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ORIGINAL PAPER

Enhancing Multiplication Performance in Students with Moderate Intellectual Disabilities Using Pegword Mnemonics Paired with a Picture Fading Technique

Dimitrios A. Zisimopoulos

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Abstract The present study examined the effectiveness of an instructional package that included an adapted version of pegword mnemonics paired with a picture fading technique in teaching two students with moderate intellectual disabilities to recall 28 single-digit multiplication facts between 2 and 9. The instructional package was assessed using a multiple baseline design across students. Results indicated that instruction produced substantial and immediate effects in that both students increased their accuracy at recalling basic multiplication facts, maintained the newly acquired skill, and were able to generalize it across material, format, and another trainer. These results have implications for teaching students with intellectual disabilities basic math facts that are considered important for gaining access to the general curriculum.

Keywords Intellectual disabilities · Pegword mnemonics · Picture fading technique

Nowadays, ordinary classrooms in mainstream schools consist of an ever widening culturally, linguistically, and academically diverse student body, including a growing number of students with intellectual disabilities. Although children without disabilities acquire basic skills with few problems, children with intellectual disabilities often complete their schooling without mastering such skills (Parmar et al. 1994). Due to this lack of knowledge of math facts, students may learn neither math computation nor higher-order mathematics (Vaughn et al. 2007). However, the No Child Left Behind Act of (2001) requires that all students, regardless of their

D. A. Zisimopoulos (✉)
Faculty of Primary Education, University of Patras, V. Varela Palaiopanagia, 30300 Nafpaktos, Greece
e-mail: dzisimop@sch.gr

disability, should be included and make adequate yearly progress in high-stakes assessments. Nevertheless, while great efforts have been made in order to conceptualize how to gain access to the general curriculum for students with learning disabilities, few of these efforts have addressed the needs of learners with intellectual disabilities (Wehmeyer et al. 2002). Therefore, teachers need to reconsider the process through which the educational programs of students with intellectual disabilities are designed and implemented so as to ensure that access to the general curriculum is provided (Wehmeyer et al. 2001).

In mathematics education over the last two decades, emphasis has been placed on developing children's conceptual understanding and problem solving rather than computational skills in order for children to construct their own knowledge base (Kroesbergen and Van Luit 2005). Nevertheless, even advocates of contemporary approaches to mathematics acknowledge that automaticity in math facts has an important role to play (Isaacs and Carroll 1999). Therefore, one of the essential components for developing mathematical thinking according to the guidelines in the National Council of Teachers of Mathematics (NCTM 2000) Standards is the attainment of computational fluency (i.e., speed and accuracy). Component skills have to be learned fluently prior to the instruction of a composite skill (e.g., problem solving), so that students may readily acquire the more advanced composite skill (e.g., Carnine et al. 2004; Stein et al. 1997). Similarly, in the Greek Individual Subject Curriculum regarding Mathematics for students with mild and moderate intellectual disabilities who attend a special or an inclusion class, emphasis is given to the fundamental goal of mathematics instruction, that is, problem solving in the context of everyday life situations. However, component skills, such as multiplication facts, are considered as a means to solve more complex problems (MNERA-PI 2004).

Traditionally, the instruction of basic mathematical skills has been the focus of mathematics curricula designed for students with intellectual disabilities. Accuracy in counting, recognizing numerals, and multiplication facts are among those basic skills that are considered functional for students with intellectual disabilities in order to achieve successful inclusion into school and adequate levels of independent living as adults (Shapiro 1996; Butler et al. 2001).

Nevertheless, although multiplication facts are a fundamental part of the primary math curriculum, students still practice them by writing down the series of numbers, "looking at them", reciting them, and listening to tapes (Steel and Funnell 2001). In addition, in order to solve basic mathematical problems, students with mild disabilities often use counting strategies (Lerner 1999), which are considered insufficient for multiplication, division, and more complex problems (Stein et al. 1997).

It is worth mentioning that comprehensive reviews of the literature focusing on teaching strategies for students with intellectual disabilities have been sparse, including only a few studies referring to basic math facts (Butler et al. 2001; Mastropieri et al. 1991). The findings support the use of direct teaching procedures such as a task analysis approach, modeling, prompting, feedback, time trials, and peer tutoring. Furthermore, Browder et al. (2008) in their extensive meta-analysis on teaching mathematics to students with significant cognitive disabilities found that systematic instruction should include the use of a specific prompt fading procedure with feedback to teach a set of defined responses across time.

