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Errorless Learning: An effective method for teaching math fact fluency

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Abstract

The purpose of this action research project was to evaluate the errorless learning technique as a method of teaching middle school students with disabilities math fact fluency. The study included seven participants, all middle school-aged boys. The research was conducted in a rural middle school in Northwest Iowa. Quantitative data was collected and compared from the beginning of the study in the baseline collection to the post-test. Results suggest that the errorless learning technique is an effective method for teaching math fact fluency.

Keywords: errorless learning, math fact fluency

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ERRORLESS LEARNING: AN EFFECTIVE METHOD FOR TEACHING MATH FACT FLUENCY

One thing that every human in the US and many other countries have had in common: each is surrounded by math in some capacity. Not only are mathematical skills important for a student's grade in their math class but "they are fundamental to the success of a student through their education and into their professional careers" (Baker & Cuevas, 2018, p.13). Jimenez & Saunders (2018) describe more specifically the areas math is needed for success: "Competency in mathematics has great implications on an individual's ability to perform academically, to live independently (e.g., budgeting, scheduling, paying bills), to obtain and maintain employment, and to be social (e.g., paying tabs, playing games) (p.23). The goal is for students to not just cram and temporarily retain knowledge for their math fact check, but rather to become fluent in their facts.

The question of how to retain facts long-term is particularly important when educating students with disabilities. Baker & Cuevas (2018) highlight research that shows students with disabilities, especially learning disabilities, are at a higher disadvantage when it comes to gaining math fact fluency. Thus, causing students with learning disabilities to depend on other slower and less accurate methods when solving math facts. Their slower pace of completion and learning is contributing to an even greater gap between students with learning disabilities and their typical peers. Students with disabilities are being left behind when it comes to the fluency of math facts, a deficit not only affecting their performance in school but also creating areas of concern when they enter adulthood. The school system is not equipped with enough strategies when it comes to teaching math fact fluency, especially relevant methods for teaching students with disabilities. Instead, students are forced to try and fail until either they learn the fact, or it is

time to move on to the next unit. Much research has been done to determine the best method for teaching math facts to general education students, but there is limited research on the best methods for teaching math to students with learning disabilities.

The purpose of this action research study is to examine the effectiveness of errorless learning paired with math fact fluency for students with disabilities in middle school. Dalphonse (2022) states that through " errorless learning, instructors use prompting to ensure the learner correctly responds every time (hence ‘errorless’). Prompts can involve varying degrees of intrusiveness and must be correctly faded to prevent dependence on prompts." This action research project aims to find an effective and lasting solution to the gap in math fact fluency for students with a learning disability. The research will be completed in a way that is financially achievable for all economic levels as well as able to be implemented by one single adult. The idea for this research was derived from the ABBLS-R program for students with autism.

The resources used in this review are research journal articles that have been peer-reviewed and found through the DeWitt Library, most of them published in the *Journal of Developmental and Physical Disabilities, Journal of Behavioral Education, Journal of Applied Behavior Analysis, and Journal of Research in Special Educational Needs.* The ideas of errorless learning, error correction, and math fact acquisition will be discussed through the literature review.

Review of the Literature

Errorless Learning

The first area of review is errorless learning. Errorless learning is one method recommended for teaching math facts to students with disabilities is errorless learning. This method is described by Leaf et al. (2020): "Errorless, or near-errorless, learning procedures involve attempting to prevent errors during all teaching sessions" (p.2). In the research by Leaf et al. (2020, 28 children with autism spectrum disorder (ASD) were taught new material through the errorless learning procedure or error correction procedure. The children were placed in groups at random; however, both groups were provided with the same stimuli based on popular media. Each student was given a full probe as a baseline and again as a post-test including 18 trials; in between students were given smaller daily probes that only included six trials. All students were given unbiased feedback after providing their responses. According to the findings, error correction and errorless learning procedures were both very effective methods to teach tact skills to these students. All but one student in the error correction group, as well as one student in the errorless learning group, were able to master their skills by the end of the study. However, when looking at independence, the error correction learning style produced more independent correct responses than errorless learning.

