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The Effects of Folding-In of Basic Mathematics Facts for Students with Disabilities

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Research in the area of elementary mathematics has been limited in recent years. Direct instruction methods, including drill tasks, have been recommended for elementary students who have mathematics difficulties. This project involves two studies that examined the effectiveness of a specific direct instruction intervention, Folding-In, on the math computation achievement of elementary students. Weekly Curriculum-based measurement (CBM) progress monitoring data, as well as achievement test data, were used to monitor the effectiveness of the intervention, with improvements noted in math fact fluency in both a university-based clinical tutoring and a classroom intervention setting.

At the primary level, mathematics difficulties are often exhibited in both basic fact mastery and fluency as well as in more complex, problem-solving tasks. The need for effective math interventions in these areas is immediate at the elementary level, not only to identify students who need targeted, intensive math instruction, but also to potentially reduce the number of students who are at-risk for experiencing difficulties in mathematics (Fuchs, et. al., 2005). As response-to-intervention emerges as a process for identifying students with special needs, research must continue to examine the effectiveness of mathematics interventions to provide educators with the tools and strategies necessary to address learning difficulties.

Effective mathematics interventions are needed for the approximately 5-8% of school-age population who have been identified with a disability in the area of mathematics (Badian, 1983; Geary, 2004). Students who have been identified with a disability in mathematics will need quality instruction and interventions in order to make progress in the area of mathematics. Data-based research that addresses mathematics interventions for students with disabilities is critical.

In a review by Kroesbergen and VanLuit (2003), 58 studies of elementary math interventions were examined. It was found that the skill area most positively affected by strategic interventions was basic math skills such as learning the four basic mathematical operations and automatizing these basic math facts. It seems that in mathematics instruction, as well as other curricular areas, direct instruction develops automaticity with basic skills. Current math reforms are calling for a trend toward more implicit teaching and conceptual understanding of mathematics concepts (National Council of Teachers of Mathematics, 2000), but this approach may need to be supplemented with more explicit direct instruction for students with math difficulties. While the goal is for students to understand the mathematical processes they are using, students need to be able to quickly and accurately apply those processes. Elementary teachers need to utilize instructional interventions which yield the best results in specifically meeting the needs of students with mathematics difficulties so these difficulties don't persist into adulthood (Miller & Mercer, 1997)

Although the research base for mathematics instructional strategies is just beginning to expand, a characteristic for effective interventions has been identified. The use of direct instruction (Kroesbergen & VanLuit, 2003), particularly drill tasks (Burns, 2004), is an effective way to remediate basic skills and is necessary to address the needs of students who have difficulty with math concepts (Burns, 2005). In their analysis of current research on mathematics interventions, Kroesbergen and VanLuit (2003) concluded that direct instruction is the most effective method of instruction for basic math facts. Mastery and fluency of math facts requires adequate attention and memory (Fuchs, et. al., 2005), and direct drill instruction and practice addresses these needs by providing substantial opportunities to respond and review skills (Burns, 2005). Direct instruction using drill tasks has been shown to: 1) improve acquisition of new skills (Burns, 2005), 2) lead to better retention of skills (Singer-Dudek & Greer, 2005), 3) develop automaticity with basic skills (Kroesbergen & VanLuit, 2003), and 4) contribute to improved performance on higher-level tasks (MacQuarrie, Tucker, Burns, & Hartman, 2002).

Another important consideration in math instruction is that student learning is more positively impacted when instruction is provided at an individual's instructional level (Burns, 2004). Specific criteria for an optimal math instructional level, particularly in the area of math fact fluency, may depend on specific instructional needs (Burns, 2004), but research regarding reading interventions, specifically sight word instruction, can provide some basic recommendations for the appropriate instructional level. Research has examined two current strategies for implementing drill tasks using ratios of known and unknown items – Incremental Rehearsal (IR; Tucker, 1989) and Drill Sandwich (DS). Using IR, the teacher gradually increases the ratio of known and unknown items, beginning with one unknown and one known item and ending with one unknown and nine known items. Drill sandwich involves presenting all unknown and known items in a set at once rather than gradually increasing the number of items presented. Research in the area of reading has shown that better acquisition of unknown sight words has been achieved with a ratio of 60% known items and 40% unknown, but improved retention occurred with a ratio of 80% known and 20% unknown items (Roberts, Turco, and Shapiro, 1991). In addition, a comparison of retention rates at 1, 2, 3, 7, and 30 days found that the Incremental Rehearsal (IR) approach with 90% known and 10% unknown sight words led to the best retention, as opposed to traditional or Drill Sandwich (DS) approaches (MacQuarrie, et al., 2002). When used to teach math facts, Burns (2005) also found that IR with a ratio of 90% known and 10% unknown effectively increased students' fluency with multiplication facts. While there does not yet appear be a consensus on the most effective instructional ratio, the practice of reviewing known items with unknown items does positively impact student learning (Burns, 2004).