Prompt fading is an errorless procedure that involves the addition of a prompting stimulus that is gradually removed or faded by reducing its intensity or components (Browder and Lalli 1991). Numerous studies have employed variations of prompt fading on academic tasks for persons with moderate to severe disabilities (e.g., Lalli and Browder 1993; Rivera et al. 2002; Wolery et al. 1992). Research has shown the effectiveness of the use of prompt fading strategies in word-recognition teaching (e.g., Rivera et al. 2002; Tien-Yu and Ming Chung 2005); however, relevant studies in teaching basic math facts are not plentiful. One such example is the study by Morton and Flynt (1997) who compared the effectiveness of two prompting techniques—constant time delay and prompt fading—for teaching multiplication facts to elementary students with learning disabilities and found that both procedures were effective.

Review of the special education literature also reveals a large body of research concerning mnemonic strategies as a viable instructional option that may increase student performance (e.g., Mastropieri and Scruggs 2000; Pressley et al. 1982; Scruggs and Mastropieri 2000). Mnemonic strategies are systematic procedures for enhancing memory by providing effective cues for recall as a "cognitive cuing structure" such as word, sentence, or picture devices (Bellezza 1981). Through these procedures, students develop better ways to encode new information for easier retrieval (Mastropieri and Scruggs 1998). Mnemonic strategies are commonly divided into imagery illustrations, such as pictures or diagrams, and word-based devices, using words to aid memory (Access Center 2003). It is considered though more effective to integrate imagery illustration and word-based devices as opposed to using them separately (Lee et al. 2006).

Nevertheless, research related to the use of mnemonic strategies for the improvement of basic multiplication fact recall has been sparse, focusing mainly on students with learning disabilities. Greene (1999) and Wood and Frank (2000) examined the utility of pegword mnemonics regarding only 14 and 15 multiplication facts, respectively, that were identified as most difficult to memorize by the participants (i.e., students with learning disabilities). In the pegword strategy, numbers are associated with rhyming pegwords (e.g., one-sun) and pictures resulting in the answer. There is only one research study to date describing the effectiveness of a multimedia software program developed to teach students with learning disabilities and mild intellectual disabilities to effectively use peg and keyword mnemonic strategy to learn multiplication facts (Irish 2002). Although students were able to accurately retrieve a greater number of multiplication facts after intervention in this particular study, students with mild intellectual disabilities did not manage to achieve scores indicative of mastery (i.e., scores greater than 85%).

In the light of the findings of studies that have been conducted regarding the effects of mnemonics and their potential benefit for a fraction of the students with mild disabilities, more research is warranted regarding their effectiveness to teach students with moderate intellectual disabilities how to accurately recall multiplication facts. Moreover, results of recent research indicate that instruction in strategies alone does not necessarily lead to automaticity (Woodward 2006); frequent practice is essential (Cumming and Elkins 1999). Furthermore, the use of time-consuming strategies, such as the pegword strategy, for solving basic math facts directly interferes with fluency in such facts. It is considered important that once students acquire basic math facts, the use of time-consuming strategies be faded (Jolivette et al. 2006). Therefore, the primary goal of the present study was whether or not the use of an adapted version of pegword mnemonics paired with a picture fading technique and systematic revision practice would increase accuracy of basic multiplication facts in students with moderate intellectual disabilities.

Specifically, the following research questions guided the study: (1) Is the adapted version of pegword mnemonics paired with a picture fading technique effective in teaching two students with moderate intellectual disabilities to recall accurately single-digit multiplication facts? (2) Would extended practice lead the two students to generalize the acquired skill across other material, format, and another trainer? (3) Would extended practice lead the two students to maintain their ability to recall multiplication facts over time?

Method

Participants and Setting

Participants in the study were two elementary students with moderate intellectual disabilities enrolled in a special education class of an elementary school located in a small urban school district in Nafpaktos, Greece. Formal assessment that was held by a Greek state multidisciplinary team included the Greek standardization of the *Wechsler Intelligence Scale for Children* (WISC-III) (Georgas et al. 1997), the *ATHENA Test for the Diagnosis of Learning Difficulties* (Paraskevopoulos et al. 1999) and educational assessment measures (criterion-referenced tests, checklists, etc.). Each student had experienced difficulties in mastering basic multiplication facts, as reported by their general class teachers. Participants were selected by their special education teacher to participate in the study because they had failed to adequately recall basic multiplication facts through traditional methods (i.e., drill and practice with flashcards) in general and special education class. They had learned only a few multiplication facts through rote memorization and a skip counting strategy (i.e., counting in multiples).

