Scores

ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	10.53	2	5.27	0.05	0.95	3.86
Within Groups	1196.4	12	99.7			
Total	1206.93	14				

A one-way ANOVA test was also conducted in order to determine if there was any significant difference in means between the control, experimental, and mixed strategy groups. The ANOVA test shown in Tables 7 and 8 revealed that there is no significant difference between the means of the three treatment groups $F(2,12) = 0.05$, $p = 0.95$. These results suggest that the three treatments did not make a significant difference between means in the results of the math anxiety survey among the three groups.

Discussion

Overview of the Study

Math anxiety is widely prevalent across classrooms today. Children experiencing math anxiety tend to feel negatively about math and their math ability. Research has shown that math

anxiety can stem from high-stress techniques used in the classroom by teachers such as timed testing (Geist, 2010). However, little research has been done on alternative math fact assessments. One alternate method of assessment includes math fact interviews. Math fact interviews are used to assess all four components of math fact fluency which include accuracy, efficiency, appropriate strategy use, and flexibility (Bay-Williams, Kling, 2014, 2019). This study was designed to answer the following questions: Do timed tests increase math anxiety among elementary students? Do timed tests decrease math anxiety among elementary students? Do math fact interviews increase math anxiety among elementary students? Do math fact interviews decrease math anxiety among elementary students? To address these questions, students were given a survey to determine their level of math anxiety pre and post treatment. Three different treatments were implemented during the eight-week period, and results were examined to see if there was any difference in math anxiety scores.

Summary of Findings

Math anxiety scores of 15 fourth-grade students were documented before and after the eight-week treatments and comparisons were made within each treatment group and between treatment groups. The findings did not show a significant difference within the control (timed testing) and mixed strategy (timed testing and math fact interviews) groups. However, the research did show a significant difference within the experimental (math fact interviews) group. Additionally, there was no significant difference between the control, experimental and mixed strategy groups.

Recommendations

Based on the given data, the researcher recommends the use of math fact interviews with students in order to assess math fact fluency. The data showed consistency in decreases in math

anxiety among the experimental group which indicates that the math fact interviews could have provided a lower-stress environment for math fact assessment. However, the other groups did have particular students who had major decreases in math anxiety. This is why the researcher also recommends that teachers conduct varied forms of math fact assessment that address all components of math fact fluency with students.

There is a need for more research around math anxiety, especially in relation to specific instructional and assessment techniques that are implemented in the math classroom. While there is significant research on math anxiety and its effects on students (Ashcraft, 2002; Ramirez et al., 2013; & Scarpello 2007) as well as significant research on math fact fluency development (Bay-Williams & Kling, 2019; Boaler, 2014; Henry & Brown, 2008; Woodward, 2006), there is not enough research on the connection between math anxiety and math fact fluency development.

The researcher recommends this study to be implemented with a larger sample size. Due to limited resources and time, this study was done with a small number of students which resulted in a small amount of data. This study conducted with a larger sample of students would provide more data and a clearer picture of significance between treatments. The researcher also recommends this study be implemented with varied types of math fact assessments. Timed testing still needs to be researched in its connection to math anxiety, but there are other types of assessments that could be utilized as a treatment to determine any connection to increases or decreases in math anxiety.

The researcher also recommends further professional development around math anxiety and math facts assessment. Boaler (2014) said about timed testing in particular, “Teachers and administrators use these tests with the very best of intentions, but they use them without knowledge of the important evidence that is emerging from neuroscience” (p. 469). Boaler goes

on to encourage the use of more strategy-based instruction around math fact fluency that aligns with current brain science research. More professional development in these areas would provide teachers with more knowledge on how to make the best decisions in their math classrooms around math facts and assessment.

Limitations

While the researcher took great care in planning and implementing the action research, several factors may have limited the study and results. The first limiting factor was the small sample size. While the researcher does have three full classes of 25, 25, and 26 students, math fact interviews would have been impossible to conduct weekly with all students due to time constraints and limited resources such as extra teacher aids to conduct interviews. This is why the study was implemented with only three groups of 5 students. A larger sample size of more grade levels, classrooms, and schools would have greatly benefited the study. Another limiting factor was that this study was conducted among students only from upper middle-class families. A more diverse sample of students from different socio-economic backgrounds may have given different data results.

A final limiting factor could have been the timing of the data collection. While the math fact interviews were extremely valuable, they did take up time within the instructional day. While some weeks provided more time to administer these interviews, other weeks felt more rushed to be able to get all the interviews conducted that needed to be. For example, one week during the implementation was just a 3-day week. This meant the researcher needed to conduct 10 math fact interviews within this more constricted amount of time. More time and personnel to conduct the math fact interviews would have benefitted the study. A further recommendation would be that math fact interviews be conducted less frequently with math fact proficient

students and more frequently with students who are lower in their math fact fluency due to the amount of time teachers have to assess students. The small duration of time the intervention was implemented was also limiting on the study. The intervention was held for only eight weeks. A longer intervention would have provided more accurate data on whether or not math anxiety increased or decreased among the participants.

