JOURNAL OF APPLIED BEHAVIOR ANALYSIS 2007, **40,** 223–237 NUMBER 2 (SUMMER 2007)

TEACHING MATH SKILLS TO AT-RISK STUDENTS USING HOME-BASED PEER TUTORING

KRISTIN H. MAYFIELD AND TIMOTHY R. VOLLMER

UNIVERSITY OF FLORIDA

Home-based peer tutoring was used to teach math skills to 4 girls with deficits in mathematics and histories of abuse or neglect. Girls living in the same home formed tutoring dyads, and each participant served as both the peer tutor and the tutee during the course of the study. At the initiation of the tutoring intervention, an expert tutor provided multiple 3-min tutoring sessions to the designated peer tutor on three or four mathematics skills. The peer tutor concurrently provided 3-min tutoring sessions on the same skills to the tutee using a multiple baseline design. Results showed that participants improved their performance on all target skills. Additional interventions were implemented for some skills to improve accuracy further. Maintenance tests were also administered after 3 to 5 months of no practice on the skills. Results showed that tutors and tutees maintained their accuracy on 7 of the 12 skills assessed.

DESCRIPTORS: maltreated youth, mathematics, peer tutoring

Peer tutoring is an intervention in which one student provides instruction or academic assistance to another student. Research on peer tutoring has demonstrated educational benefits for tutors and tutees of various ages and abilities, ranging from kindergarten to secondary school, and children with autism to average achievers (e.g., Calhoun & Fuchs, 2003; Dineen, Clark, & Risley, 1977; Fuchs, Fuchs, & Karns, 2001; Kamps, Barbetta, Leonard, & Delquadri, 1994; Sideridis et al., 1997). Studies have shown that peer tutoring can improve performance in a variety of subjects including spelling, mathematics, high school driver education, and functional community skills (e.g., Bell, Young, Salzberg, & West, 1991; Blew, Schwartz, & Luce, 1985; Fueyo & Bushell, 1998; Kohler & Greenwood, 1990), and can be successfully implemented with tutors of various ability levels, including children with advanced skills and children with learning disabilities (Fuchs, Fuchs, Yazdin, & Powell, 2002; Johnson & Bailey, 1974; Mathes & Fuchs, 1994; Telecsan, Slaton, & Stevens, 1999). Taken together, this body of research has demonstrated a robust effect of peer tutoring across diverse educational settings and groups of students.

Given the variety of effective peer-tutoring interventions, it is likely that key procedural components are responsible for the outcomes. One way of identifying key components is to analyze the common features of well-documented peer-tutoring methods. Three such methods are reciprocal peer tutoring (Fantuzzo & Ginsburg-Block, 1998; Fantuzzo, King, & Heller, 1992; Pigott, Fantuzzo, & Clement, 1986), classwide peer tutoring (Arreaga-Mayer, Terry, & Greenwood, 1998; DuPaul, Ervin, Hook, & McGoey, 1998; Kamps et al., 1994), and peer-assisted learning strategies (Calhoun & Fuchs, 2003; Fuchs & Fuchs, 1995; Fuchs et al., 2001, 2002). These successful peer-tutoring interventions have been carried out in school settings and have typically provided supplemental practice for fundamental skills such as reading, spelling, or mathematics, but generally

This research was funded in part by a contract with the Florida Department of Children and Families. The content and opinions expressed herein do not necessarily reflect the position or policy of the Department of Children and Families. We thank Daniel Hackman, Anthony Nguyen, Mara Torres, Mara Baker, Linda Meckler, Taryn Manders, Courtney Ayers, and Cassie Coble for their assistance. Kristin Mayfield is now at iLearn, Inc.

Correspondence concerning this article should be addressed to Kristin Mayfield, 2715 NW 52nd Ave., Gainesville, Florida 32605 (e-mail: kris@ilearn.com).

doi: 10.1901/jaba.2007.108-05

have not been used to replace teacher-directed instruction in its entirety during the acquisition of new skills (e.g., Calhoun & Fuchs; Dufrene, Noell, Gilbertson, & Duhon, 2005; Kamps et al.). In addition, these interventions often involve extensive training (e.g., 4 to 8 hr) prior to implementation, the use of structured formats and predesigned materials to guide instruction, and precise methods of delivering feedback (Arreaga-Mayer et al.; Calhoun & Fuchs; Dufrene et al.; Fantuzzo et al.; Fuchs & Fuchs; Fuchs et al., 2001; Sáenz, Fuchs, & Fuchs, 2005).

Although these features of peer-tutoring programs may be important, peer tutoring may occur in situations that do not permit a similar amount of structure or training (e.g., children helping one another with homework after school). Therefore, it is important to determine if peer-tutoring interventions that lack some of these structured characteristics can also produce educational benefits. The current study was conducted to evaluate whether academic gains could result from a peer-tutoring intervention that did not include many of the common structured components of effective classroom-based peer tutoring.

A secondary purpose of the current investigation was to implement peer tutoring with previously maltreated children, who represent an at-risk population that has not been the focus of a controlled study on peer tutoring. In general, children with a history of abuse or neglect demonstrate significantly lower grades in math and reading compared to children without such histories (Eckenrode, Laird, & Doris, 1993), and roughly 25% to 40% (Burley & Halpern, 2001; Stein, 1997) receive special education services. Moreover, the negative effects of maltreatment on children's educational achievement persist even after they are removed from an abusive or neglectful environment (Colton, Heath, & Aldgate, 1995). Thus, we attempted to apply the beneficial effects of peer tutoring to these students.

METHOD

Participants and Setting

Four children had been referred by caregivers who were enrolled in a class that taught evidence-based parenting practices. The participants were selected because they were of school age, had a history of maltreatment, lived with another previously maltreated child in an out-of-home placement, and were available for experimental sessions. Two of the children were residing with a relative, and 2 of the children were residing in a group home. Amelia was a 9-year-old girl who was enrolled in general education classes in a public elementary school. Keesa was a 13-year-old girl who was enrolled in special education classes in a public middle school. Jada was a 15-year-old girl who was enrolled in an alternative school during part of the study and a public high school during the remainder of the study. Olivia was a 16-year-old girl who was enrolled in an alternative school during part of the study and a general educational development program during the remainder of the study. All children were concurrently enrolled in mathematics courses during the portion of the study that coincided with the academic calendar year. In addition, Amelia and Keesa also participated in one or two other mathematics interventions that targeted different mathematics skills than those required for the current study.

Pairs of tutors and tutees were formed by matching the children who lived in the same home, and all children served as both a peer tutor and tutee during the course of the study. The tutoring pairs were as follows: Pair 1: Amelia as tutor and Keesa as tutee; Pair 2: Keesa as tutor and Amelia as tutee; Pair 3: Jada as tutor and Olivia as tutee; Pair 4: Olivia as tutor and Jada as tutee.

