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Teaching Basic Math Skills to Preschoolers Using Connecting Math Concepts Level K

Abstract: This study investigated the effects of teaching basic math skills to 16 children (11 typically developing, 5 with developmental delays) in an integrated university preschool. *Connecting Math Concepts Level K* (*CMC—K*; Engelmann & Becker, 1995) was delivered by the classroom teacher to small groups of 4 to 6 children over 6.5 weeks. All children were pre- and posttested using the Cognitive Domain of the Battelle Developmental Inventory (BDI) and the placement test for *Connecting Math Concepts Level A* (*CMC—A*; Engelmann, Carnine, Kelly, & Engelmann, 1996). Results of the BDI showed a Cognitive Domain effect size of .61 for typically developing children (subdomains ranged from .05 to .87). Children with developmental delays had a Cognitive Domain effect size of .54 (subdomains ranged from .38 to 1.59). On the *CMC—A* placement test, typically developing children had a mean pretest score of 4.55 and a mean posttest score of 7.90. Those children with developmental delays had a mean pretest score of 3.80 and a mean posttest score of 7.20. Implications for future research are discussed.

Despite the importance of math skills in our everyday lives, statistics have shown that the achievement level of students in the United States has remained low in comparison to other countries. For example, results of the 1995 Third International Mathematics and Science Study (TIMSS) noted that among 41 countries, U.S. fourth graders placed 12th and eighth graders placed 28th in the area of math (International Study Center, 2001). Similarly, as noted by the National Center for Education Statistics (2001) in its National Assessment of Educational Progress (NAEP), only 26% of 4th graders, 27% of 8th graders, and 17% of 12th graders performed at or above a proficient level (i.e., mastery of math skills for that grade). Interestingly, the Nation's Education Goals, as signed into law by President Clinton in 1994 noted, "By the year 2000, United States' students will be first in the world in mathematics and science achievement" (U.S. Department of Education, 1994, Mathematics and Science section). Given the results of the TIMSS and NAEP, it appears that we, as a nation, did not reach this goal.

In order to improve student success in mathematics, the National Council of Teachers of Mathematics (NCTM) has reviewed and revised their goals and standards for teaching and assessing mathematics. In 2000, the NCTM developed standards for prekindergarten students for the first time. The inclusion of these standards hinged on the organization's belief that what is learned in early childhood years is critical to the development of a child's mathematical skills

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(NCTM, 2000). The standards for prekindergarten through second grade cover 10 skill areas including the following: (a) numbers and operations, (b) algebra, (c) geometry, (d) measurement, (e) data analysis and probability, (f) problem solving, (g) reasoning and proof, (h) communication, (i) connections, and (j) representation. For each of these skill areas, the NCTM outlined the content and specific expectations for children in prekindergarten through second grade.

One Direct Instruction math program that addresses the NCTM goals and standards for teaching and assessing mathematics is *Connecting Math Concepts* (*CMC*; Engelmann, Carnine, Kelly, & Engelmann, 1996). Several key aspects of *CMC* make it effective (Carnine, 1991). These include (a) the program's use of time during each lesson (i.e., students receive more efficient instruction during instructional time), (b) the rate of introduction of new concepts (i.e., topics are introduced during a lesson and are designed to allow for a deep understanding of the topic), (c) explanations of concepts and activities designed to practice the concepts (i.e., concepts build upon previous knowledge), (d) guided and independent practice during each lesson (i.e., practice is provided with and without assistance from the instructor), and (e) appropriate examples of concepts (i.e., examples are included that allow for proper practice of the skills and concepts in each lesson).

