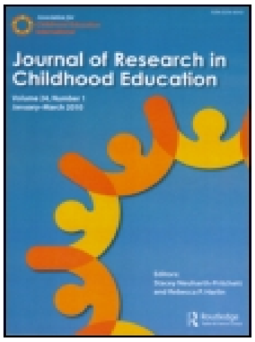

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Effects of Teaching Patterning to 1st-Graders

Charlene Hendricks
Linda Trueblood
Robert Pasnak
George Mason University

Abstract. Seven-year-olds who had difficulty understanding 1st-grade work received one of two forms of small-group instruction. Half of the children were randomly assigned to receive four months of instruction in recognizing, comprehending, and reproducing both logical and arbitrary patterns (sequences) involving numbers, letters, shapes, colors, orientations, causes and effects, and temporal events. The other children received yoked instruction in the academic subject matter their teachers thought most useful. At the end of the school year, the patterning group significantly outperformed the control group on measures of patterning and academic achievement. This is empirical evidence showing that a broad understanding of the many different possibilities for pattern rules is an important thinking ability that facilitates academic achievement for 1st-graders.

Patterning is an overarching kind of thinking about serial orders that transcends seriation. While unidimensional seriation is an understanding of relations between items that can be ordered on some dimension of magnitude, many serial orders do not involve increasing or decreasing magnitudes. Little research has been done on the effects of teaching patterning, even though it is routinely taught in early elementary school curricula. Manuals for teaching patterning have been published (Burton, 1982; Ducolon, 2000; Jarboe & Sadler, 2003) and cogent arguments have been advanced in support of teaching it (Hopkins, 1984), but only two studies were found that actually tested for positive effects on academic performance from teaching patterning. The first was Herman's (1973) dissertation, which showed that giving 24 lessons on very simple color, shape, and size patterns to impoverished African American and Latino kindergartners at the beginning of the school year produced small but statistically significant gains in numeracy at the end of the school year. The second was a multiple baseline experiment with four 1st-grade boys by Hendricks et al. (1999). These boys were taught over 400 patterns, ranging from simple linear orderings of colors and/or sizes and shapes, to increasing or decreasing numerical series, to alphabet sequences, to time (clock) sequences and sequences described in narrative scripts. This instruction, when combined with class inclusion instruction, led to significant year-end gains on the Diagnostic Achievement Battery-2, a composite measure of early numeracy and literacy. These two studies provide some empirical evidence, although it is sparse, that time spent on patterning is justified.

Even without instruction, children starting elementary school begin or continue to develop the ability to understand positional

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sequences involving orientation or rotation, temporal and causal sequences of activities or events, and repetitive arbitrary sequences of colors or shapes (e.g., red, blue, green, red, blue, green, ...). They also are taught to understand simple sequences of letters (A, B, C, ...), and then develop an understanding of more complex alphabetizations with irregularly spaced letters (such as D, K, M, T, ...). They know or learn simple sequences of numbers (1, 2, 3, ...), and then can proceed to more complex numerical sequences and sequential relations, like equally spaced numbers (5, 10, 15, 20) and numbers that increase irregularly (3, 9, 17, 40). They are also taught time sequences represented on clock faces. Regular sequences are much easier to understand than irregular ones, which may be too difficult for children starting elementary school.

Different sequences make different demands on a child. Thus, recognizing the sequence AB, AB, AB requires knowledge of similarities, differences, and ordinal relations—knowledge that preoperational children possess (Piaget, 1932/1965). A sequence with color as a second dimension requires sufficient decentration to consider both dimensions, a cognitive ability gained at about the age children enter 1st grade (Piaget, 1924/1969). That is, if the first pair of letters was a red AB, the next a blue AB, and the next a red AB, the following letter should not only be A but also blue, as opposed to red or any other color. Even more demanding sequences using three dimensions require additional understanding. For example, understanding a sequence of green circle, yellow 7, green square, yellow 8, green circle, yellow 9, green square, and yellow 10 makes all of the demands of the previous task, and requires understanding an increasing sequence of numbers as a third dimension simultaneously. This more complex reasoning requires concrete operational thought. Hence, development from forming and understanding simple sequences to forming and interpreting complex sequences presumably corresponds to development from intuitive, perceptually driven thought to more logical thought (from preoperational to concrete operational thinking, in Piagetian terms).