Sessions were conducted in the children's homes. The experimenter visited the homes up to 5 days per week and typically conducted one to three experimental sessions per visit. The length of the sessions varied from approximately

5 min to 45 min depending on the phase of the study.

Materials

Practice worksheets. Ten-item practice worksheets were constructed for each of the arithmetic and prealgebra skills trained in the study (e.g., multiplying decimal numbers, solving proportions, simplifying radical expressions; descriptions and examples of each skill are available from the first author). Items on the worksheets were arranged in two columns, with five problems in each column. Different versions of the practice worksheets were created by changing the numbers and letters used in the problems and by varying specific features of the problem within predetermined criteria (e.g., changing the placement of the decimal to one of three different locations for problems testing the multiplication of numbers with decimals). Nineteen to 66 different practice worksheets were created for each skill based on the length of time required for the tutee to master the skill, and some worksheets were used more than once.

Tests. Ten-item tests were also constructed for each of the 13 mathematics skills. The format of the tests was identical to that of the practice worksheets except for the heading on the paper (specifying the test version instead of the practice version). Between 35 and 65 versions of each test were created for each skill in the same manner as the practice worksheets according to the length of time the participants needed to master the skills, and some versions were used more than once.

Response Measurement and Reliability

The primary dependent measure was accuracy on the tests. The number of correct answers on each test was divided by 10 (possible correct answers) and multiplied by 100% to generate a percentage correct. Correct answers were defined as a written combination of numbers, letters, and symbols that represented a mathematically accurate method of solving or simplifying a problem. Solutions were not required to be written in simplest form (e.g., the fraction equivalent of .4 could be written as 4/10 instead of 2/5), except for the skill of reducing fractions (because simplification was the response being trained). All parts of a solution had to be solved accurately for the answer to be scored as correct (e.g., both –15 and 19 had to be included in the answer to $|2 - b| = 17$).

The experimenter (the first author) served as the expert tutor and primary observer throughout the investigation. A second observer regraded all of the tests for 32% of sessions conducted during the tutoring intervention. If the experimenter had marked any of the problems (e.g., with a small dot) while grading the tests during the experimental sessions, all of the items were marked to reduce or eliminate potential bias of the second observer. Interobserver agreement was calculated by dividing the number of test items scored the same by both observers (either correct or incorrect) by the total number of test items and multiplying the quotient by 100%. The average interobserver agreement was 99% (range, 90% to 100%) across participants. Reliability data were also collected for the additional interventions and maintenance phases using similar procedures. A second observer regraded all of the tests for 29% of these sessions, and the average interobserver agreement for accuracy of test performance was 98% (range, 92% to 100%) during the additional interventions and maintenance phases.

Procedure

Preexperimental skills assessment. Before the study began, the experimenter assessed each participant's mathematics skills by administering tests containing arithmetic and prealgebra problems. The experimenter told the participant that she could earn one penny for each problem she answered correctly, and she could skip problems if she did not know how to solve them. Following the pretests, the experimenter selected three or four skills for each tutor–tutee

pair based on their performance on the skills assessment.

Baseline. During baseline, each participant completed tests of the skills during each session but did not receive instruction on how to perform the skills. The participant was told that she could earn one penny for each problem she answered correctly, as well as a bonus penny for answering all of the problems on the test correctly. She was also told that she could skip problems if she did not know how to solve them. The experimenter timed how long it took the participant to complete each test and then graded her answers.

The only feedback provided to participants at the end of every session was the total number of pennies earned during the session on all of the tests combined. The participants used their earnings to purchase snacks and prizes (e.g., school supplies, a portable CD player, gift cards) from the experimenter. Participants were allowed to purchase items at any point during the study.

Tutoring. Using a multiple baseline design, a tutoring intervention for each skill was introduced in a sequential fashion after accuracy on the skill stabilized during the baseline condition. The tutoring intervention consisted of two components: tutor training and peer tutoring.

At the beginning of each tutor-training session, the experimenter provided 3 min of tutoring on the skill to the participant serving as the peer tutor. The only materials used during these sessions were writing utensils, practice worksheets (as described above), and a timer to measure the length of the tutoring session. The session ceased when the timer beeped (after 3 min) regardless of the interaction in progress. During the sessions, the experimenter provided explanations of how to solve the problems, modeled correct solutions, and faded instructional prompts while delivering corrective feedback for the participant's errors and praise for correct responses.

To illustrate, during the initial 3-min session for simplifying radical expressions, the experimenter explained the meaning of radical signs and how to use the index of the radical sign to simplify the expression. The experimenter modeled the simplification of at least the first problem (e.g., $\sqrt[4]{c^6d^8} =$) by showing the participant how to divide the index into the exponents of the variables under the radical sign and write the variables outside (as well as inside, when appropriate) the radical sign with new exponents. The experimenter prompted the participant to provide parts of the solution (e.g., asking how many times 4 divides evenly into 6). The experimenter then assisted the participant by delivering prompts (e.g., asking what the remainder would be after the index is divided into an exponent) as the participant solved additional problems of the same variety during the remainder of the 3 min. The experimenter provided fewer prompts across the session as the participant emitted more correct responses. The experimenter provided additional prompts and assistance to participants (i.e., modeling and explanations of solutions) if participants emitted more incorrect responses.

Throughout the tutor-training session, the experimenter praised the participant for correct responses and provided corrective feedback for incorrect responses. When the 3-min session ended, the peer tutor completed a 10-item test of the tutored skill to assess skill acquisition resulting from the tutoring session. Tutor training was repeated for each of the target skills until they were mastered by the tutor (i.e., three nonconsecutive scores of 100% accuracy on the skill).

After each 3-min training session and 10-item test, peer tutoring was implemented. The peer tutor provided instruction on the same skill to the tutee. This typically occurred within approximately 0.5 hr of the peer tutor finishing the 10-item test (with tutor training and testing of other target skills often occurring during the

time lapse). The experimenter told the peer tutor that she had 3 min to teach the tutee the skill the experimenter had taught her, and she would receive one penny for every problem the tutee answered correctly on the test administered after the peer-tutoring session. The only materials provided to the peer tutor and tutee were writing utensils, practice worksheets (as described above), and a timer. The experimenter did not provide any instructions to the peer tutor on how to teach the skills or any instructions to the tutee on how to perform the problems, nor did the experimenter provide the tutor with feedback on her tutoring or an answer key to the practice worksheets used during the tutoring sessions. At the end of the 3-min session, the experimenter told the participants that the time was up. The tutee then completed a 10-item test of the skill to assess skill acquisition following the tutoring session. This procedure was repeated for each of the target skills in the peer-tutoring phase until they were mastered by the tutee (i.e., three nonconsecutive scores of 100% accuracy on the skill).

General tutoring procedure. The instructions before the tests and the monetary reinforcement contingencies were the same during the intervention phase (i.e., tutor training and peer tutoring) as in baseline. In addition, no feedback on test performance was delivered after any tests except for the total number of pennies earned during the session (as in baseline). Participants were allowed to purchase items from the experimenter using their earnings as described above.