Several studies have examined the effectiveness of the *CMC* program. Tarver and Jung (1995) found that students who received *CMC* instruction in first and second grades scored significantly higher than their same age peers who received a discovery learning curriculum, *Math Their Way*. Tarver and Jung also found that students instructed with *CMC* had higher scores on a survey about their attitudes toward mathematics. Vreeland et al. (1994) found that *CMC* was effective in teaching math skills to third- and fifth-grade students. The following year, first through fifth grades all received *CMC* instruction. Despite the inability of some classes in each grade level to complete an entire level of the program in 1 school year (due to late arrival of the materials), all students who were pre- and posttested showed gains on the Kaufman Test of Educational Achievement—Comprehensive Form. Further, Snider and Crawford (1996) compared the effectiveness of *CMC* to *Invitation to Mathematics* (the basal used by the school) in teaching math skills to fourth graders. Posttest results indicated that children instructed with *CMC* scored higher on the National Achievement Test, a basic multiplication facts test, and two curriculum-based assessments, one based on the basal and the other on *CMC*, than the children instructed with *Invitation to Mathematics*. With these gains in mind, Crawford and Snider (2000) conducted a follow-up study in which both fourth-grade classes were instructed with *CMC*. Results of this study indicated improved performance on both standardized and curriculum-based measures.

With the growing research base for *CMC* and with the NCTM standards in mind, Science Research Associates (SRA), the publisher of *CMC*, developed a guide, *Meeting the NCTM Standards Through Connecting Math Concepts* (Kelly, 1994), that examined how levels of the *CMC* program met the NCTM standards. For example, *CMC Level A* (*CMC—A*) activities were examined and were found to address the NCTM standard for understanding numbers (i.e., the curriculum focuses on the concepts of counting, place value, more than, and addition).

Direct Instruction research in early childhood education has focused on cognitive development (e.g., Losardo & Bricker, 1994; Mills, Dale, Cole, & Jenkins, 1995; Seifert & Schwarz, 1991; Stallings, 1987). More recent research has investigated the effectiveness of Direct Instruction on language development in early childhood education (Benner et al., 2002; Waldron-Soler et al., 2002). However, in the area of mathematics, most research has investigated the effectiveness of programs aimed at elementary and secondary students. For example, a study conducted by Parsons, Marchand-Martella, Waldron-Soler, Martella, and Lignugaris/Kraft (2004) examined the use of a peer-delivered *Corrective Mathematics* (*CM*) program. Results suggested that the combination of *CM* and peer-delivered instruction was effective in improving student performance in math on the WJ—R as well as on the *CM* placement test. Similarly, a study by Sommers (1991) found that at-risk middle-school students made improvements in math scores when *CM* was combined with the school's regular math text. In a 7-year follow up, Sommers (1995) found that students averaged a 9.9-month gain in math skills in 8 months of instruction.

A prepublication program for kindergarten children, *Connecting Math Concepts Level K* (*CMC—K*), has not been investigated to date. As Finn (1994) noted, it is crucial to test and investigate the use of new curricula and ideas to examine their benefits and drawbacks. The purpose of this investigation was to assess the effects of the *CMC—K* program in teaching basic math skills to preschool children with and without developmental delays.

Method

Participants

This investigation included 16 of 24 children (ages 3 to 5 years) who attended an integrated university preschool. The 16 children included in this study participated in the preschool program 5 days per week, whereas the other 8 children attended the preschool 2 to 3 days per week.

The preschool included morning (9:00 a.m.–11:30 a.m.) and afternoon (12:30 p.m.– 3:00 p.m.) sessions. Placement of the children into morning or afternoon sessions was based on parent preference. Of the 16 children included in this study, 11 participated in the morning session and 5 were in the afternoon session. Eight girls and 3 boys were in the morning session. Five children were identified as having a delay in one or more areas of development including cognitive, motor, social, and language skills. Six of these 11 children were Caucasian, 4 were of Spanish-American heritage, and 1 of Japanese-American heritage. Children ranged in age from 3 years 5 months to 5 years 4 months (mean age = 4 years 4 months).

Of the five children in the afternoon session, two were girls and three were boys. All five children were Caucasian. Children ranged in age from 4 years 1 month to 5 years 3 months (mean age = 4 years 6 months).

Setting

The integrated university preschool was located on the campus of a comprehensive university in the Pacific Northwest (campus enrollment = 8,015). Preschool staff included one certified lead teacher who had an elementary education certificate and was working on her master's degree in special education. She had 4 years of experience teaching preschool-age children and served as the math instructor for this study. She also administered the curriculum-based placement test used in this investigation. Six work-study college students and six college students completing special education or developmental psychology internships also worked part-time in the preschool. The six college students completing their internships administered the norm-referenced assessment used in this investigation.