Konstantinos, an 11-year-old fourth grader, was diagnosed as having moderate intellectual disabilities and some difficulties in focusing and sustaining attention according to the interpretation of his performance on the WISC-III. He demonstrated infrequent, mild behavior problems such as inappropriately displaying frustration and being noncompliant when asked to do something he did not want to do. Nevertheless, he had very good expressive and receptive communication skills and was able to engage in conversation with his peers and teachers.

Konstantinos attended the special education class 2 h every day, receiving individualized or small-group instruction, and for the rest of the day, he remained in his regular classroom. His Individualized Education Program (IEP) included goals focusing on basic math computations in addition, subtraction, introductory multiplication, and telling time. It is worth mentioning that due to the lack of standardized measures of math achievement in Greece, criterion-referenced tests and curriculum-based measurements are the only reliable tools of assessment. Criterion-referenced test results conducted in the special education classroom revealed that he was demonstrating an emerging competence in basic operations with numbers up to 100 and that he was close to obtaining multiplication facts of 5 and 10′s. Specifically, Konstantinos was able to recall 70% of the 5 and 10 multiplication tables by using a skip counting strategy. According to the special education teacher, his main areas of weakness regarding math included multiplication facts and telling time. Regarding multiplication facts, he received instruction in the special education classroom the current year.

Nikos, a 12-year-old fifth grader, was diagnosed as having moderate intellectual disabilities. He was able to engage in conversations with peers and teachers, but had some difficulty articulating some words. He demonstrated no behavior problems and was very compliant to oral instructions. Regarding his strengths, he could add and subtract up to 100 and expressively stated time to the hour and half-hour. His IEP regarding math included goals focusing on basic math computations in multiplication and division, selecting money to purchase an item when given the price and coin combination, and telling time to 5-min intervals. Criterion-referenced test results conducted in the special education classroom revealed that he had obtained only multiplication facts of 5 and 10′s by using a skip counting strategy and a few more with small operands (i.e., 2×2, 2×3, 3×3) through rote memorization.

Both students were considered promising candidates for participation in the study since they had the following prerequisite skills: (a) visual and auditory acuity within normal limits, (b) a reading age of 7 years (c) attending to teacher and materials for at least 15 min, and (d) verbal imitation of spoken words. In addition, their school attendance was regular.

All sessions were carried out in the school's special education classroom. Participants received instruction individually from their regularly assigned special education teacher. The teacher was male, had a Master's degree in special education, and was experienced in systematic instruction and data collection. Prior to the implementation of instruction, the author provided the teacher with flashcards and an instruction script that delineated the steps of the pegword mnemonics and picture fading procedures. The author also conducted inter-rater and procedural reliability checks.

Each instructional session lasted from 10 to 15 min three times a week during their daily lesson in the special education classroom. All sessions were conducted individually. The engagement time varied depending upon the number of the multiplication facts that were included in the training sets and the individual student's speed of processing and responding. Regarding additional math instruction, the teachers who interacted with the students provided no classroom instruction or review of multiplication facts during the training period.

Materials

Twenty-eight multiplication facts were selected from the standard 1 to 10 multiplication table (see Table 1). Using the commutative law (e.g., $6 \times 8 = 8 \times 6$) and the principles of multiplication by zero and by one, the number of combinations to be mastered was reduced to 45 (Wong and Evans 2007). In addition, 5 and 10′s had been already mastered by the two students using a skip counting strategy (e.g., 5, 10, 15 …) and traditional flashcards; therefore, the number of facts to be learned further was reduced to a manageable 28 (Table 1).

These multiplication facts were displayed on flashcards in a mnemonic form, as proposed by Mastropieri and Scruggs (1991), Greene (1999), Wood et al. (1998) and Wood and Frank (2000), but with a few adaptations. As Wood and Frank (2000) stated, the pegword strategy is considered complicated for students; therefore, it was used in their study only for a few multiplication facts. The strategy requires that participants first associate the smaller numbers with previously taught rhyming pegwords (e.g., six-sticks and seven-heaven), then associate the larger number with a corresponding rhyming pegword (e.g., forty-two-warty shoe), and finally to remember the picture that had previously been associated with these two pegwords, resulting in the answer (e.g., $6 \times 7 = 42$; sticks in heaven with a warty shoe) (Greene 1999).