Eight of the tutoring sessions (Sessions 9 to 16) for the long division skill (learned by Pair 3) were 10 min in length instead of 3 min because of the complexity of the skill and the amount of time needed to work through one problem. All other tutoring sessions for the long division skill and all other skills, however, lasted 3 min and were immediately followed by a test of the skill. Following mastery of a skill (i.e., three nonconsecutive scores of 100% accuracy on the skill), subsequent sessions involved only the administration of the 10-item test on that skill. Termination of tutor training and peer tutoring were independent events such that a tutor who scored 100% three times on a skill no longer received 3-min training sessions on that skill but continued to deliver peer tutoring until the tutee met the mastery criterion on the skill (i.e., three nonconsecutive scores of 100%). In a similar manner, a peer tutor who had not met the mastery criterion on a skill continued to receive tutor training sessions but ceased delivering peer tutoring if the tutee reached the mastery criterion on that skill.

The tutoring intervention was implemented successively such that each girl served as either the tutor or tutee and then switched (although there were as many as three overlapping sessions during which 1 participant continued to deliver tutoring on the first set of skills while receiving tutoring on the second set of skills). The order of presentation of the skills varied across sessions, but each skill was tutored (if the mastery criterion had not been met) and then tested on separate worksheets during every session.

Additional interventions. After the tutoring procedure was completed, additional interventions were implemented for skills that had not been mastered by the tutees. The purpose of the additional interventions was to provide supplemental instruction that might lead to performance improvements for the tutees beyond the accuracy achieved through peer tutoring alone. Six of the 14 skills received additional interventions (three skills for Keesa, one skill for Amelia, and two skills for Jada). The additional intervention for Keesa involved an increase in magnitude of the reinforcer provided for scoring 100% on a test (from $0.11 used in the tutoring phase to $1.00) across all three skills. For Amelia, improvements in calculating percentages initially occurred after the experimenter provided brief instructions to the tutor

(i.e., Keesa) coupled with an unlimited amount of time for the peer-tutoring sessions (averaging 10 min instead of 3 min). She later met the mastery criterion (i.e., three nonconsecutive scores of 100% accuracy) after the reinforcer magnitude was increased (from $0.11 to $1.00 for 100% accuracy on each test), and she was told she could stop practicing after scoring 100% three times (i.e., goal setting). For Jada, solving absolute value equations initially improved after introducing a modified error-correction procedure in conjunction with practice of prerequisite skills and an increase in reinforcer magnitude. She later met the mastery criterion when goal setting was introduced and the experimenter began implementing the tutoring sessions for this skill. Jada also achieved mastery for calculating percentages under conditions similar to those used for absolute value equations (i.e., modified error-correction procedure, prerequisite skill practice, increased reinforcer magnitude, goal setting, and experimenter-delivered tutoring).

Because the goal of the additional interventions was to examine potential supplements to the peer-tutoring procedure, they were generally not implemented for the tutors. Instead, if the tutor had not met the mastery criterion on a skill by the end of the tutoring phase and additional interventions were implemented for the tutee (i.e., for three of the skills for Pair 1 and one skill for Pair 2), the tutor continued to receive tutor training. Tutor 3 (Jada), however, received one additional intervention for the long division skill because she demonstrated very low accuracy during the tutoring phase, and no additional interventions were implemented for Tutee 3 (Olivia). The additional intervention involved corrective feedback on Jada's previous test and an increase in reinforcer magnitude (from $0.11 to $1.00 for a score of 100%).

With the exception of long division for Jada, which consisted of eight additional intervention sessions, only the final five additional intervention sessions prior to the tutee achieving the mastery criterion are presented in the current data analysis because the primary purpose of the current study was to determine the effects of peer tutoring in isolation.

Maintenance. On the final 2 days that the experimenter provided academic services to the participants, the students completed tests of all skills taught during their participation (including skills learned as both the tutor and the tutee). Maintenance tests were given on 2 consecutive days, with no performance feedback delivered between tests except for the participant's total earnings during the session (as during other phases of the study). Maintenance data were obtained on all skills except solving absolute value equations and changing percentages to fractions because programmed interventions were still in place for these skills on the last day of service provision for Pair 4. The maintenance interval for each skill ranged from 3 to 5 months, depending on the length of time between the final intervention session for each skill and the service termination date.

RESULTS

Pair 1

Figure 1 displays Pair 1's accuracy on the tests across sessions. During baseline, the tutor and tutee performed all four math skills with 0% or 10% accuracy, except for solving proportions, which the tutee performed with 0% to 60% accuracy. The introduction of the tutoring intervention resulted in performance increases on all skills for both participants, although only performance on the adding signed numbers skill reached mastery (i.e., three nonconsecutive scores of 100% accuracy). Amelia (the tutor) and Keesa (the tutee) achieved the mastery criterion on adding signed numbers after six and four sessions, respectively, and then did not receive further tutoring. Even without tutoring (after Session 9 for the tutor and Session 7 for the tutee), the participants maintained high accuracy on adding signed numbers through the end of the phase.