Specific errorless learning strategies were compared to identify a uniform idea of the most effective strategy. An analysis of previous research by Markham et al. (2020) compared a variety of interventions related to within-stimulus errorless learning. The interventions compared included stimulus fading, stimulus shaping, and superimposition. The research supported that stimulus fading is the most utilized method of errorless learning. Furthermore, it was identified

that out of the learning procedures, within-stimulus errorless learning procedures were more effective.

A comparison between errorful and errorless learning was studied by Bridger and Mecklinger (2014) in Germany with 48 participants. The participants were studying for an upcoming exam on German nouns. The study used a computer program that presented the information on a computer screen. Erroful and errorless learning trials were intermixed through each study segment. The results showed that when the errorful learning style was used, the same error was committed on the final exam. On the flip side, the questions that utilized errorless learning produced correct answers on the final exam. The questions presented through an errorless learning procedure were corrected on the exam. The results of the Bridger and Mecklinger (2014) study suggest that errorless learning is effective in the acquisition of new skills.

De Werd, Boelen, Rikkert & Kessels (2013) reviewed 26 studies to determine the effectiveness of errorless learning in adults with dementia. Errorless learning was used to help individuals with dementia relearn life skills that they lost due to the disease. Life skills were presented in a variety of ways throughout the 26 studies, but most commonly modeling and verbal instructions were used to carry out the errorless learning procedure. The results showed that the errorless or error-reducing teaching style significantly and positively impacted the participants' ability to relearn skills. The individuals were not only able to perform skills at the time of instruction but were also able to retain the skill for an extended time. De Werd, Boelen, Rikkert & Kessels (2013) highlighted the immense impact errorless learning can have on this population.

Craig, McLaughlin, Derby & Clark (2016) researched the effectiveness of using flashcards with the errorless learning process when identifying and sorting shapes. The study included one three-year-old student from a preschool classroom. Researcher Craig et. al. (2016) modeled how to sort shape tiles, then asked the student to sort by shape. The first three lessons included large shape tiles, circles, squares, rectangles, and triangles. During the first lesson, only the first two shapes were used. In the second lesson, rectangles and triangles were used. The third lesson used all four shapes. Researchers then repeated the sorting of all four shapes but with small, shaped tiles. The last session included all four shapes in both sizes. As the sorting occurred, if the student said the incorrect shape name, the instructor would return it to the missed shape pile until the correct answer was given three times. Because of a few limitations, the study included only seven sessions of sorting shapes and eight sessions of naming shapes. Results of the study suggest that the flashcard system and errorless learning technique assisted the student in mastering the skills introduced.

The errorless learning technique was also used in language arts. Herberg, McLaughlin, Derby & Weber (2012) used the errorless learning technique to increase reading accuracy and fluency in middle school students. The study included two components, reading accuracy and fluency. The student participant was instructed to read a passage while the instructor tracked elapsed time and errors. Passages were repeated until the student was able to read 80 words per minute or higher. Flashcards were used as a supplemental activity to the passages. Words were presented to the student: if they were read correctly, they would be moved to the end of the pile. If read incorrectly, the instructor provided the correct answer and put the word back into the pile a couple of cards behind. Results positively impacted students' reading accuracy and fluency.

Error Correction

Another teaching procedure commonly used in skill acquisition is error correction. Leaf et al. (2020) defines error correction as a “procedure that is used following an incorrect response that will increase the probability of a correct response on subsequent trials" (p.2). Error correction procedures used by Leaf et.al. (2020) included saying "no," modeling, removing eye contact from the student, repetition, and repeating. Twenty-eight students participated in a study comparing error correction and errorless learning procedures. The students were placed in their groups at random. In the error correction group, students were presented with the same stimuli as the errorless learning group—comic book characters. The difference between the two groups came after the student answered incorrectly, students in the error correction group were met with a combination of the procedures listed above. Specifically, students were presented with a verbal response "no" and a corrected answer. All but one student in each respective group performed at a mastery level. The only difference between the results of the two teaching strategies is the independence level achieved. Error correction yielded 90.8% correct and independent responses while errorless learning scored lower at 75.3%.