Students with intellectual disabilities exhibit deficits in attention, semantic memory, logical reasoning, and outer directedness. Therefore, they may demonstrate a more limited propensity to rehearse, organize, or elaborate upon new information (Scruggs and Mastropieri 1995). Due to this fact, an adapted version of the pegword strategy was used. Prior to the introduction of multiplication facts, students were taught to associate 15 number words with rhyming pegwords as proposed by Wood et al. (1998) (e.g., two-shoe and 30-dirty) with the addition of numbers 60 (sixty-witchy) and 70 (seventy-heavenly) (Greene 1999). One to three of these associations were introduced daily, depending on the learning rate of the participant, for a period of approximately 2 weeks before commencement of the main study. The criterion for moving onto the multiplication fact training phase was students' ability to say the correct pegword without prompts when orally provided with the corresponding number (e.g., for 32 the student responded ''warty shoe'') and the correct number when orally provided with the corresponding pegword for two consecutive days.

Table 1 Multiplication facts used in the study

First week sessions	2×2						
	2×9	3×9	4×9	6×9	7×9	8×9	9×9
Second week sessions	2×4	3×4	4×4				
Third week sessions	2×7	3×7	4×7	6×7	7×7		
Forth week sessions	2×3	3×3					
Fifth week sessions	2×8	3×8	4×8	6×8	7×8	8×8	
Sixth week sessions	2×6	3×6	4×6	6×6			

Three numbers, 12, 16, and 18, were not included in the pegword family since each of these numbers is the corresponding answer to two separate multiplication facts (e.g., $3 \times 4 = 12$ and $2 \times 6 = 12$). Therefore, these numbers were included in the second set of flashcards that contained multiplication facts without their answers on one side and corresponding pegwords or combinations of pegwords with visual associations on the other side. For example, the number 32 was illustrated by combining ''dirty'' for number thirty and ''shoe'' for number two. At this point, the use of the pegword strategy was adapted in two distinct ways in order to be introduced in a meaningful context without leading the students to the demanding corresponding elaborations usually provided with the strategy. Greene (1999) and Wood et al. (1998), in order to help students encode new information for easier retrieval, designed their pegword strategy so that it associates the answer 32 to the multiplication fact 4 (door) $\times$8 (gate) with the corresponding pegword combination ''dirty shoe'', leading the students to remember the fact and the answer with the complex pegword association ''door on a gate by a dirty shoe''. In the current approach, the proposed pegword combination ''dirty shoe'' was used as well; however, instead of the above pegword association, the more meaningful sentence ''a dog is fetching a dirty shoe'' was used. One might say here that this approach does not assist students in building a ''semantic memory'' bridge between the multiplication fact, the pegword combination, and the subsequent answer as stated by Greene (1999). Therefore, in an effort to help students recall the corresponding pegword combination and the subsequent answer to the multiplication fact, a ''visual memory'' bridge—that is a picture identical to the one that is associated with the pegword combination—was added on the side of the flashcard that contained the multiplication fact without its answer. In order to gradually shift students' attention from pictorial prompts to multiplication facts, a pictorial prompt fading strategy was employed. More specifically, according to the picture fading steps of this technique, four types of instructional flashcards were created for each multiplication fact. The first type of instructional flashcards contained a multiplication fact and an answer on one side printed in 30-point Times New Roman font, with a picture drawn below the algorithm and the corresponding pegword phrase, which were orally presented to the student by the special education teacher. The second type contained the same multiplication fact and the picture, without the answer, and the pegword phrase. The third type contained the multiplication fact without the answer printed in 48-point Times New Roman font with the same, but faded, picture. The fourth type of instructional flashcards contained the multiplication fact printed in 48-point Times New Roman font without the presence of the picture. The math fact was located in the center of the flashcard. This certain type was used as well in baseline probes, weekly training probes, and follow-up sessions. A sample of instructional flashcards is shown in Fig. 1. However, it is worth mentioning that the proposed use of pegword combination is not the only version, and further adaptations by teachers can be used as well.

A probe sheet, which contained in random order the 28 multiplication facts introduced throughout the practice sessions printed vertically, was used to record students' responses during the generalization sessions.