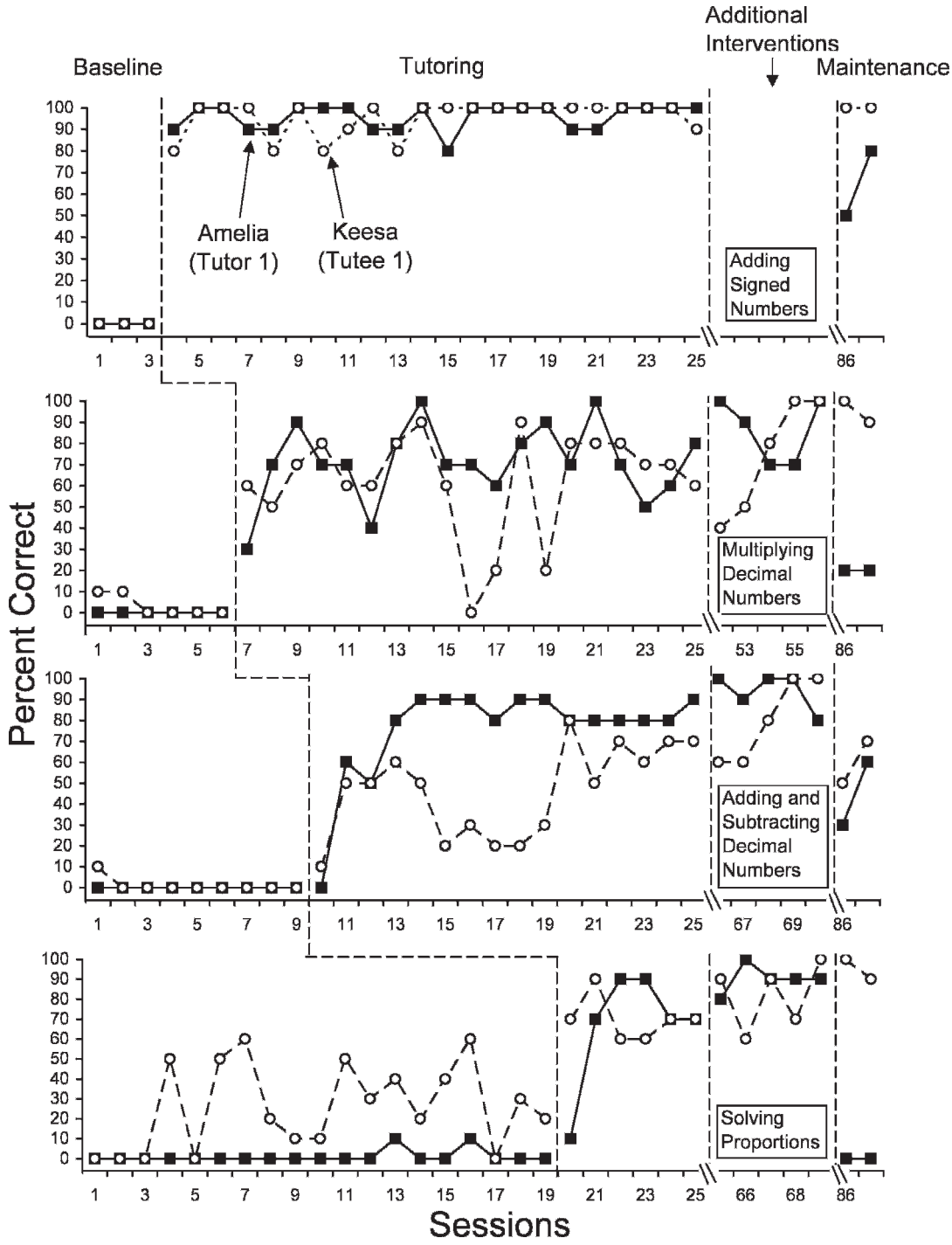

Figure 1. Pair 1's accuracy on the math skills across baseline, tutoring, additional interventions, and maintenance. The five sessions prior to the tutee achieving the mastery criterion are displayed in the additional interventions phase. The filled squares represent the tutor's performance, and the open circles represent the tutee's performance.

Following the conclusion of the tutoring phase, Keesa (the tutee) received additional interventions on the three unmastered skills (i.e., multiplying decimal numbers, adding and subtracting decimal numbers, and solving proportions). Data from the five additional intervention sessions conducted prior to Keesa achieving the mastery criterion are shown in Figure 1 (data from all additional intervention sessions are available from the first author). Keesa reached the mastery criterion on Sessions 56, 70, and 69 for multiplying decimal numbers, adding and subtracting decimal numbers, and solving proportions, respectively. Amelia (the tutor) met the mastery criterion on Sessions 34, 39, and 51 for the same skills, respectively, even though she did not receive additional interventions for these skills. Mean scores for the additional intervention sessions shown in Figure 1 were 86%, 94%, and 90% for Amelia (the tutor) and 74%, 80%, and 82% for Keesa (the tutee), for multiplying decimal numbers, adding and subtracting decimal numbers, and solving proportions, respectively. Maintenance performance was generally low for Amelia, but Keesa maintained a relatively high level of accuracy on three of the four skills after approximately 4.5 months of no programmed practice.

Pair 2

Figure 2 displays Pair 2's accuracy on the tests across sessions. Neither the tutor (Keesa) nor the tutee (Amelia) scored above 0% correct on any of the skills during baseline, but both improved on all skills after the introduction of the tutoring procedure. They met the mastery criterion for changing decimal numbers to fractions after four and five tutoring sessions, respectively, and after six and 18 tutoring sessions for reducing fractions. Both participants maintained high levels of performance on these skills during the remainder of the tutoring phase, even though tutoring sessions ceased after they met the mastery criterion. Amelia also met the mastery criterion for adding and subtracting time after 25 tutoring sessions, and Keesa scored 100% on this skill after 10 tutoring sessions but did not reach mastery for this skill.

Because Amelia (the tutee) met the mastery criterion on three of the four skills during the tutoring phase, only one additional intervention was conducted to improve her accuracy on calculating percentages. Amelia met the mastery criterion on this skill after Session 60, and Keesa (the tutor) met the mastery criterion after Session 88, even though she did not receive an additional intervention for this skill. The five data points collected in this phase prior to Amelia achieving the mastery criterion are shown in Figure 2. Amelia's mean score during these sessions was 76% accuracy, and Keesa's mean score during these sessions was 70% accuracy. Amelia subsequently demonstrated low accuracy on all the maintenance tests except reducing fractions, whereas Keesa maintained comparable performance on at least one of the two tests for all four skills.

Pair 3

Figure 3 displays Pair 3's accuracy on the tests across sessions. Following low accuracy on all skills during baseline, performance increased when the tutoring procedure was introduced (though at least five tutoring sessions were required before performance increased on the long division skill). The tutor (Jada) and tutee (Olivia) met the mastery criterion for changing percentages to decimals after four and three tutoring sessions, respectively, and maintained accurate performance during the remainder of the tutoring phase without further tutoring. In addition, they both performed the skill with high accuracy on the maintenance tests administered after 3.5 months of no practice sessions.

Olivia (the tutee) met the mastery criterion for long division after 14 tutoring sessions and maintained high accuracy during most of the remaining sessions of the tutoring phase without further tutoring. The tutor (Jada), however, received an additional intervention