Kodak, Fuchtman, and Paden (2012) "compared the effectiveness of three training procedures, echoic and tact prompting plus error correction and a cues-pause-point" (p. 155) concerning intraverbal tact and mands in two students with ASD. Each student participated in multiple sessions per day all consisting of 12 trials. The trials were split into three groups for the three training procedures. During the echoic prompting with error correction, students were asked a question, given time to respond, provided an echoic prompt if the answer given was incorrect, and finally given five seconds to provide a correct answer. The four steps were

repeated five times per trial. The results of the study showed that out of the three procedures studied, echoic prompting plus error correction was the most effective method tried.

Two separate groups of researchers, Carroll et.al. (2015) and McGhan et.al. (2013), evaluated multiple error correction procedures for a handful of students each. Their findings were similar to the idea that error correction is beneficial; however, the specific method used should be based on the individual student rather than on a generalized idea from research. The error correction procedures evaluated by Carroll et.al (2015) were identical to those Leaf et.al. (2020) studied with their students.

Rapp et.al. (2012) researched to determine the effect error correction with response repetition had on math facts. Data was collected by one graduate student and one undergraduate student. The researchers would take turns working 1:1 with a student or observing and collecting data from out of sight. The study included four students with intellectual disabilities and some displayed behaviors during math class. Three of the four students were presented with a set of 10 cards with varying math facts. Each set was arranged purposely by the researchers and only consisted of a single math fact. The students were given five seconds to provide the correct answer after which the student received verbal praise. If an incorrect answer was provided, or the student failed to answer within five seconds, the instructor would follow the response repetition plan. Response repetition includes "a trainer instruct[ing] the participant to repeat the correct answer five times while the participant was looking at the respective card" (Rapp et al. 2012 p.22). The other student was presented with five math problems each on a blank sheet of paper to allow for space to work. A similar response repetition procedure was used for incorrect written answers; however, instead of repeating the same problem, the student would complete the problem with a similar strategy to the first. Results of the study proved the effectiveness of the

response repetition strategy on students with intellectual disabilities in three out of the four students who participated.

Leaf, Alcalay, Leaf, Tsuji, Kassardjian, Dale, McEachin, Taubmna & Leaf (2016) completed a study comparing most to least prompting and error correction procedures. The study included two preschool students who had both been diagnosed with autism. Instructors used a prompt feedback assessment to collect baseline data on receptive labeling. Each student was expected to identify eighteen pictures. Half of the pictures were taught with the most to least prompting and the other half with error correction. During most to least prompting, the participant was provided with three pictures in which they were expected to point at the correct card. Instructors would start by asking a question and pointing immediately to the correct card. The prompting would continue to fade until the student was able to independently find the correct picture. In the error correction process, students were presented with three pictures and asked a simple question. If the student answered correctly, praise was immediately given. Following incorrect answers, the instructor would say, "No, that's not it" (Leaf et al. 2016, p.220) and then provide the correct answer. The same question would repeat immediately. Results indicated that both procedures were effective with the participants. One student's results suggested that most to least was more effective than error correction. The other student had opposite results.

Mathematic Fact Acquisition

Another area playing into this study is the acquisition of math facts specifically in the United States. "Since the 1960's international comparative studies have consistently demonstrated that students in the USA lag behind students in other developed countries in mathematics performance" (Nickel, 2021, p.6). Researcher Nickel analyzed past research on the

most effective math instruction strategies. It was discovered that adding technology and using other digital tools increases motivation and in turn, provides growth of math facts. The research did not address the steps required for students to retain math knowledge.