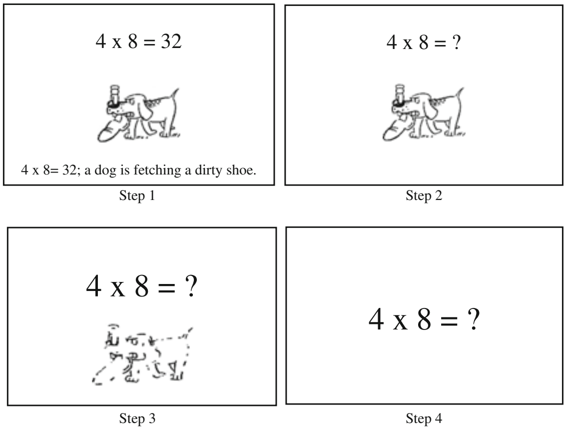

Fig. 1 Sample overlays of four instructional flashcards

Dependent Measure and Data Collection

The dependent variable used to evaluate the efficacy of the instructional package was the percentage of multiplication facts the participants answered correctly in the assessments conducted during baseline, training, generalization, and follow-up sessions. Two-minute probes were used to collect data on correct responses in baseline and follow-up sessions. During baseline and follow-up sessions, once the student was prompted to begin, the special education teacher started the countdown timer and after the 2-min period prompted the student to stop. The student was shown the fourth type of instructional flashcards of each fact described above and was asked by the special education teacher to provide the correct answer without counting on fingers. Facts for which the student gave the correct answer within 4 s were identified as known. Those for which the student gave an incorrect answer, no answer, or the correct answer after 4 s were identified as unknown. If a student made a self-correction within the 4-s time period and it was correct, the answer was coded as correct. Students' response was scored as correct or incorrect on the data-recording sheet, which was hidden from view. During training, probes were conducted weekly throughout the duration of the study in an identical way with the probes in the baseline and follow-up sessions. Training probes, however, included only the set of multiplication facts that students were practicing at the certain week and the sets that had already been practiced in previous weeks. During generalization sessions, 2-min probe sheets were administered to students who were asked to say the fact aloud and complete the correct answer in the probe sheet.

Mastery was defined as the student's accurate response within 4 s in more than 90% of the multiplication facts that were included in the probes.

Experimental Design and Conditions

A single-subject multiple baseline design across subjects was employed in the study to demonstrate experimental control and to evaluate the effectiveness of the instructional package. Multiple baseline designs are particularly useful for measuring the acquisition of academic skills over time (Tawney and Gast 1984). Although multiple baseline research designs often include three or more subjects in order to demonstrate treatment effectiveness, two subjects are considered appropriate (Kazdin 1982; Richards et al. 1999). The dependent variable in this research was the percentage of correct responses regarding previously unknown multiplication facts. The independent variable was the instructional package of adapted pegword mnemonics paired with the picture fading procedure. The instructional package was introduced to the first student (i.e., Nikos), once the baseline performance was stable. The baseline condition was maintained for the second student (i.e., Konstantinos). When the first student obtained mastery criterion on the third set of multiplication facts, the intervention was introduced to the second student. Immediately following the training phase, generalization sessions were held while follow-up sessions were conducted at 1, 3, and 10 weeks in order to assess maintenance.

Procedure

Baseline

During the baseline, in order to establish relative accuracy, recall of basic multiplication facts was measured by the number of correct responses to 28 single-digit multiplication facts that were presented on separate computer-printed 4 × 6 in white index cards. Baseline probe sessions occurred in a 1:1 arrangement. At the beginning of each baseline assessment session, the special education teacher confirmed the student's willingness to participate. In addition, each student was encouraged to do his best. They were reassured that there was no problem if they could not respond to any multiplication fact. Students were shown multiplication facts without answers in a random order and asked by the special education teacher to give the correct answer within 4 s. During baseline, the students were not provided feedback about their performance. They were, however, socially reinforced for attending and staying on-task. Multiplication facts scored incorrect for three consecutive assessment sessions were added to the student's individual multiplication instructional package.

Pegword Mnemonics Paired with a Picture Fading Technique

During this phase, the special education teacher introduced the unknown multiplication facts using pegword mnemonics paired with the picture fading technique and systematic review practice. In the presentation of the timetables, the pattern suggested by Silbert et al. (1990) was followed, that is 10, 2, 5, 9, 4, 7, 3, 8, and 6 timetables with the exclusion of 0, 1, 5, and 10 timetables and the commuted pairs were used in order to reduce the multiplication facts to a manageable 28. Therefore, the number of multiplication facts included in each training set varied in number from two to eight facts. In addition, the order of the flashcards was changed between each trial so that the order of presentation was not predictable.