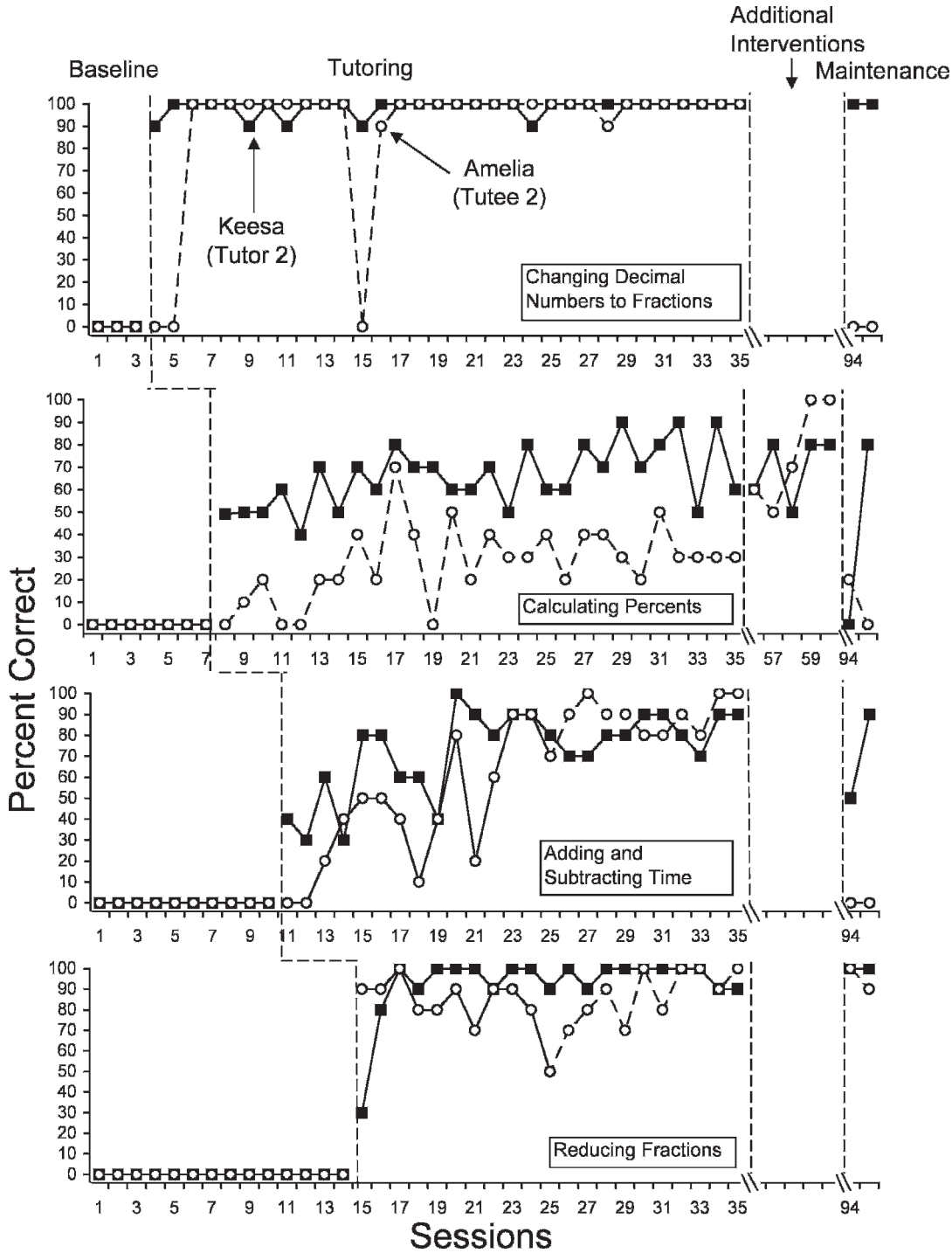

Figure 2. Pair 2's accuracy on the math skills across baseline, tutoring, additional interventions, and maintenance. The five sessions prior to the tutee achieving the mastery criterion are displayed in the additional interventions phase. The filled squares represent the tutor's performance, and the open circles represent the tutee's performance.

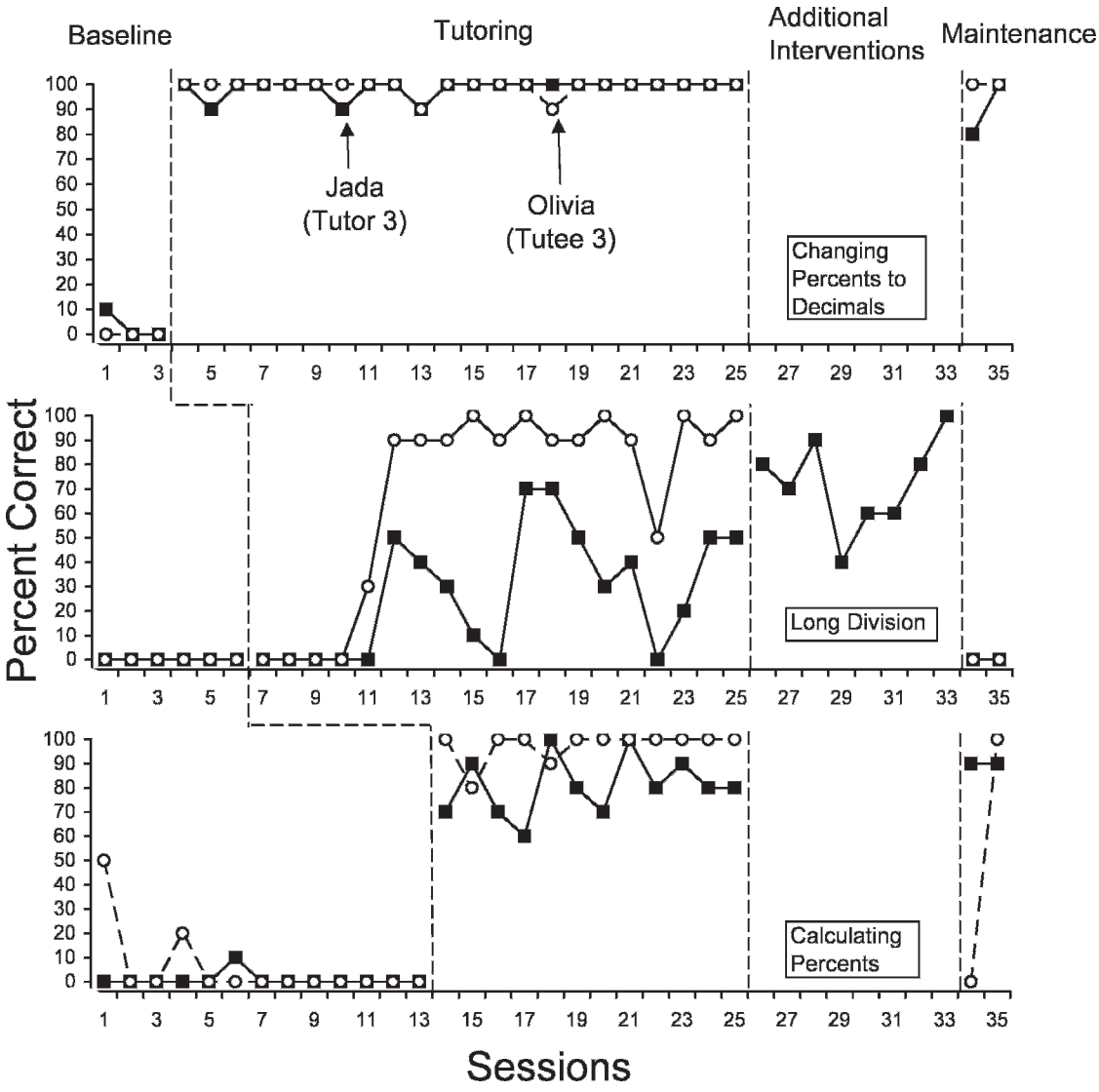

Figure 3. Pair 3's accuracy on the math skills across baseline, tutoring, additional interventions, and maintenance. The filled squares represent the tutor's performance, and the open circles represent the tutee's performance.

on long division because she did not score 100% during the tutoring phase. After receiving eight additional intervention sessions, however, Jada achieved a score of 100%. Neither she nor Olivia scored above 0% on the long division maintenance tests.