Burns, Nelson & Kanive (2015) completed a study determining the number of repetitions needed for elementary students to remember multiplication facts. This study included data from over 15,000 students in either 3rd, 4th, or 5th grade. To assist with data collection, researchers used the program "Star Math, which is a computer-adapted system" (Burns, Nelson & Kanive, 2015, p.400). The study broke multiplication facts down into 62 levels. For each level, the participants would take a 40-question baseline test. If the student correctly responded to all 40 items, the student would pass that level. If the student incorrectly answered questions, they participated in a 5-to-15-minute session. During this independent session, students would answer and receive feedback. For incorrect answers, the program would highlight the correct answer and the question would be repeated for the student. Once the practice session is complete, the student takes another 40-question test; when the student can answer all questions correctly within two minutes, the level is considered passed. Results of the study concluded three ideas: students who were higher learners required fewer repetitions, multiplication facts with 2s and 3s were easiest, and as the grade level increased the number of repetitions decreased.

Researchers Lund, McLaughlin, Neyman, & Everson (2012) also completed their research on the acquisition of single-digit multiplication facts but used flashcards and a math racetrack for instruction. Participants included two elementary-aged students with learning disabilities. The study focused on 18 facts that each student did not master. The 18 facts were split into 3 sets; only one set would be focused on in each session. Students were asked to state the question and the answer within five seconds. If the student answered incorrectly, the problem

was reviewed and put back into the pile specifically to reappear two questions later. The process continued until the student reached mastery of all facts in that set. The same set was used until the student reached mastery three sessions in a row. Another researcher included the math racetrack before showing students flashcards. The racetrack included 28 spots for facts; the first 12 were the current set of focus, and the rest reviewed problems. The time taken for the student to correctly make their way around the racetrack was tracked. When a student incorrectly answered a problem, the instructor would correct the answer and have the student repeat it before continuing. Once the student had completed the racetrack, the same routine was carried out with the flashcards. Results concluded that both students were able to increase their multiplication fact knowledge through the pairing of direct instruction by flashcards and the math racetrack.

Another intervention used to aid math fact acquisition is detect, practice, and repair (DPR). Researchers, Poncy, Fontenelle & Skinner (2013) utilized the DPR model with eleven fourth-grade students to differentiate and individualize instruction of math facts. Baseline, as well as daily intervention probes, were collected at the beginning of the day. Each probe consisted of 48 math fact problems presented in a grid view. Subtraction, multiplication, and division were all covered based on the students' individual needs. Students received a packet with three sheets of paper: the first page served as the detect component, the second was practice, and the last repair. During the detect portion, students answer questions to a 30-beat-per-minute metronome. Students then circled either five problems they did not get to or ones they did not feel confident in. On the second page, students would write the questions circled on the previous page into the problem boxes. Students would then use the next five minutes to cover, copy, and compare their five problems previously circled. The students were given one minute to answer a group of problems; the correct answers were then graphed and put away for the next day. Results

suggested that the DRP model was successful at differentiating for students with a variety of needs. Building off the previous statement, because the instruction was tailored to the specific student, researchers found growth in each student.

Krawec, Huang, Montague, Kressler & de Alba (2012) studied "the effectiveness of Solve It! Is a cognitive strategy intervention designed to improve the math problem solving of middle school students with learning disabilities" (p.80). The study occurred over two years with a whole grade level of students each year. Solve It! is a specific program that required teacher training and careful attention to scripted lessons. Lessons lead students through specific methods to solve math story problems. One instructor would teach while the other observes and collects data. Results determined that the classes that used the Solve It! lessons maintained a variety of strategies to solve a variety of problems.

Methods

Participants

Participants included in the study consisted of seven middle school students (5th-2, 6th-1, 7th-2, 8th-2), all with intellectual disabilities. To be included in the study, students had to of met the following criterion: (a) their school placement must be in a Strategist II, special education classroom; (b) the students struggle with acquiring new math knowledge; (c) parents gave consent for their child to participate in the study. During this study, all students were taught using the errorless learning technique. The students in the study will be referred to as students 1-7 for privacy. The student's number was assigned at random.