Curriculum and Materials

The prepublication *CMC—K* program was used in this study. This program includes 30 lessons. It is a kindergarten level of the *CMC* program. Each lesson contains an introduction and a review of various concepts and skills. These concepts and skills include (a) rote counting, (b) numeral recognition, (c) writing numerals, (d) counting of objects, (e) numeral association, (f) concepts of more and less, and (g) what number comes next? In this program children are instructed using the Direct Instruction model in which the instructor models the skill, the instructor and children practice the skill together, and the children perform the skill on their own or as a small group.

Rote counting. Each lesson includes instruction on rote counting skills. The program begins with the children counting up to 5 and works toward counting up to 50.

Numeral recognition. The children are shown a row of numbers and are instructed to say what each number is. The program begins by identifying the numeral 2 and works up to identifying all numbers up to 19, in random order.

Writing numerals. In each lesson, children are given the opportunity to write numerals. First, the children write the numeral by tracing the dots. In the same lesson, they write the number with fewer dots to follow, thus allowing them to finish writing portions of the numeral on their own.

Counting objects. Children are instructed to count lines or symbols as well as to count pennies by watching and listening to them drop into a can.

Numeral association. This skill is taught in each lesson through different techniques. In the earlier lessons, children see boxes with a numeral in the top half and lines in the bottom half. They are told to circle each box that has the corresponding number of lines to match the numeral. In later lessons, the children are instructed to read the number in each box and write the corresponding number of lines.

Concepts of more and less. For the concept of *more*, the instructor presents lines on a dry erase board and then draws more lines to represent this concept. The children respond to the prompt, "Did I get more?" For the concept of *less*, the concept is presented in a similar manner as mentioned previously. The concepts are taught together in three ways. The first way is to draw and erase lines on a dry erase board, asking the children each time if the instructor got more or less. Next, the children draw more lines on their worksheet or cross out lines to make less. The final way to teach this concept is by asking the children if a certain number is more than or less than another number (e.g., "Is 5 more than or less than 8?").

What number comes next? Children are asked what number comes after another number. For example, "Tell me what number comes next. 4, 5, 6, 7…." In successive lessons, the instructor says one or two numbers and the children say the next one. Finally, the children are instructed to tell the instructor what number comes next when one number is given.

Other materials. Dry erase boards, markers, and erasers; pencils and erasers; pennies and a tin can; and worksheets, binders, data recording sheets, stickers, and gummy bears were used in this study.

Dependent Variables and Measures

All children were assessed before and after the program using the Battelle Developmental Inventory (BDI; Newborg, Stock, Wnek, Guidubaldi, & Svinicki, 1984) as well as a curriculum-based placement test from *Connecting Math Concepts: Lesson Sampler* (Engelmann et al., 1996).

Battelle Developmental Inventory. The children were assessed before and after the math program using the Cognitive Domain of the BDI. The Cognitive Domain is divided into four subdomains: (a) Perceptual Discrimination, (b) Memory, (c) Reasoning and Academic Skills, and (d) Conceptual Development. Items included in the Perceptual

Discrimination subdomain were designed to assess the child's skill to discriminate and respond to features of objects (e.g., matching simple shapes). The Memory subdomain was designed to assess a child's recall skills (e.g., recall story facts). The Reasoning and Academic Skills subdomain was designed to assess critical thinking skills and scholastic abilities (e.g., identify the parts missing in a picture). Finally, the Conceptual Development subdomain was designed to assess the child's skill in forming relationships, grouping objects, and recognizing properties of objects (e.g., sorting objects by shape).

Standard scores in the form of normal curve equivalents (NCE) served as the dependent measure across the total Cognitive Domain score and its four subdomains. NCEs have a mean of 50 and a standard deviation of 21.06 (Cohen & Spenciner, 1998). Effect sizes were calculated by subtracting the mean pretest score from the mean posttest score and dividing the difference by the pooled standard deviation. Effect sizes of .25 or greater are considered to be educationally important (Adams & Engelmann, 1996).