As educators strive to develop and use more effective math instructional strategies and interventions, careful attention must also be given to monitoring the effectiveness of interventions. Curriculum-based measurement (CBM) has proven to be a reliable and valid tool for monitoring individual student achievement (Stecker & Fuchs, 2000). Stecker, Fuchs, and Fuchs (2005) identified three important characteristics of CBM: assessment of student progress in relation to long-term goals, utilization of frequent data collection and reporting for instructional planning, and the technical adequacy of CBM procedures. Fuchs, et al. (2008) identified ongoing progress monitoring as one of the seven principles of effective intervention for students with mathematics disabilities. Researchers and educators alike concede that CBM is not just a summative evaluation tool; when used appropriately, it is a formative assessment tool which can and does hold teachers accountable for student achievement (Clarke & Shinn, 2004). In the area of math CBM, specific grade level computation skills are assessed, with the number of correct digits scored and charted to monitor progress.

Research has demonstrated the use of drill tasks (e.g. IR, DS, traditional) in the area of reading, specifically for use with sight words, but research is limited in their use with math facts. Folding-In (Shapiro, 2004) is an explicit technique for reviewing basic skills, including addition and subtraction facts, and developing fluency with a focus on an appropriate instructional level ratio of known and unknown facts.

The purpose of this study was to examine the effectiveness of a drill task intervention, Folding-In, with students who have below average mathematics skills. Folding-In was implemented on an individual basis for approximately 20 minutes per session in both a university-based clinical tutoring setting as well as a classroom intervention setting. These studies sought to further examine the critical elements of effective mathematics interventions in combination with regular progress monitoring in order to positively impact the math fact accuracy and fluency of third- and fourth-grade students.

Method

Participants and Setting

Study 1. One 9-1 year old third-grade African-American female student was the participant in this study. This student, R. S., attended a private school in a large metropolitan school district in the Midwest and participated in the university-based clinic for students with learning differences at the request of her mother. This was her third year in the clinic program. R. S. was not receiving special education services, but previous testing results from the Weschler Individual Achievement Test (WIAT-II; Wechsler, 2002) indicated below average performance with standard scores of 78 on both the Numerical Operations and Math Reasoning subtests. Her Composite Verbal/Nonverbal Intelligence standard score was 95 and in the average range as measured by the Reynolds Intellectual Assessment Scales (RIAS; Reynolds & Kamphaus, 2003). R. S. participated in general education third-grade instruction in all academic areas except mathematics which was provided daily in a general education second-grade classroom.

Study 2. Three fourth-grade students (2 boys, 1 girl) from one elementary school served as participants in this study. The students were from a large urban school district in the Midwest. This particular elementary school had a 95% attendance rate, 16% mobility rate, and 79% of the students received free/reduced lunch. Participating students were identified by a multidisciplinary team as students who qualify for special education support in the area of mathematics.

Student 1 (M.C.) was a 9-11 year old Hispanic boy. Student 1 had been receiving special education services for a learning disability for 3.0 years. Student 2 (J.M.) was a 10-0 year old Hispanic girl identified with an other health impairment who had been receiving special education services for 1.4 years. Student 3 (E.C.) was a Native American boy who was 10-11 years old and had been receiving special education services for a learning disability for 3.4 years. All participants had ability scores in the average range. Student 1 (M.C.) had a full-scale standard score of 90 on the Universal Nonverbal Intelligence Test (UNIT; Bracken & McCullen, 1998). Student 2 (J.M.) had a full-scale standard score of 94 on the Comprehensive Test of Nonverbal Intelligence (CTONI; Hammill, Pearson, & Wiederholt, 1996). Student 3 (E.C.) had a full-scale standard score of 88 on the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2003). Each student received an hour of resource mathematics instruction per day in a group with 3 or less students. The students were selected because they all had IEP goals in the area of math calculation, and they all received the same mathematics instruction.