Training sessions for every set of multiplication facts were started by confirming the student's willingness to participate. Following the student's assent to participate, the special education teacher delivered each set of multiplication facts. There were four steps for teaching each multiplication fact. During the first step, he presented the following prompt: "I'm going to show you a multiplication flashcard with a picture and a sentence on it. I want you to listen carefully and repeat what I say". Afterward, the teacher placed the first type of the instructional flashcards on the table in front of the student and immediately modeled the correct response (e.g., $4 \times 8 = 32$; A dog is fetching a dirty shoe). Each student was expected to imitate the model and give the correct response. Following correct responses, the special education teacher restated the answer made by the student by saying, "Yes, the answer is thirty-two, a dog is fetching a dirty shoe", providing the student with social reinforcement (i.e., a verbal praise). Following incorrect responses, the special education teacher gave corrective feedback by saying, "No. The answer is thirty-two, a dog is fetching a dirty shoe. Repeat it". In the case of no response, the same corrective feedback was given to the student. Subsequently, the special education teacher associated the correct answer with the corresponding rhyming pegword (i.e., thirty-two-dirty shoe) by saying, "What is the answer to the multiplication fact? Thirty-two. What is the last phrase in the sentence? Dirty shoe. Listen. Thirty-two—Dirty shoe. Do they end the same? Yes! Thirty-dirty and shoe-two". Each student remained at the first step until he had correctly responded to the model on three consecutive presentations.

The same instructional procedure was repeated during the second step of the training. In this step, the special education teacher presented the second type of flashcard. If the student responded correctly, verbal praise was given. If the student responded incorrectly or was unable to respond, he repeated the previous step in the training. If the student then responded correctly on that trial, the second type of flashcard was reintroduced and the fading procedure continued. The students would not move to the next fading step until they responded correctly on three consecutive presentations of the second type of flashcards. The instruction procedure was repeated identically in the third step (the flashcard with the faded picture and the multiplication fact without its answer) and the final step (the flashcard with the multiplication fact without its answer). Training sessions continued with each set of multiplication facts until the student had responded to each multiplication fact with at least 90% accuracy on two consecutive days. At the end of each session, a cumulative revision of all the multiplication facts that had been practiced until that session was conducted. Subsequently, the participants were allowed to play with a digital educational game on the special education classroom's desktop.

Generalization

Generalization sessions were held in the special education classroom on three consecutive school days immediately after the completion of training sessions. Both students demonstrated generalization of the multiplication facts across another trainer, material, and format of the multiplication facts. Regarding setting, the author was not granted permission to arrange generalization sessions in their general classes. To assess generalization across material and format, both students were prompted to complete a 2-min probe sheet containing the 28 multiplication facts that were introduced during the training phase in a vertical orientation as proposed by Koscinski and Gast (1993). In addition, to assess generalization across trainers, another school teacher administered the probe sheet in the special education classroom. At the end of each session, students were socially reinforced for the completion of the task.

Follow-Up

Follow-up sessions were conducted with Konstantinos and Nikos after 1, 3, and 10 weeks, in order to assess maintenance. Two-minute probes were administered in the same manner as during the baseline phase. Each student participated in the follow-up probe sessions individually. At the end of each session, students were socially reinforced for their effort.

Reliability

Interobserver agreement was based on the number of correct responses. All responses in probes and probe sheets were scored regarding accuracy by the special education teacher during all phases and simultaneously by the author as well in 33% of the sessions. Percent agreement for the number of multiplication facts mastered was calculated by dividing the number of agreements by the sum of the agreements and disagreements and multiplying by 100. The mean interobserver agreement for the number of multiplication facts mastered was 98% (range 95–100%).

During training, procedural reliability data were collected on 38% of all sessions with regard to: a) implementation of strategy steps by the special education teacher and b) error correction and feedback use. The information was recorded on an implementation checklist. The special education teacher's level of procedural fidelity was calculated by dividing the number of steps implemented correctly by the number of correct plus incorrect steps and multiplying by 100. Results indicated 99% compliance with the designated procedure.