Data Collection

Baseline testing, sessions, and posttest were all conducted within the student's public-school classroom. Students worked 1:1 at the back of the classroom with one table and two chairs. During baseline collection, students were initially presented with a choice of math fact type. There was a total of 192 math facts: 55 addition, 55 subtraction, 55 multiplication, and 27 division. The students were then presented with 3x5 notecards, each with a different math fact written in black sharpie across the front. The students were given five seconds to respond to the math fact presented on the notecard. If the student failed to respond or gave an incorrect response, the card was placed into a pile that corresponded. Facts that were answered correctly and within five seconds were placed into another pile for known math facts. During baseline collection, no response verbal or visual was given from the researcher after students responded. The results were tracked in an excel spreadsheet with each student's responses by individual math facts.

Working sessions were conducted similarly; students worked 1:1 with their teacher at the back of the classroom. Instead of being presented with all 192 facts within a week, the sessions consisted of 10 facts. Math facts were presented in the same way as in the baseline collection, by reading the facts to the student. If students answered correctly, praise and affirmation were given to the student. If the answer was incorrect, the errorless learning teaching procedure was followed. The errorless learning procedure involves providing the student with the correct answer, repeating the question and answer, and having the student mirror. The incorrect fact was then put to the side while another fact was presented. If the fact is answered correctly, it is put down in the pile and the previous fact was reintroduced to the student. Each time the student answers incorrectly, the errorless learning procedure is followed. To end the learning session, the 10 cards are presented one last time and marked correct or incorrect to track the progress of using the errorless learning procedure.

Findings

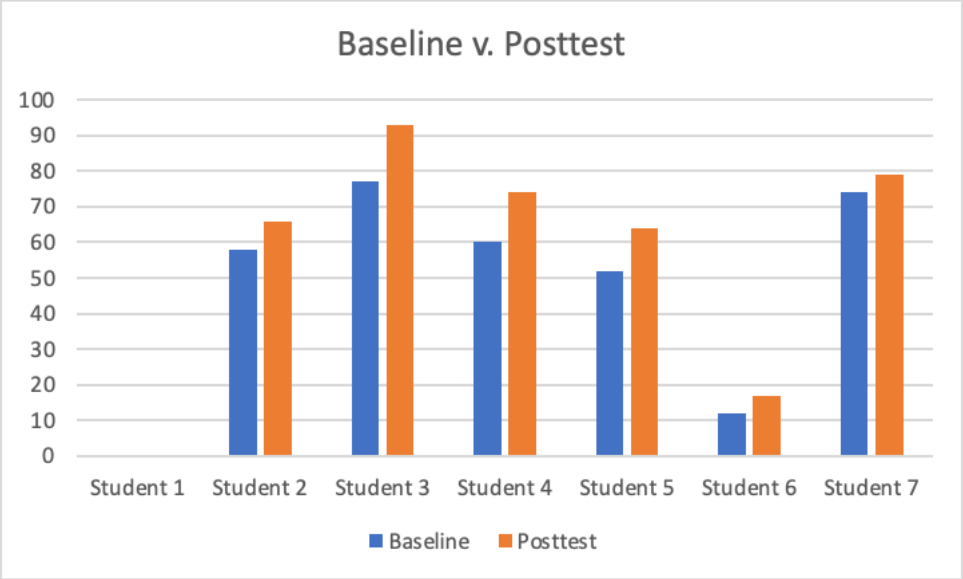
Each student answered 192 math facts including addition (55), subtraction (55), multiplication (55), and division (27) problems. The individual responses were tracked on an Excel document; students received a "1" for correct answers and a "0" for incorrect answers. The total correct answers per student were then broken down into percentages of knowledge of all facts combined. Results from the baseline assessment suggested that all students involved would benefit from this instruction. As anticipated, division for most of the students was the lowest of the math facts monitored.

Student 1 was unable to acquire new facts through the first four sessions. Student 1 was discontinued from the study through professional judgment due to developmental abilities and stress level. The student did not participate in the posttest data collection.

Student 2 correctly answered 111 out of 192 (58%) math fact problems during the baseline. Due to extended absences during week three of the study, the student was able to participate in only one out of the two sessions. During learning sessions, the student quickly moved through addition and subtraction problems. After seven sessions of errorless learning intervention, Student 2 raised their correct answers from 111 (58%) to 127 (66%).