Research on Understanding Patterns

The natural development of *young* children's understanding of sequences has received little study. Ridge (1978) presented a factor analysis of 4- to 7-year-olds' strategies toward tasks involving linear patterns of colored blocks, but there has been no published follow-up of this oral report. Manning (1995) examined strategies employed by kindergartners for recognizing temporal and spatial correspondences between written and spoken words. She found that such interactions between strategies were complex and variable over time. Nelson's (1993) study of autobiographical memory also involved preschoolers' understanding of temporal sequences. Her basic premise was that even preschoolers can remember everyday, familiar events and recite a narrative description, or "script," of a sequence of actions that are generally followed in familiar activities, such as going to the park. Nelson found that as memory capacity increased, children's scripts became more elaborated and precise. But, she provided no information or suggestion on how this was related to an understanding of logical sequences of time or cause and effect, or to forming sequences on other dimensions, such as number, position, and the alphabet.

The ability to construct temporal sequences reflecting everyday activities has been incorporated into tests of cognitive ability—the Kaufman-ABC (Kaufman & Kaufman, 1983) and the various Wechsler scales (Wechsler, 1991). The Raven Progressive Matrices (Raven, Court, & Raven, 1992) involve analysis of a variety of positional sequences. Thus, test developers have found patterning to be a useful component of measures of the development of reasoning. However, no one has hypothesized just what the relationship between understanding patterns and reasoning might be. What is absent from available literature is a study of patterning as a separate component of thinking. Patterning may be an ability to form abstract ideas that incorporates much of the reasoning involved in the transition from the kind of thinking done by preschoolers to that developed by early elementary school children, especially thought involving unidimensional series of magnitudes, reversing relationships, and transitivity. If this is true, patterning would be an important mode of thought that, when mastered, serves to promote overall cognitive competence and school readiness.

It is especially likely to facilitate mastery of transitivity, which is the understanding that if A is found to be bigger than B, and B is independently found to be bigger than C, then A *must* be bigger than C. Understanding the place of an item in a pattern depends on understanding how it is related to items just preceding or following it. Any item in a pattern is precisely defined by, and also defines, characteristics of neighboring items. The main difference between patterning and transitivity is that the latter *requires* the ability to use the relations of A and C to B to infer the relationship between A and C. In the transitivity problem, the relation between A and C cannot be observed directly. When analyzing a pattern, the child can either make use of the transitive relation or, since all of the elements in the sequence ABC are present simultaneously, compare A and C directly, even though B intervenes. The first step in being able to make inferences about transitive relations between items would be the recognition of both logical and arbitrary patterns of items, when the item just preceding and just following any particular item is defined by the pattern rule. This would enhance the possibility of using any item as a mediator to relate the items neighboring it to each other. That would be transitivity per se.

Hendricks et al. (1999) ascertained the effects on a few 1st-graders of learning set instruction on both patterning and class inclusion. The learning set method, espoused by some comparative and educational psychologists (Gagné, 1968; Gelman, 1969; Kingsley & Hall, 1967; Pasnak, Hansbarger, Dodson, Hart, & Blaha, 1996), relies on a large variety and number of exemplars to achieve wide generalization of the principle taught, and requires few teaching skills beyond warmth and enthusiasm. The children improved on class inclusion from 28 percent to 92 percent correct, and on patterning from 42 percent to 84 percent. After the experimental instruction, the students were allowed several months to apply their new cognitive competence to profit from classroom instruction. Academic achievement, as measured by the Diagnostic Achievement Battery-2, or DAB (Newcomer, 1990), showed significant improvement. Since the experimental instruction covered nothing from the DAB, it appears that learning to understand class inclusion and many types of patterns may have facilitated better reasoning in the broad sense. This, in turn, could have led to better academic achievement as measured by the DAB. These results suggest that patterning and class inclusion may be reasoning abilities that provide a foundation for the development of many other secondary aspects of reasoning at about this age. The impetus of newfound competence in understanding patterns and class relations may have led to a broad growth in reasoning, which might show up in mastery of academic material. Researchers have presented theoretical accounts of how understanding patterns may play a role in both reading (Manning, 1995) and mathematics (Besemer, 1981). However, while the multiple baseline design that Hendricks et al. (1999) used does offer proof that the children improved on patterning and class inclusion, it does not offer proof that the academic gains were due to that instruction.