Dependent Measures

Several procedural considerations were accounted for to ensure the validity of the results of each study. As recommended by Kratochwill (1992), strategies were used in the design and implementation of this study to improve the validity of the conclusions. For example, multiple reliable objective assessments were used to measure both pre-test/post-test performance as well as weekly progress monitoring. For both studies, the following three dependent measures were utilized:

Math Fact Accuracy. Math fact accuracy procedures were followed for both studies with students individually assessed prior to each intervention session. For study 1, R.S. was assessed with single-digit addition and subtraction facts to 10 utilizing a set of 121 basic fact flashcards that was prepared using index cards. For the second study, students were assessed with addition and subtraction facts of sums 10 through 18 with a set of 266 basic fact flashcards prepared for each student. The criteria for known facts were the correct answer provided within three seconds.

Woodcock Johnson III math subtests. Students in both studies were pretested and post-tested on the Math Calculations and Math Fluency subtests of the Woodcock-Johnson III Tests of Achievement (WJ III; Woodcock, McGrew, & Mather, 2001). Students were assessed prior to intervention and were post-tested within one week after the intervention.

Curriculum-based Measurement. Study participants were assessed with multiple skill (addition and subtraction) math curriculum-based measurement (CBM) probes developed by AIMSWeb® (Edformation, Inc., 2004). Due to the clinic setting used in the first study, the participant was assessed weekly using math CBM. During the second study, participants were assessed twice a week using CBM probes. Second grade level probes were used in both studies. Follow-up data was collected utilizing a CBM probe two weeks after the conclusion of the intervention sessions. These CBM probes contained both one- and two- digit addition and subtraction problems. Each probe had two pages of problems arranged in six rows with seven problems in each row. Students answered as many problems as they could in a two-minute time frame. The Math CBM probes were scored by counting the number of Correct Digits (CD) the student wrote (Edformation, Inc., 2004).

Procedures

The Folding-In intervention was selected to address the student's target behavior of fluency and accuracy with basic math facts. A Folding-In technique (Shapiro, 2004) was utilized to practice math facts weekly during university and classroom tutoring sessions based on Tucker's (1989) recommendations for Incremental Rehearsal (IR). An increasing ratio leading to 70% known facts and 30% unknown facts was selected for the intervention period. During the math fact pre-assessment prior to each intervention session, the instructor would individually assess each student and sort the fact flashcards into a set of known facts and a set of unknown facts. Each intervention session began by allowing the student to select three flashcards to work on from the set of unknown facts and seven flashcards from the set of known facts. The unknown facts were drilled with the known facts. According to the Folding-In procedure (Shapiro, 2004), unknown facts were systematically drilled with known facts.

Several considerations were made in establishing the specific procedure for the students in these studies. Based on the students' inconsistent performance with known math facts, no known facts were ever removed from the drill set. Instead, practice began with a ratio of 1 unknown fact and 7 known facts, and proceeded to a final set of 3 unknown facts and 7 known facts. As recommended by Burns (2004), the ratio never exceeded 30% unknown facts. In addition to providing an acceptable instructional level, this also gave students more opportunities to respond with all items, known and unknown (Burns, 2005). During each session, students were given at least 10 opportunities to respond to all 3 unknown facts. See the Appendix for the Folding-In Procedures.*Study 1.* The instructor was a graduate student participating in a graduate level university clinic course. The instructor was a full-time elementary resource teacher with a bachelor's degree in elementary education and early childhood special education who had eight years of special education teaching experience.

The intervention was implemented during a university-based clinic program on the campus of the university. All testing occurred in a quiet distraction-free clinic observation room. Interventions were implemented in a campus classroom. R. S. attended 10 of the 12 scheduled 20 minute Folding-In intervention sessions. At the conclusion of each intervention activity, R. S. completed a two-minute math CBM probe.*Study 2.* The instructor was an elementary resource teacher working with kindergarten through fourth-grade students. This instructor had 3.5 years of experience as a special education teacher. She had a bachelor's degree in special education and was a graduate student working towards her masters in learning disabilities.

The intervention took place during a 10 week period. The intervention occurred during each student's resource time for mathematics. All testing was completed in the resource classroom which was quiet and free from distractions.

This study used a multiple baseline design across individuals (Kazdin, 1982). A multiple baseline design was chosen to allow all participants to receive the intervention while providing baseline information in order to study the effectiveness of Folding In for teaching math facts. The students were randomly placed as student 1, student 2, and student 3 to determine which student would receive the intervention first. Student 1 (M.C.) received 6 weeks of intervention, student 2 (J.M.) received 4 weeks of intervention, and student 3 (E.C.) received 2 weeks of intervention. During each week of intervention, each student received the intervention on day 1 and was given the CBM probe on day 2. On day 3 the intervention was implemented and on day 4 a second CBM probe was given. Day 5 was used to implement the intervention or a CBM probe due to illness or absence. Each Folding-In intervention took approximately 20 minutes.