Results

Recall of multiplication facts was measured by the percentage of correct responses regarding the 28 math facts described in Table 1. The students' scores were tracked on weekly probes in order to evaluate the effectiveness of mnemonics. Overall, the two participants responded in a similar way to the instructional approach. Figure 2 depicts the recall data for each student separately regarding accuracy scores across the phases of the study. Both students consistently responded at a 0 to 7% correct level on all baseline probes of the unknown multiplication facts. The data

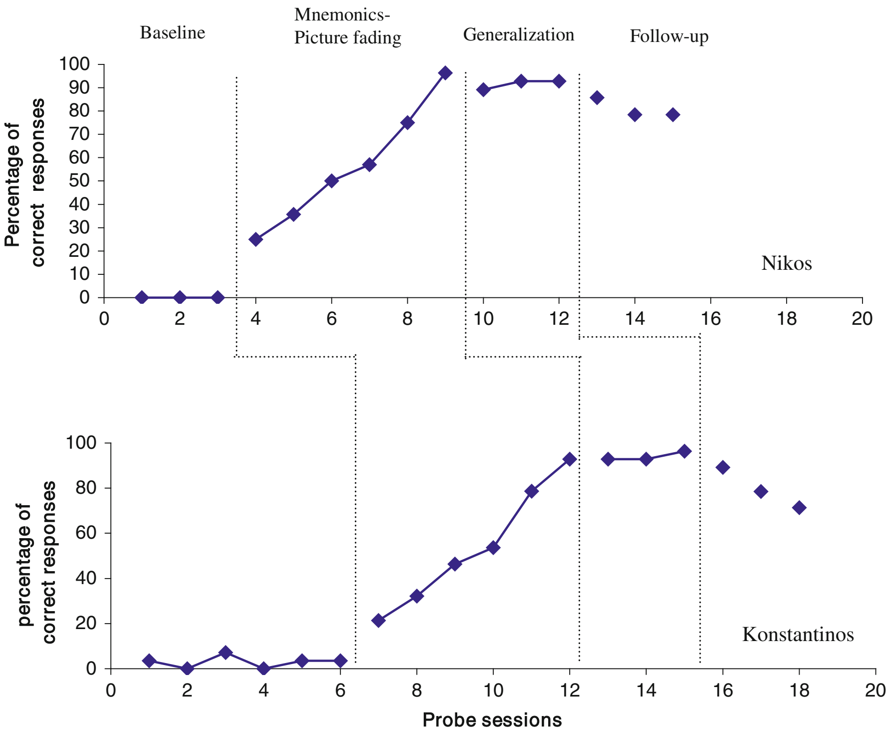

Fig. 2 Students' percentages of correct responses on probe sessions

concerning the training phase indicate that pegword mnemonics paired with picture fading technique were effective in teaching the two students multiplication facts. As can be seen from the figure, Konstantinos and Nikos met the established criterion (scores greater than 90%) during training, showing a substantial improvement in performance. Instruction with mnemonics yielded immediate improvement to nearly errorless performance. More specifically, Konstantinos responded at a 0% correct level during the baseline probes. When mnemonics paired with the picture fading technique and systematic reviews were implemented, Konstantinos responded correctly in 96.4% of multiplication facts in 18 sessions with percentage scores ranging from 25 to 96.4%. Nikos responded at a 0% to almost 7% correct level during the baseline probes. During training, Nikos reached the mastery criterion within 18 sessions. His multiplication percentage scores ranged form 21.4 to 92.8%.

Generalization and follow-up data also revealed the effectiveness of the intervention. In generalization sessions, both students were able to generalize their new knowledge across another trainer, material and format of presentation regarding multiplication facts. Konstantinos's performance ranged from 92.8–96.4% and Nikos's from 89.2–92.8%. During follow-up, Konstantinos's and Nikos's performance ranged from 78.5–85.7% and 71.4–89.2%, respectively.

Discussion

The principal aim of this study was to examine the implementation of an integrated approach including an adapted version of a pegword strategy and picture fading technique for teaching students with moderate intellectual disabilities to recall multiplication facts. Teaching students with intellectual disabilities basic skills in mathematics is considered an important educational as well as vocational goal (Heward 2006). Students with such skills are more likely to be independent and able to shop, make change, hold a job, and live independently. Despite the importance of basic math facts in everyday life, little of the research has involved students with moderate intellectual disability. In part, this may be because it is assumed that very low intelligence explains poor mathematical skills in this group of students. However, as Conners et al. (2001) have shown, intelligence is neither the only nor the most important predictor of students' success in learning. Previous studies reported successful use of pegword mnemonics (Irish 2002) and prompt fading (Morton and Flynt 1997) in teaching multiplication facts to students with mild disabilities. No research is reported, however, using these instructional procedures in teaching basic math facts to students with moderate intellectual disabilities. Therefore, the results of this study replicate and extend previous research on ways to enhance the academic performance of the aforementioned students.