The same form of the BDI was used for the pre- and posttest assessments. Test–retest coefficients for the Cognitive Domain Total for each age group of the children participating in the study were as follows: 36 to 47 months, .98; 48 to 59 months, .95; and 60 to 71 months, .93 (Newborg et al., 1984).

A faculty member at the university who taught a class on assessment trained the college students to administer the BDI. During training the students were given a sample scoring sheet and were shown how to administer the test. Training and demonstration on assessment procedures took place for approximately 1 hr in the preschool. Rules regarding following the standardized assessment procedure were emphasized.

Connecting Math Concepts Level A placement test. The instructor assessed the children individually following the placement test guidelines. This curriculum-based placement test includes four parts that assess concepts found in the *CMC—K* curriculum. In the first part, the children are instructed to "count to 10." On the second part, the children are told to count objects printed on paper. The third part of the placement test consists of the children orally responding to questions of, "What number comes after ___?" On the final part, the children are told to write four different numerals that the instructor says. There are a total of 10 questions on the placement test. Placement guidelines indicate that if children make one or more mistakes in the first two parts of the placement test, they should be placed into *DISTAR Arithmetic I*. If the children pass sections one and two, but not sections three and four, placement would be in Lesson 1 of *CMC—A*. If the children pass all four sections, placement is in Lesson 11 of *CMC—A*. If the children pass all four sections and are able to answer simple arithmetic questions such as 5 plus 1 equals? and 6 plus 2 equals?, possible placement is in *CMC—B*. The number of correct answers out of 10 on the placement test and curriculum placement levels served as the dependent measures.

Number of lessons and instructional sessions. The number of lessons completed by the children as well as the number of instructional sessions were recorded. Children received math instruction 5 days a week and completed one lesson per instructional session. Therefore, the children completed all 30 lessons of the program over 6.5 weeks.

Design

This study included a preexperimental (one-group pretest–posttest) design (Martella, Nelson, & Marchand-Martella, 1999). As previously noted, pre- and posttest assessments were conducted before and after the math program.

Procedures

Prior to instruction, the instructor placed the children into small groups, created data sheets, and prepared the necessary materials to begin instruction.

Grouping. Children were divided into small groups based on instructional level, as determined by the *CMC—A* placement test. The morning session included two groups, one with six children and one with five children. The afternoon session included one group of five children.

CMC—K instruction. The instructor spent approximately 10–20 min per instructional day with each group for math instruction. The children sat at a half circle table with the instructor on one side and the children around the other. One lesson was targeted for each instructional day. The instructor followed the script included in the program. The children were told to answer in unison or individually, based on the script, as well as to complete their own worksheets. When children had difficulty, the instructor provided help as needed. Graduated guidance or most-to-least prompting was used by beginning with hand-over-hand direction, gradually moving to shadowing and finally, using only verbal direction (Martella, Marchand-Martella, & Agran, 1994). One area that required extra help was when the children were expected to write numerals. These children had limited experience with writing skills and often needed assistance with writing activities.

Response errors were corrected as follows. For example, if children incorrectly identified a numeral, the instructor would correct it by saying, "This is a 4. What numeral?" and starting over on that task. Signal errors were corrected by saying "Say it all together" followed by repeating the task or question.

Stickers, points, and gummy bears were used as reinforcers throughout instruction. Upon completion of each worksheet, children chose a sticker to put on their worksheet. When behavior and on task time were an issue, the instructor kept track of points for behavior. If the children participated and were on task, they received points. If the children did not participate or were off task, the instructor received points. These points were set up as a game to see who would have the most points at the end. Gummy bears were used as a reward for having the most points at the end of a lesson.

Results

Battelle Developmental Inventory

Table 1 shows the children's mean normal curve equivalent (NCE) pre- and posttest scores on the BDI (the Cognitive Domain and its four subdomains) as well as standard deviations, gains, and effect sizes.