Results

Math Fact Accuracy

Study 1. At the beginning of each intervention session, data was collected for the accuracy in answering 121 addition and subtraction facts to 10. R.S. increased her accuracy with math facts to 10 from 87% to 96%.

Study 2. When assessed on 266 addition and subtraction facts of sums 10 through 18, two of the three students improved the percentage of facts answered correctly. Student 1 (M.C.) improved from 35% to 50%; Student 2 (J.M.) improved from 52% to 67%; and Student 3 (E.C.) decreased accuracy from 60% to 58%.

Effect sizes for all dependent measures were calculated with Cohen's $d = \frac{M_1 - M_2}{\sqrt{SD_1 + SD_2/2}}$.

Effect sizes were evaluated using Cohen's effect sizes of .20, .50, and .80 as small, medium, and large, respectively (Cohen, 1992). The effect size of the math fact accuracy for students in both studies was medium with a Cohen's $d = .51$.

Woodcock Johnson III.

Pre-test and Post-test results for the Math Calculations and Math Fluency subtests are in Table 1. The Math Calculations effect size was medium ($d = .61$) and the effect size for the Math Fluency subtests was large ($d = 1.05$).

CBM. Graphs of the CBM data are provided in Figures 1 and 2. All students made gains in the number of correct digits from baseline to follow-up. However, data collected during the intervention period were more variable for three of the four students. M.C. showed the most gains during intervention. M.C. had been randomly selected to receive the intervention first in the second study which provided him with the highest number of intervention sessions. M.C. received 12 intervention sessions during the study.

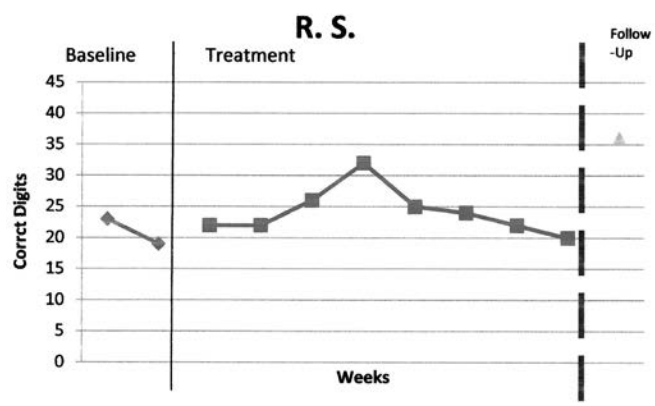
Table 1

Woodcock Johnson III Standard Scores from Pretest to Postest

	Math Calculations		Math Fluency	
	Pretest	Posttest	Pretest	Posttest
Study 1				
Student 1 (R.S)	86	86	92	100
Study 2				
Student 1 (M.C.)	78	77	67	77
Student 2 (J.M.)	83	88	80	96
Student 3 (E.C.)	82	87	74	80
Mean	82.25	84.5	78.25	88.25
SD	3.30	5.06	10.58	11.44

Figure 1

Study 1: CBM progress monitoring of basic math facts.



Discussion and Recommendations

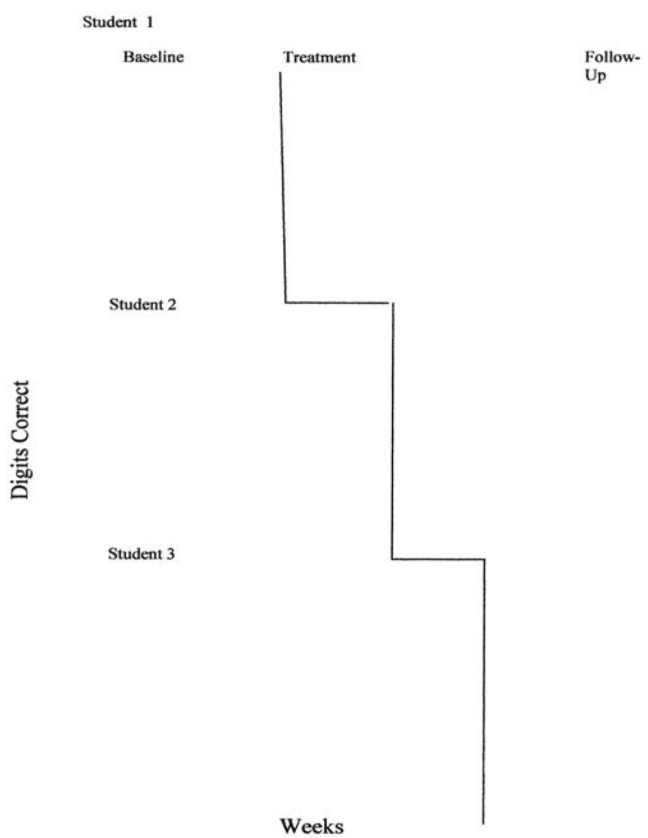
In this study students made progress toward improved accuracy and fluency of addition and subtraction math facts. A large effect was found on the math fluency measure while moderate effects were revealed on the math calculations subtest and math fact accuracy. These findings are encouraging based on the duration and frequency of the intervention. The findings from this study support the use of the folding in of basic math facts with students who have deficits in the area of mathematics.