Olivia met the mastery criterion on calculating percentages after four tutoring sessions and maintained accurate performance with no further tutoring during the remainder of the phase. Jada scored 100% on calculating percentages during Sessions 18 and 21 but did not meet the mastery criterion for this skill. Olivia scored 0% on the first maintenance test, but both participants demonstrated high accuracy on the second maintenance test.

Pair 4

Figure 4 displays Pair 4's accuracy on the tests across sessions. Both participants scored

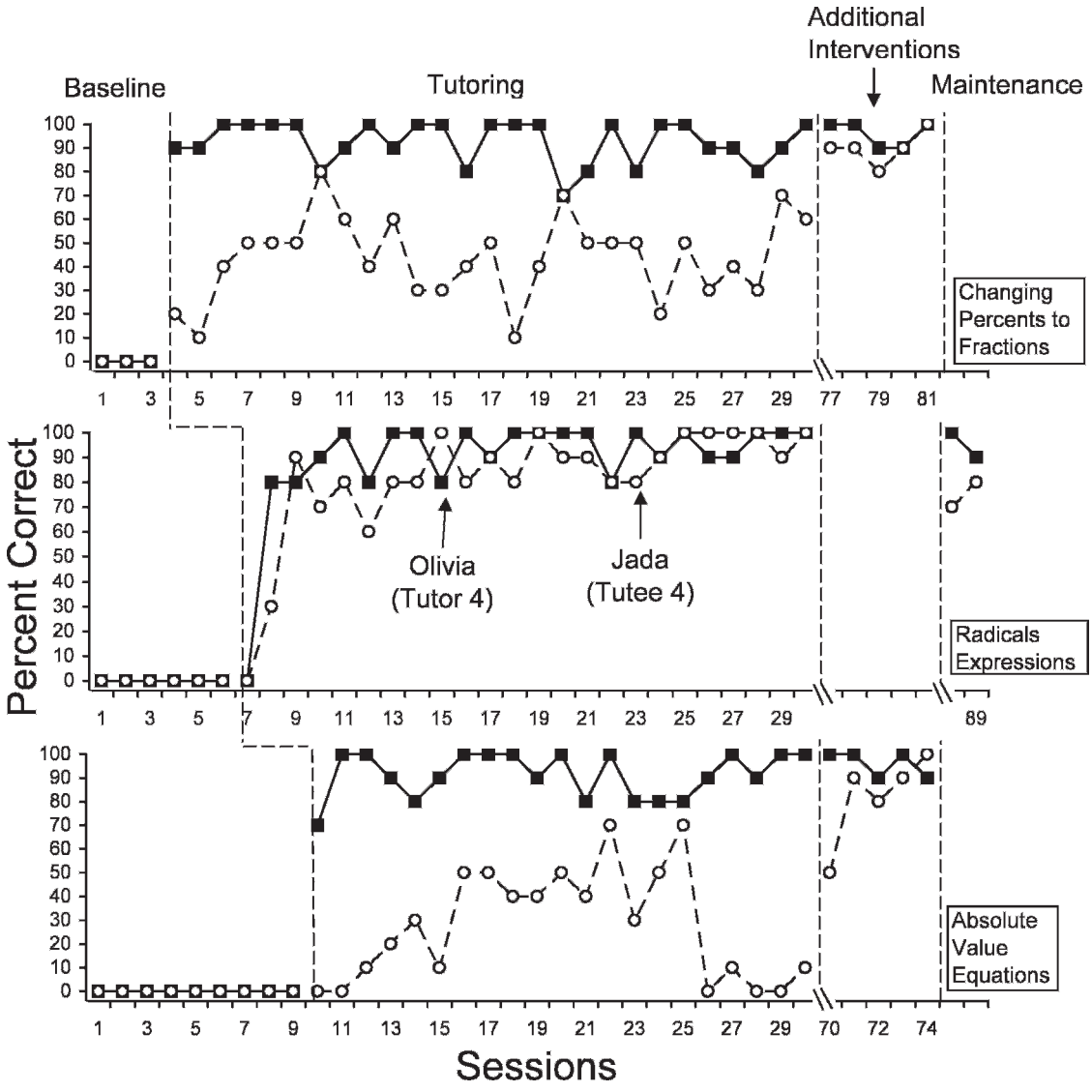

Figure 4. Pair 4's accuracy on the math skills across baseline, tutoring, additional interventions, and maintenance. The five sessions prior to the tutee achieving the mastery criterion are displayed in the additional interventions phase. The filled squares represent the tutor's performance, and the open circles represent the tutee's performance.

0% on all skills during baseline, but performance increased after the introduction of the tutoring sessions. The tutor (Olivia) and tutee (Jada) met the mastery criterion for simplifying radical expressions after eight and 19 tutoring sessions, respectively, and maintained high accuracy for the remainder of the tutoring phase without further tutoring. Both participants also demonstrated high accuracy on at least one of the maintenance tests for simplifying radical expressions after 3 months of no programmed practice.

Olivia met the mastery criterion for changing percentages to fractions and solving absolute value equations after five and seven tutoring sessions, respectively, and continued to demonstrate high accuracy during the remainder of the phase with no further tutoring. Additional

interventions were implemented on these skills for Jada (the tutee) because she did not meet the mastery criterion during the tutoring phase. She subsequently met the criterion on Session 81 for changing percentages to fractions and Session 74 for absolute value equations. She scored an average of 90% on the final five sessions prior to mastering changing percentages to fractions and 82% on the five sessions prior to mastering absolute value equations. Olivia's mean score for these sessions was 96% for both skills.

DISCUSSION

The purpose of the current investigation was to evaluate the effects of peer tutoring, in which children with histories of maltreatment served as mathematics tutors for other previously maltreated children. The intervention was conducted in a home setting and did not include extensive prior training for participants or a formal structure for the peer-tutoring interactions. The experimenter initially provided math instruction to the peer tutors but did not train them how to implement tutoring sessions or provide answer sheets for the peer-tutoring practice materials. Tests of the tutored skills were administered throughout the study, and results showed that the tutors and tutees improved their performance on all math skills. In addition, when tutoring sessions ended after participants met the mastery criterion, both tutors and tutees maintained high levels of performance on tests of the mastered skills during the remainder of the tutoring phase. These results suggest that students can improve their accuracy on math skills through home-based peer tutoring without supplemental instruction from an expert and without highly structured procedures.