Typically developing children. For the Perceptual Discrimination subdomain, the gain score for typically developing children was .73 with an effect size of .05. Their gain score for the Memory subdomain was 13.00 with an effect size of .87. For the Reasoning and Academic Skills subdomain, these children had a gain score of 5.82 with an effect size of .37. Their gain score and effect size for the Conceptual Development subdomain were 14.36 and .75, respectively. Finally, for the Cognitive Domain, these children had a gain score of 12.10 with an effect size of .61.

Children with developmental delays. For the Perceptual Discrimination subdomain, children with developmental delays had a gain score of 20.60 with an effect size of 1.59. Their gain score for the Memory subdomain was 8.60 with an effect size of .38. The gain score for the Reasoning and Academic Skills subdomain was 30.40 and the effect size was 1.04. For the Conceptual Development subdomain, their gain score was 7.40 with an effect size of .41. Their gain score for the Cognitive Domain was 14.60 with an effect size of .54.

Combined group score. The gain score for the Perceptual Discrimination subdomain was 6.93 with an effect size of .43. On the Memory subdomain, the gain score across children was 11.63 with an effect size of .64. The gain score across children on the Reasoning and Academic Skills subdomain was 13.50 with an effect size of .53. For the Conceptual Development subdomain, they had a gain score of 12.19 with an effect size of .58. Finally, these children had a Cognitive Domain gain of 12.88 and an effect size of .52.

Table 1

Mean Scores on the Battelle Developmental Inventory

	Subdomains				Total
	Perceptual Discrimination	Memory	Reasoning and Academic Skills	Conceptual Development	Cognitive Domain
	Typically Developing Children (n = 11)				
Pretest	49.36	52.64	54.36	45.09	52.45
(*SD*)	(19.51)	(14.19)	(17.69)	(22.02)	(20.43)
Posttest	50.09	65.64	60.18	59.45	64.55
(*SD*)	(11.77)	(15.62)	(13.25)	(16.06)	(19.04)
Gain	.73	13.00	5.82	14.36	12.10
Effect Size	.05	.87	.37	.75	.61
	Children With Developmental Delays (n = 5)				
Pretest	29.40	41.20	11.60	27.00	25.40
(*SD*)	(15.92)	(18.10)	(20.51)	(17.78)	(26.85)
Posttest	50.00	49.80	42.00	34.40	40.00
(*SD*)	(9.11)	(26.13)	(35.82)	(17.97)	(27.53)
Gain	20.60	8.60	30.40	7.40	14.60
Effect Size	1.59	.38	1.04	.41	.54
	Combined Group (n = 16)				
Pretest	43.13	49.06	41.00	39.44	44.00
(*SD*)	(20.31)	(15.86)	(27.20)	(21.97)	(25.26)
Posttest	50.06	60.69	54.50	51.63	56.88
(*SD*)	(10.70)	(20.05)	(23.13)	(20.05)	(24.12)
Gain	6.93	11.63	13.50	12.19	12.88
Effect Size	.43	.64	.53	.58	.52

***Connecting Math Concepts Level A* Placement Test**

Results were examined for typically developing children and those with developmental delays. Additionally, a combined placement test score was calculated.

Typically developing children. Out of 10 correct on the placement test, typically developing children had a mean pretest score of 4.55 (range = 0–10). The mean posttest score for these children was 7.90 (range = 4–10).

Of the 11 typically developing children who participated in this study, pretest results recommended that 6 children begin instruction in *DISTAR I*, while posttest results for 5 of these children recommended that instruction begin in Lesson 1 of *CMC—A*, and 1 was recommended placement into Lesson 11 of *CMC—A*. Two of the typically developing children had pre- and posttest placements into Lesson 1 of *CMC—A*. Pretest results recommended that one of the typically developing children begin instruction in Lesson 11 of *CMC—A* and posttest results recommended that this child take the *CMC—B* placement test. Finally, two children had a pre- and posttest recommendation to take the *CMC—B* placement test.

Children with developmental delays. On the pretest, the mean score for children with developmental delays was 3.80 (range = 0–7). The posttest score for these children was 7.20 (range = 3–10).