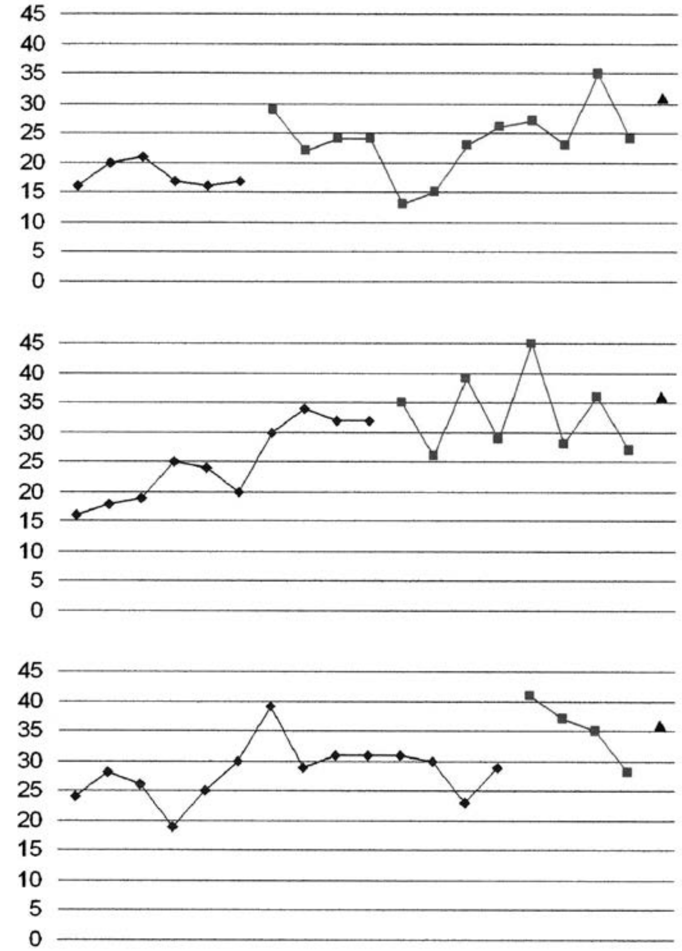
Based on the results, recommendations can be made to improve the implementation of the Folding-In intervention. In the first study the Folding-In intervention was implemented once a week, in the second study Folding-In was implemented twice a week. Based on comparison between studies and students in study 2, it is recommended that the intervention be implemented a minimum of two times per week for at least a six weeks. The student in study 2 who received the intervention twice a week for 6 weeks made the most improvement as shown by the CBM graph. This recommendation for the frequency of the intervention is supported by Burns' (2005) conclusion regarding the correlation between the automaticity of math facts and the number of opportunities to respond to instruction.

Although the students demonstrated improved accuracy and improved fluency on some measures, the question of their CBM assessment information remains. Students demonstrated a moderate effect on the Math Calculations subtest of the WJ III and a had large effect on the Math Fluency subtest of the Woodcock-Johnson III, but had inconsistent weekly performance on CBM's. Follow-up data indicated that all students maintained improvements in fluency as compared to their baseline CBM fluency scores. This information combined with improved WJ III Fluency standard scores indicated

Figure 2

CBM progress monitoring of basic math facts.





a positive application of the Folding-In intervention for these students. The pretest to posttest improvements in fluency scores also may suggest that the Folding-In procedure in conjunction with CBM progress monitoring can positively impact math fact fluency. While the test-taking component of CBM progress monitoring alone has not been shown to directly improve fluency (Stecker & Fuchs, 2000), the students in this study benefited from the weekly feedback they received in charting their results.