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Appendix A

Math Anxiety Survey

Instructions for Section 1: “This questionnaire is going to start with some math questions. I want you to read each question and pretend that you are going to answer it. Then I want you to circle the feeling that accurately matches your emotions about how nervous you might be when answering that question. So remember, you do not actually have to answer the questions, but I just want you to pretend you are going to answer them and see how it makes you feel. It could make you feel not nervous AT ALL, a little nervous, somewhat nervous, very nervous, or VERY, VERY nervous. Do you understand? Let’s do one together…” Practice Item: Who’s the President of the United States?”

(Complete first section of the survey)

Instructions for Section 2: “Now you are going to read some sentences about situations that have to do with math. Try to pretend each situation is happening and think about how nervous it makes you feel. It could make you feel not nervous AT ALL, a little nervous, somewhat nervous, very nervous, or VERY, VERY nervous. Do you understand? Let’s try one. Pretend...” Practice Item: You’re about to ride a roller coaster.

(Complete second section of the survey)

Adapted from SEMA:

Wu, S. S., Barth, M., Amin, H., Malcarne, V., & Menon, V. (2012). Math anxiety in second and third graders and its relation to mathematics achievement. *Frontiers in psychology*, *3*, 162. https://doi.org/10.3389/fpsyg.2012.00162

Name: _____

Section 1

	Not nervous AT ALL 	A little nervous 	Somewhat nervous 	Very nervous 	VERY, VERY nervous 
Practice: Who's the president of the United States?	○	○	○	○	○
1. George bought nine pizzas that had eight slices each. How many total slices did George have to share at this party?	○	○	○	○	○
2. Is this right? 6 x 7 = 44.	○	○	○	○	○
3. How much money does Annie have if she has six dimes and fifteen pennies?	○	○	○	○	○
4. How do you write the number four hundred seventy-six thousand, nine hundred twelve?	○	○	○	○	○
5. Draw an hour and minute hand on a clock so that it would read 3:15 PM.	○	○	○	○	○
6. Draw a pentagon and a rectangle on the board.	○	○	○	○	○
7. Count aloud by 5 s from 105 to 155.	○	○	○	○	○
8. Mom ran errands for 1 hour and 45 minutes. If she left at 2:15pm, what time did she return?	○	○	○	○	○
9. Is this right? 3,200 ÷ 8 = 400?	○	○	○	○	○
10. Daisy has more money than Ernie. Ernie has more money than Francesca. Who has more money – Daisy or Francesca?	○	○	○	○	○

Section 2	Not nervous AT ALL 	A little nervous 	Somewhat nervous 	Very nervous 	VERY, VERY nervous 
Practice: You're about to ride a roller coaster.	○	○	○	○	○
11. You are in math class and your teacher is about to teach something new.	○	○	○	○	○
12. You have to sit down to start your math homework.	○	○	○	○	○
13. You are adding up all the money in your piggy bank.	○	○	○	○	○
14. Someone asked you to cut up an apple pie into eight equal parts.	○	○	○	○	○
15. You are about to take a math test.	○	○	○	○	○
16. You are in math class and you do not understand something. You ask your teacher to help you.	○	○	○	○	○
17. Your teacher gives you a bunch of multiplication problems to work on.	○	○	○	○	○
18. Your teacher gives you a bunch of division problems to work on.	○	○	○	○	○
19. You are in class doing a math problem on the board.	○	○	○	○	○
20. You are listening as your teacher explains to you how to do a math problem.	○	○	○	○	○

Appendix B

Multiplication Within 100

Name: **Date:**

Set 1:

1 x 8 = _____	6 x 0 = _____	9 x 1 = _____	3 x 1 = _____
2 x 5 = _____	3 x 2 = _____	8 x 2 = _____	2 x 7 = _____
4 x 5 = _____	10 x 5 = _____	0 x 4 = _____	7 x 10 = _____
10 x 3 = _____	0 x 0 = _____	5 x 6 = _____	10 x 2 = _____

Set 2:

3 x 5 = _____	6 x 2 = _____	4 x 4 = _____	5 x 3 = _____
6 x 5 = _____	4 x 6 = _____	4 x 8 = _____	6 x 10 = _____
9 x 6 = _____	7 x 4 = _____	3 x 3 = _____	6 x 6 = _____

Set 3:

8 x 9 = _____	7 x 9 = _____	3 x 8 = _____	7 x 7 = _____
9 x 5 = _____	8 x 6 = _____	7 x 6 = _____	7 x 8 = _____
10 x 9 = _____	9 x 9 = _____	5 x 8 = _____	8 x 8 = _____

S/C - Self correction was made
DM - Direct model
C - Circle # student started w/ & write a C above it.