Of the five children with developmental delays who participated in this study, results of the pretest recommended placement of three children into *DISTAR I*, while posttest results for two of these children recommended placement into Lesson 1 of *CMC—A* and one child into Lesson 11 of *CMC—A*. Two of the children had pretest placement into Lesson 1 of *CMC—A*, while posttest results recommended that one of the children begin instruction in Lesson 1 of *CMC—A* and one begin instruction in Lesson 11 of *CMC—A*.

Combined group score. The mean pretest score for the combined group was 4.31 out of 10 correct (range = 0–10). The combined group had a mean posttest score of 7.69 out of 10 correct (range = 3–10).

Discussion

This study examined the effectiveness of the prepublication *CMC—K* program in teaching basic math skills to preschool children with and without developmental delays. Results indicated that these children had improved performance on the Cognitive Domain of the BDI and on the *CMC—A* placement test. An important aspect of this study is the effect sizes for the BDI. Adams and Engelmann (1996) noted that effect sizes greater than .25 are considered to be educationally significant. All but one of the effect sizes for the scores on the BDI (the Perceptual Discrimination subdomain for typically developing children) were above .25. Adams and Engelmann noted that effect sizes above .50 are not usually seen in educational research. These effect sizes are important to note as they reflect the magnitude of change in the children's scores after *CMC—K* was implemented.

It is interesting to examine the specific task results of the *CMC—A* placement test. According to the NCTM standards, one goal of instruction for prekindergarten is to help these children develop an "understanding" of numbers (NCTM, 2000). This study examined the effectiveness of *CMC—K* in reaching this goal. Pretest results indicated that 9 children could count to 10, 12 could count six objects on a piece of paper, and 10 could count nine objects on a piece of paper. On the posttest, results indicated that all 16 children could complete these tasks without errors. Similarly, writing tasks showed improvement. On the pretest, when asked to write the numerals 7 and 4, only 5 children could. On the posttest, 9 and 11 children, respectively, could complete this task. When asked to write the numeral 5, 3 children could on the pretest, and 10 children were able to write this numeral on the posttest. Finally, when asked to write the numeral 8, four children could complete the task on the pretest, and nine completed the task successfully on the posttest.

With the increasing emphasis on mathematical performance and on preschool education, the results of this study are important. Results from the TIMSS (International Study Center, 2001) and the NAEP (National Center for Education Statistics, 2001) demonstrate the inability of current programs and curricula in teaching math skills to all students. A more recent focus on improving math skills is to intervene during the early childhood years. This study examined the use of a Direct Instruction approach in teaching basic math skills to young children. With increasing emphasis on what should be included during early childhood education, teachers need to examine research-validated practices to provide an effective and appropriate education for these children.

The results of this study are also important because research conducted in the area of math has focused on teaching math skills to older students. For example, studies investigating the effectiveness of *Corrective Math* have yielded positive results with elementary and secondary students (Parsons et al., 2004; Sommers, 1991, 1995). Similarly, research for *CMC* has focused on elementary-age students (Crawford & Snider, 2000; Snider & Crawford, 1996; Vreeland et al., 1994).

Despite the positive findings of this investigation, several limitations are present. First, there was a lack of experimental control. Due to resources available, the design of this study was a preexperimental design (one-group pretest–posttest) and did not include a control group or random assignment of children into groups. Without a control group, the results of the children receiving *CMC—K* instruction cannot be compared to those who did not receive *CMC—K* instruction. Future studies should include a control group and use random placement of children into groups. Second, there was an inability to assess children in all domains of the BDI. Future research should examine the results in every domain of the BDI to better investigate the effects of *CMC—K*. Third, the same form of the BDI was used for both pre- and posttest assessments. Future research should use alternate forms of assessment measures. Fourth, this study was conducted in one preschool classroom; therefore, results obtained from this study may not generalize to other settings or preschools. Finally, there were no data on the fidelity of the independent variable. Therefore it is not possible to conclude that *CMC—K* was implemented exactly as stipulated in the program. Future studies should gather data to verify the implementation of the independent variable.

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