Although the data for both studies proved favorable to use of Folding-In as an effective mathematics intervention, continued research in its use with other subjects and settings is recommended to support these findings. The implementation of the intervention was provided for 12 weeks across two educational settings with instruction provided by a certified special education teacher; further research should examine its use as an individual intervention for longer periods of time. This study provides not only the ongoing data collected for each student throughout the intervention period, but it also provides explicit instructions so that it can be applied with other students in other settings (Kratochwill, 1992). In addition, the impact of daily math instruction cannot be ruled out as a contributing variable to the student's success.

The results of both studies support the present body of research in the area of mathematics interventions. While Burns (2004) and MacQuarrie, et al. (2002) reported consistent results for the use of drill tasks with an appropriate instructional ratio of known and unknown sight words, this current study confirms Burns' (2005) findings that similar drill tasks can positively affect the learning of basic math facts. Before any math fact drill task intervention can be implemented, it is essential that students first have a conceptual understanding of the targeted mathematical process (i.e. addition and/or subtraction). A foundational understanding of addition and subtraction, combined with fluency in basic math facts, helps students develop more flexibility in approaching math problem-solving tasks (Varol & Farran, 2007).

It is recommended that future research includes examining the minimum number of intervention sessions necessary in order for change in math achievement. Another area of interest includes the practical application of the Folding-In intervention that includes other individuals such as paraeducators and parents who can implement the Folding-In procedure. The Folding-In procedure includes detailed step-by-step directions. With training and supervision by an appropriately credentialed educator, paraeducators and parents could be trained to implement the intervention.

Limitations to the current study include a limited number of students within a narrow age range. It is recommended that future research with the Folding-In intervention include early elementary students as well as upper elementary and middle school students. Having basic mathematics skills in place in early elementary is critical and interventions to assist students with difficulties in mathematics are needed. Another limitation would be the length of the intervention. Future research will need to determine the most effective use of time with the Folding-In intervention.

Conclusion

Overall, the effectiveness of the Folding-In intervention for the students in this study supports further research in using this strategy with other students who are struggling with basic math fact recall. Folding-In incorporates several research-based recommendations for effective mathematics interventions. Include those research-based recommendations here. Society continues to place a high demand on proficiency with mathematics tasks. When appropriately monitored and modified using CBM data, Folding-In is a valuable tool for educators seeking to prepare struggling math students for the demands of life-long math skills.

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Appendix
Folding-In Technique with Math Facts

Preassessment Phase: To determine which number facts are known and unknown, at the beginning of each session the student is administered a quiz in which he or she is asked to answer computational problems. The number of problems not answered within 3 seconds or incorrect provides an indication of the facts that have and have not been learned. This data is recorded to test for retention of known facts.

Instructional Structure: The student then participates in a 20-minute session in which facts are reviewed using the Folding-In technique.

Step 1: The student selects 7 cards from the pile of preassessed known facts.

Step 2: The student selects 1 card from the pile of preassessed unknown facts.

Step 3: The teacher presents the first unknown fact to the student. The student is required to write the fact on a piece of paper, say it to him/herself three times, and then turn the paper over.

Step 4: The teacher presents the flashcards in the following order –

1st unknown, 1 known
1st unknown, 2 known
1st unknown, 3 known
1st unknown, 4 known
1st unknown, 5 known
1st unknown, 6 known
1st unknown, 7 known

Step 5: The group of known facts are shuffled. The 2nd unknown fact is then presented and the student writes the fact, says it three times, and turns the paper over.

Step 6: The teacher presents the flashcards as follows –

2nd & 1st unknown, 1 known
2nd & 1st unknown, 2 known
2nd & 1st unknown, 3 known
2nd & 1st unknown, 4 known
2nd & 1st unknown, 5 known
2nd & 1st unknown, 6 known
2nd & 1st unknown, 7 known

Step 7: This process is repeated again for the third unknown fact.

Step 8: If the student hesitates or is incorrect on any fact, the teacher instructs him/her to complete a brief correction procedure. The teacher tells him/her the correct answer and has him/her write the incorrect fact three times. The incorrect fact is then presented again to the student.

Step 9: When all facts have been folded in, the entire group of 10 facts is presented three times. Each time, the packet of index cards is shuffled to prevent the student from simply remembering the sequence of responses.

Step 10: The final step is a test of the 10 facts that the student has practiced. On this test, a mark is placed on the unknown fact cards if a student is correct on this trial. When an unknown fact attains three consecutive marks, it is considered a learned fact.