More specifically, the research was carried out in order to determine whether or not increased accuracy in recalling multiplication facts can be extended to all basic multiplication facts (2′s through 9′s with the exception of 5′s), generalized across material, format, and another trainer, and maintained over time. Overall, the two participants responded in a similar way to instruction. After instruction was received, both participants' accuracy in all basic multiplication facts was greater than 90%. The improved accuracy scores for Konstantinos and Nikos were rather surprising. It appears that although students with moderate intellectual disabilities face enormous academic difficulties during their school life, they can successfully employ a mnemonic strategy. Konstantinos, in particular, demonstrated consistent task engagement. Difficulties in focusing and maintaining his attention on the math tasks were reduced greatly. Perhaps the use of visual representations and pegword associations increased students' attention and built a more elaborate mental framework for multiplication, leading to more efficient storage and retrieval of information (Flores et al. 2006). As Scruggs et al. (1987) stated, mnemonic strategies can enable students to learn new skills or information in a way that is more meaningful to them through acoustic-imaginal linking. Therefore, general potential of mnemonic strategies can be extended to benefit a wider range of students, including students with intellectual disabilities. In addition, Mastropieri and Scruggs (1991) reported that students preferred mnemonic instructional methods and materials to conventional ones. Students' preference of mnemonic instruction is considered an important factor because students are unwilling to make efforts with strategies which they feel are not effective.

A second possible explanation for both students' performance may be the use of a picture fading technique that requires the students to respond to a relatively predictable visual cue. Anecdotally, students reported that they were enjoying the instruction, each time looking forward to the next session, maybe because they preferred the highly predictable answer prompt always present on the flashcards. Finally, learning styles may have influenced students' willingness to participate in the study, since students whose learning modality is visual may prefer prompt fading (Morton and Flynt 1997).

Furthermore, generalization data indicate that both students were able to generalize the new skills across typical materials that are commonly used in general education classrooms (i.e., probe sheets). This is considered important since generalization to nontrained stimuli is a well-documented problem for students with moderate disabilities (Westling and Fox 2000). Finally, maintenance data indicate that students with intellectual disabilities can preserve the newly acquired skills, although practice would be required occasionally in order for them to meet the established criterion.

Although the present study provided support regarding the accuracy in recalling multiplication facts of students with moderate intellectual disabilities, three limitations in the area of external validity, the degree to which the results can be generalized beyond the experimental conditions (Kazdin 1982) should be acknowledged and considered in interpreting these findings. First, that participants in this study are not representative of all students with moderate intellectual disabilities restrict the generalizations that can be made about the effectiveness of the instructional package to the whole population of students with similar intellectual disabilities. A second reason for exercising caution when interpreting the results of this study is that both students were instructed individually in a quiet setting. Therefore, the results should not be generalized to inclusive settings such as a general education classroom without further research. Additional research is considered necessary regarding the participation of more students and the implementation of the proposed integrated approach to different settings including class-wide application and learning centers. Third, the generalization measures in this study did not extend to problem solving and real world application of skills as called for by the National Teacher of Mathematics Standards (2000). Future research should involve instruction and measurement in this area.

There is one more limitation of this study, which hinders the direct comparison across phases. At different phases, different numbers of trials were used; therefore, the percentages were computed on sets of tasks which were not identical in respect to their number of probes. For this reason, Fig. 2 should be interpreted with caution when comparing one phase to another. More research is needed as well to examine the effectiveness of the integrated approach in teaching other essential mathematical skills highlighted in NCTM standards and Greek Individual Subject Curriculum for students with mild and moderate intellectual disabilities. Finally, the instructional approach used in the current study contains many different components. Future researchers should conduct component analysis studies to determine which component or combination of components leads to the increases in accuracy.

Although it is important to note the limitations described above, the current data suggest that accuracy in recalling multiplication facts in students with moderate intellectual disabilities can be enhanced by using an instructional package including pegword mnemonics and a picture fading technique with systematic review practice. The effectiveness of the instructional package to teach both students acquisition, storage, and retrieval of basic multiplication facts demonstrates the viability of this option for students with moderate intellectual disabilities.

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