DF - Derived Facts (notate mathematically)
____ - place line above incorrect answer
• - use a dot for every 3-4 seconds

Appendix C

Division Within 100

Name: Date:

Set 1:

8 ÷ 1 = _____	0 ÷ 6 = _____	9 ÷ 1 = _____	3 ÷ 1 = _____
10 ÷ 2 = _____	6 ÷ 2 = _____	16 ÷ 2 = _____	14 ÷ 2= _____
20 ÷ 5 = _____	50 ÷10 = _____	0 ÷ 4 = _____	70 ÷ 10 = _____
30 ÷ 10 = _____	18 ÷ 2 = _____	30 ÷ 5 = _____	20 ÷ 2 = _____

Set 2:

15 ÷ 3 = _____	12 ÷6 = _____	16 ÷ 4 = _____	15 ÷ 3 = _____
30 ÷ 6 = _____	24 ÷ 4 = _____	32 ÷ 4 = _____	60 ÷ 6 = _____
54 ÷ 6 = _____	28 ÷ 4 = _____	9 ÷ 3 = _____	36 ÷ 6 = _____

Set 3:

72 ÷ 8 = _____	9 ÷ 9 = _____	24 ÷ 8 = _____	14 ÷ 7 = _____
45 ÷ 9 = _____	48 ÷ 8 = _____	42 ÷ 6 = _____	56 ÷7 = _____
90 ÷ 9 = _____	81 ÷ 9 = _____	40 ÷ 8 = _____	64 ÷ 8 = _____

S/C - Self correction was made
DM - Direct model
C - Circle # student started w/ & write a C above it.

DF - Derived Facts (notate mathematically)
____ - place line above incorrect answer
• - use a dot for every 3-4 seconds

Appendix D

Name : _____ Score : _____

Teacher : _____ Date : _____

3 Minute Drill

10 x 8	11 x 4	12 x 3	11 x 5	9 x 3	5 x 12
2 x 9	5 x 6	11 x 12	11 x 7	9 x 2	4 x 6
4 x 3	10 x 10	2 x 7	10 x 8	10 x 11	12 x 2
6 x 2	2 x 7	8 x 11	2 x 9	8 x 10	7 x 4
4 x 5	6 x 2	2 x 12	9 x 12	5 x 3	12 x 11
8 x 10	9 x 2	4 x 8	2 x 3	10 x 4	6 x 8
12 x 4	4 x 3	12 x 4	4 x 3	8 x 8	10 x 6
9 x 3	6 x 5	9 x 4	4 x 10	11 x 8	4 x 3
8 x 7	10 x 9	2 x 5	3 x 5	9 x 10	6 x 2
4 x 6	6 x 6	11 x 7	4 x 9	5 x 3	12 x 7

Appendix E

Name : _____ Score : _____

Teacher : _____ Date : _____

3 Minute Drill

3 ÷ 1 =	9 ÷ 1 =	45 ÷ 9 =	60 ÷ 6 =	12 ÷ 12 =
60 ÷ 5 =	70 ÷ 10 =	24 ÷ 3 =	1 ÷ 1 =	84 ÷ 12 =
11 ÷ 1 =	30 ÷ 10 =	36 ÷ 6 =	33 ÷ 11 =	56 ÷ 7 =
81 ÷ 9 =	50 ÷ 5 =	33 ÷ 3 =	36 ÷ 4 =	10 ÷ 1 =
7 ÷ 1 =	54 ÷ 9 =	24 ÷ 8 =	110 ÷ 10 =	108 ÷ 12 =
21 ÷ 7 =	28 ÷ 4 =	5 ÷ 1 =	30 ÷ 6 =	63 ÷ 7 =
22 ÷ 11 =	24 ÷ 6 =	30 ÷ 3 =	7 ÷ 7 =	28 ÷ 7 =
15 ÷ 5 =	10 ÷ 10 =	24 ÷ 4 =	18 ÷ 3 =	49 ÷ 7 =
80 ÷ 8 =	16 ÷ 8 =	42 ÷ 7 =	4 ÷ 2 =	36 ÷ 12 =
40 ÷ 5 =	6 ÷ 6 =	100 ÷ 10 =	24 ÷ 2 =	42 ÷ 6 =
120 ÷ 10 =	10 ÷ 5 =	72 ÷ 12 =	8 ÷ 4 =	77 ÷ 7 =
12 ÷ 6 =	36 ÷ 9 =	60 ÷ 10 =	8 ÷ 2 =	32 ÷ 8 =