Student 3 performed highest on the baseline and posttest data. During baseline data collection, Student 3 correctly answered 147 math facts out of the 192 (77%) possibilities. Student 3 participated in eight total learning sessions. Out of all the participants, Student 3 bought into the learning sessions most as evidenced in their attitude and participation. After the learning sessions, Student 3 had mastered all facts. Posttest data shows an increase from 147 (77%) facts to 178 (93%), a growth of 16%.

Students 4, 5, 6, and 7 also participated in all eight learning sessions. Student 4 correctly answered 117 of the 192 (61%) facts presented. Student 4 worked extremely hard during learning sessions and was able to raise from 117 correct facts to 143 for a growth of 14%. Student 5 answered 100 (52%) problems correctly during baseline data collection. They were able to acquire new learning and correctly answer 123 (64%) problems during post-testing. Student 5 grew 12% between baseline testing and post-testing. Student 6 was able to acquire and maintain knowledge of 10 new facts after the eight learning sessions. They increased their correct answers by 6%. Student 7 correctly answered 143 out of 192 (74%) baseline questions. They were able to answer 152 (79%) questions at the end of the study for a growth of 5%.



Discussion

Summary of Major Findings

The study results show that errorless learning techniques had a positive impact on middle school students with special needs in math fact acquisition. All students but the one dismissed grew in their math knowledge during the study. Students (excluding student 1 data) averaged 55% correct responses on their baseline assessment. The group of students answered 66% of

questions correctly by the post-test data collection assessment. The greatest growth for any student was 16%. The data supports that this group of students was not only able to acquire more math facts during instruction, but they were also able to retain the knowledge over the four weeks.

Limitations of the Study

A specific limitation of the study included the wide range of abilities represented by the small number of participants. The range of abilities provided difficulty in comparing data between the students. The data was collected and analyzed by one individual, so errors could have occurred without notice. The length of the study (four weeks) provides another limitation to analyzing the effectiveness of the program in math fact retention. Another limitation includes student attitudes and effort applied to the study. A bias was made when specifically looking at student 1 overestimating their baseline skills. Another bias could have been present in the researcher's predetermined positive belief behind the teaching technique used.

Further Study

The current study provides promise and methodology for further research. First, additional research could be carried out for a longer duration to increase the number of sessions each participant completed. The second area that needs continued research includes the participants. Participants in this study were all middle-school-aged male students. The next steps could be to expand to middle school students – male and female, upper elementary school students, and students with and without disabilities.

A large proportion of research on errorless learning and its effect on academic skill acquisition is focused on language arts, specifically sight words. Since a majority of research is focused on language art skills, additional research could expand skills errorless learning strategies are

utilized. Math and other academic skills are very understudied as well as life skills. Just as De Werd et al. (2013) examined errorless learning techniques to reteach life skills in adults with dementia, additional research could be completed when expanding the participants to those enrolled in special education as well as students learning life skills in the beginning stages of school.

Little research has been completed evaluating the use of praise in connection with errorless learning procedures. In the Polick, Carr, & Hanney (2012) study, researchers compared general and descriptive praise with students with autism and found that descriptive praise is more effective. To expand research, descriptive praise should be used in connection with errorless learning to evaluate the effect praise can have on the acquisition of academic facts. Future research could also focus on if praise in addition to the errorless learning technique acquires new facts at a quicker rate than without.

Conclusion

As a result of this action research project as well as the literature analyzed, errorless learning can be considered an effective strategy to teach or review facts or skills for individuals of all ages and abilities. Most studies conclude that the errorless learning technique aids in moment learning and leads to positive retention rates. Literature suggests that errorless learning procedures positively impact students' learning. The research collected through this study also suggests that errorless learning was an effective learning strategy for math facts with middle school-aged students with intellectual disabilities. Although the study assessed the errorless learning method in relation to math, errorless learning methods can be used across a variety of subjects or skills to increase acquisition speed and decrease errors as analyzed in the reviewed literature.

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