During the tutoring intervention, participants demonstrated improvements in accuracy over their baseline performance for all 14 math skills. Across all pairs, the tutors met the mastery criterion for seven of the 14 skills and scored 100% on at least one occasion for nine of the 14 skills. The tutees met the mastery criterion for eight of the 14 skills. The overall mean score for all skills combined (both mastered and unmastered) on the final five sessions of the tutoring phase was 85% for the tutors and 75% for the tutees. During the additional interventions, the tutees met the mastery criterion on the six unmastered skills, and the tutors either met the mastery criterion (in four cases) or scored 100% on the skill (in one case) for all skills that had not previously been performed with 100% accuracy. Average accuracy on the two maintenance assessments across all skills, however, was 60% for the tutors and 57% for the tutees.

Although improvements were made by both tutors and tutees, 1 participant in each dyad typically outperformed the other on at least one skill. For cases in which the tutor performed better than the tutee (e.g., Pair 4), this may have been due to the experimenter delivering more effective instruction to the tutor than the tutor gave to the tutee. This may also have resulted from the tutor having stronger mathematics skills prior to the initiation of the study; however, the baseline assessments showed that neither participant could perform the skills with high accuracy. Other preexperimental assessments, however, showed that 1 participant in each pair (Keesa for Pairs 1 and 2 and Olivia for Pairs 3 and 4) scored higher than the other participant on at least 60% of the tests administered to both participants (whereas their counterparts outperformed them on no more than 11% of the tests). Given this difference in performance on the preexperimental assessments, it is also possible that instances in which the tutee outperformed the tutor (e.g., Pair 3 or Pair 1 during the maintenance phase) could be explained at least in part by the tutee's stronger entry-level math skills that enhanced acquisition of the tutored skills. Whether or not this was the case, no instances of role reversals (i.e., tutees attempting to provide instruction to the tutors) were noted by the experimenter. Anecdotally, though, if a tutor gave incorrect

feedback to a tutee, the tutee was likely to justify her correct answer to the tutor.

Because neither the tutors nor tutees could perform the target math skills with high accuracy prior to the intervention, the training sessions delivered to the tutors prior to the peer-tutoring sessions appeared to be a critical component of the current procedure. Moreover, it is likely that the modeling provided during the training sessions served as a type of training for the students on how to deliver peer tutoring. This training, however, did not involve the amount of formal structure that is typically associated with other classroom-based peer-tutoring interventions (e.g., Calhoun & Fuchs, 2003; Dufrene et al., 2005; Kamps et al., 1994). For example, the experimenter did not provide explicit preintervention instructions or a format for how to conduct peer tutoring. Nor were the participants provided with answer sheets to the practice materials used during the sessions. In addition, corrective feedback was not delivered following testing; therefore, tutors were not provided with information about errors to assist them in providing more effective tutoring during subsequent instruction. The procedures also did not require monitoring by the experimenter, as is typically the case in other procedures (Arreaga-Mayer et al., 1998; Fantuzzo & Ginsburg-Block, 1998; Fuchs & Fuchs, 1995).

Several limitations of the current procedure should be noted. First, tutoring did not involve formal components that were evaluated for procedural integrity; therefore, it is unclear which variables were responsible for the performance improvements. It is possible that the increases in performance resulted from participants receiving monetary reinforcement for correct answers. But, because monetary reinforcement occurred during baseline as well as during the tutoring phase, this was probably not a causal factor. It is also possible that the participants would have improved their performance on the skills if practice sessions alone (without the tutoring component) had been implemented. Thus, a follow-up study could be conducted in which a practice-only phase is implemented prior to the tutoring phase to determine whether skill acquisition could occur without the tutoring component.

Another limitation of the study was that the tutoring intervention was insufficient to raise all of the skills to mastery performance. Six of the 14 skills required additional interventions to reach the criterion of three scores of 100% accuracy. This finding suggests that peer tutoring may be effective at producing initial skill improvements in circumstances when expert help is unavailable (e.g., children working on homework without a skilled adult) but may need to be followed by other academic interventions to complete skill acquisition. In the current study, additional interventions (i.e., error correction and increased reinforcement magnitude) improved performance. Future studies could assess whether incorporating these components into the tutoring procedure may produce a more effective initial intervention.

A third limitation was the length of time required for some skills to meet the mastery criterion due to the need for additional interventions. Although the current procedures were relatively time efficient with regard to a lack of formal training procedures, the amount of time spent supplementing the tutoring intervention with additional interventions led to prolonged involvement of the experimenter. In contrast, a procedure used by Bell et al. (1991) to teach students driver education skills resulted in tutees achieving the performance criteria after as few as three (and as many as 11) tutoring sessions. The tutoring procedures used by Bell et al., however, included 40 min of tutor training, specially designed tutoring materials, and explicit components of direct instruction and precision teaching such as correction procedures, acknowledgment of correct responses, and 1-min fluency timings. The efficiency of such a highly structured procedure could be compared with that of a less formal procedure such as the one employed in

the current investigation by measuring the overall instructional time needed to achieve the same acquisition criteria.

Another limitation was that some skills were not performed at high levels of accuracy following the maintenance interval (e.g., long division). This may have been due to the participants' level of skill acquisition achieved during the study or to differential opportunities for using the skills during the maintenance interval. That is, some participants may have been less likely to use the target skills or other related skills in their natural academic environments, therefore reducing their opportunities for applying (i.e., practicing) these skills. For example, Amelia (a fourth grader) was less likely to use the skills taught to Pairs 1 and 2 than her partner Keesa (a seventh grader) because the skills were more advanced than the typical fourth-grade curriculum. In any case, the failure to maintain performance on some of the skills suggests that systematic review practice may be a necessary additional component of the intervention, as is recommended for effective programs of instruction (Carnine, Jones, & Dixon, 1994). Future studies could evaluate whether a monthly practice session for each skill would be sufficient to maintain high levels of accuracy (cf. Marchand-Martella et al., 1992).

A fifth limitation is related to one of the potential benefits of the tutoring procedure employed in the current investigation. That is, the current program was relatively unstructured compared to other peer-tutoring programs (e.g., Calhoun & Fuchs, 2003; Dufrene et al., 2005; Kamps et al., 1994). Although this procedure may be relatively efficient, the lack of a formal procedure may hamper attempts to replicate the current analysis. Future research should evaluate a peer-tutoring program similar to that described in the current investigation to examine the generality of these procedures.

Finally, the current study did not evaluate application or generalization of the training to untrained skills. Application or generalization tests can provide important evidence that students learn the basic concepts that underlie the skills (in addition to the procedural operations) because the skills must be applied to novel contexts. For example, when Greer and Polirstok (1982) and Polirstok and Greer (1986) administered a standardized achievement test for reading, they found that tutors and tutees demonstrated greater gains when a tutoring intervention was in place than when no intervention was implemented. Similarly, future investigations of teaching math skills could include standardized pre- and posttests with specific application items to monitor overall changes in achievement as well as application of the tutored skills.

Future research could also evaluate whether it would be more efficient to have the experimenter train both students instead of training only 1 student and having her train the other student. Expert tutoring for both students may reduce overall instructional time and lead to skill acquisition more quickly for both students if the quality of the tutoring is sufficiently better than that provided by the peer (which may have been the case for several skills in the current study). Even if improved acquisition were possible through simultaneous expert tutoring, however, this procedure is not always feasible (e.g., if a child is absent when the expert delivers the instruction but a peer who was present is available to train the child). Therefore, results of the current study provide support for the use of peers to train new skills when this is a necessary or practical instructional arrangement.

REFERENCES

Arreaga-Mayer, C., Terry, B. J., & Greenwood, C. R. (1998). Classwide peer tutoring. In K. Topping & S. Ehly (Eds.), *Peer-assisted learning* (pp. 105–119). Mahwah, NJ: Erlbaum.

Bell, K. E., Young, K. R., Salzberg, C. L., & West, R. P. (1991). High school driver education using peer tutors, direct instruction, and precision teaching. *Journal of Applied Behavior Analysis*, *24*, 45–51.

Blew, P. A., Schwartz, I. S., & Luce, S. C. (1985). Teaching functional community skills to autistic children using nonhandicapped peer tutors. *Journal of Applied Behavior Analysis*, *18*, 337–342.

Burley, M., & Halpern, M. (2001). *Educational attainment of foster youth: Achievement and graduation outcomes for children in state care* (No. 01-11-3901). Olympia: Washington State Institute for Public Policy.

Calhoun, M. B., & Fuchs, L. S. (2003). The effects of peer-assisted learning strategies and curriculum-based measurement on the mathematics performance of secondary students with disabilities. *Remedial and Special Education*, *24*, 235–245.

Carnine, D., Jones, E. D., & Dixon, R. (1994). Mathematics: Educational tools for diverse learners. *School Psychology Review*, *23*, 406–427.

Colton, M., Heath, A., & Aldgate, J. (1995). Factors which influence the educational attainment of children in foster family care. *Community Alternatives: International Journal of Family Care*, *7*, 15–36.

Dineen, J. P., Clark, H. B., & Risley, T. R. (1977). Peer tutoring among elementary students: Educational benefits to the tutor. *Journal of Applied Behavior Analysis*, *10*, 231–238.

Dufrene, B. A., Noell, G. H., Gilbertson, D. N., & Duhon, G. J. (2005). Monitoring implementation of reciprocal peer tutoring: Identifying and intervening with students who do not maintain accurate implementation. *School Psychology Review*, *14*, 74–86.

DuPaul, G. J., Ervin, R. A., Hook, C. L., & McGoey, K. E. (1998). Peer tutoring for children with attention deficit hyperactivity disorder: Effects on classroom behavior and academic performance. *Journal of Applied Behavior Analysis*, *31*, 579–592.

Eckenrode, J., Laird, M., & Doris, J. (1993). School performance and disciplinary problems among abused and neglected children. *Developmental Psychology*, *29*, 53–62.

Fantuzzo, J., & Ginsburg-Block, M. (1998). Reciprocal peer tutoring: Developing and testing effective peer collaborations for elementary school students. In K. Topping & S. Ehly (Eds.), *Peer-assisted learning* (pp. 121–144). Mahwah, NJ: Erlbaum.

Fantuzzo, J. W., King, J. A., & Heller, L. R. (1992). Effects of reciprocal peer tutoring on mathematics and school adjustment: A component analysis. *Journal of Educational Psychology*, *84*, 331–339.

Fuchs, L. S., & Fuchs, D. (1995). Acquisition and transfer effects of classwide peer-assisted learning strategies in mathematics. *School Psychology Review*, *24*, 604–620.

Fuchs, L. S., Fuchs, D., & Karns, K. (2001). Enhancing kindergartners' mathematical development: Effects of peer-assisted learning strategies. *The Elementary School Journal*, *101*, 495–510.

Fuchs, L. S., Fuchs, D., Yazdin, L., & Powell, S. R. (2002). Enhancing first-grade children's mathematical development with peer-assisted learning strategies. *School Psychology Review*, *31*, 569–583.

Fueyo, V., & Bushell, D. (1998). Using number line procedures and peer tutoring to improve the mathematics computation of low-performing first graders. *Journal of Applied Behavior Analysis*, *31*, 417–430.

Greer, R. D., & Polirstok, S. R. (1982). Collateral gains and short-term maintenance in reading and on-task responses by inner-city adolescents as a function of their use of social reinforcement while tutoring. *Journal of Applied Behavior Analysis*, *15*, 123–139.

Johnson, M., & Bailey, J. S. (1974). Cross-age tutoring: Fifth graders as arithmetic tutors for kindergarten children. *Journal of Applied Behavior Analysis*, *7*, 223–232.

Kamps, D. M., Barbetta, P. M., Leonard, B. R., & Delquadri, J. (1994). Classwide peer tutoring: An integration strategy to improve reading skills and promote peer interactions among students with autism and general education peers. *Journal of Applied Behavior Analysis*, *27*, 49–61.

Kohler, F. W., & Greenwood, C. R. (1990). Effects of collateral peer supportive behaviors within the classwide peer tutoring program. *Journal of Applied Behavior Analysis*, *23*, 307–322.

Marchand-Martella, N. E., Martella, R. C., Agran, M., Salzberg, C. L., Young, K. R., & Morgan, D. (1992). Generalized effects of a peer-delivered first aid program for students with moderate intellectual disabilities. *Journal of Applied Behavior Analysis*, *25*, 841–851.

Mathes, P. G., & Fuchs, L. S. (1994). The efficacy of peer tutoring in reading for students with mild disabilities: A best-evidence synthesis. *School Psychology Review*, *23*, 59–80.

Pigott, H. E., Fantuzzo, J. W., & Clement, P. W. (1986). The effects of reciprocal peer tutoring and group contingencies on the academic performance of elementary school children. *Journal of Applied Behavior Analysis*, *19*, 93–98.

Polirstok, S. R., & Greer, R. D. (1986). A replication of collateral effects and a component analysis of a successful tutoring package for inner-city adolescents. *Education and Treatment of Children*, *9*, 101–121.

Sáenz, L. M., Fuchs, L. S., & Fuchs, D. (2005). Peer-assisted learning strategies for English language learners with learning disabilities. *Exceptional Children*, *71*, 231–247.

Sideridis, G. D., Utley, C., Greenwood, C. R., Delquadri, J., Dawson, H., Palmer, P., et al. (1997). Classwide peer tutoring: Effects on the spelling performance and social interactions of students with mild disabilities and their typical peers in an integrated instructional setting. *Journal of Behavioral Education*, *7*, 435–462.

Stein, E. (1997). Teachers' assessments of children in foster care. *Developmental Disabilities Bulletin*, *25*, 1–17.

Telecsan, B. L., Slaton, D. B., & Stevens, K. B. (1999). Peer tutoring: Teaching students with learning disabilities to deliver time delay instruction. *Journal of Behavioral Education*, *9*, 133–154.

Received August 9, 2005
Final acceptance December 20, 2006
Action Editor, Henry Roane