Overview of Current Study

The results Hendricks et al. (1999) obtained from instructing 1st-graders on patterning and class inclusion resemble those that Pasnak et al. (1987), Pasnak, Holt, Campbell, and McCutcheon (1991), and Pasnak et al. (1996) obtained from instructing younger children (kindergartners) on simpler concepts (the oddity concept and operational seriation). That is, increasing children's competence in key reasoning abilities that are age-appropriate may improve the children's academic performance. Such findings support the position that the constructs taught are truly important reasoning abilities that provide foundations for much reasoning by children at the ages in question. They also have important practical applications, especially when the children who benefit are those who have difficulty understanding academic subject matter taught at their grade level. Hence, the following experiment was undertaken to determine the practical utility of instruction in patterning. If the positive results of Hendricks et al. (1999) have general validity, three important questions must be answered. First, what is the effectiveness of patterning instruction alone, without collateral instruction in class inclusion? Perhaps the positive year-end results that Herman (1973) obtained for numeracy can be replicated on a broader measure. Second, since individual instruction is impractical in the regular education classroom, can patterning instruction in a small-group format be successful? Finally, it is always a possibility that children would profit more if equal time, resources, attention, and encouragement were spent teaching children subject matter already known to be important, instead of the experimental instruction. Accordingly, as a control, half of children were taught normal subject matter their teachers thought especially important. These instructional sessions, matched in timing and extent to the sessions on sequencing, provided a test of the practical utility of the patterning instruction. This type of "active control" group (Pasnak & Howe, 1993) is especially appropriate when time and resources are expended on behalf of an experimental group. Active control groups are much better for equalizing Hawthorne, familiarity, and expectancy effects than are control groups, which receive nothing out of the ordinary (passive control groups).

Method

Research Design

An experimental group-control group design, with a restricted random assignment of participants to the patterning or active control group, was employed. The restriction was that three children from each teacher's class were in each group, to equalize teacher and class differences. All children were pretested and posttested on academic achievement, since gains from the experimental instruction would be indirect and offset at least in part by the small-group instruction of the active control children directly on academics. Hence, differences between the groups were likely to be small, and small differences mandate the precise measurement of gains provided by pretests. Since school authorities did not wish to lose more instructional time to testing, only posttests were given for patterning. This variable should be directly affected by the experimental instruction, and group differences should be large, obviating the need for pretests. Scores from the Slosson Intelligence Test-Revised (SIT-R) were obtained to permit statistical equalization of children's general cognitive competence.

Participants

The three cooperating public elementary schools were located in suburbs that contained a mixture of apartment complexes, townhouses, and single family homes. All 12 first-grade teachers were asked to identify six pupils who had no identifiable handicaps (i.e., learning disabilities or English as a Second Language), but who were having difficulty understanding class material. Three pupils from each class were randomly assigned to sequencing instruction, and three were assigned to control instruction.

After attrition, 62 children remained when posttesting was conducted. The mean age of the 12 girls and 21 boys in the experimental group was 7.106 years (SD = .475). One was Latino, 6 were African American, 22 were white, 2 were of Middle Eastern descent, and 2 were Asian American. The mean age of the 11 girls and 18 boys in the control group was 7.161 years (SD = .417). There was a Latino, 5 African Americans, 18 whites, 3 of Middle Eastern descent, and 2 Asian Americans.

Materials

Patterning Instruction Materials. "Patterning" may be operationally defined as the ability to recognize an ordering of numbers, letters, shapes, symbols, objects, or events according to some rule of progression. The learning set contained 480 problems, which were presented in a variety of media to increase generalization. A 19" x 23" felt board was used for problems involving 10 sequences of numbers, 20 of letters, and 40 shape patterns that were mounted on felt strips. Strings of 5-18 colored Perler Fuse beads were melded together to form 20 patterns of colors. Twenty patterns were of 6-8 larger colored plastic beads placed in wooden frames. There were 80 patterns of animal stickers mounted on construction paper. Fifty temporal and causal cartoon sequences were presented on 3" x 3" cards, which could be placed in the appropriate order. Computer-generated graphic patterns of varying levels of difficulty were also presented. These included 70 shape, 35 letter, 45 number, and 35 clock patterns. Similar but new patterns—15 number, 10 letter, 25 shape, and 5 clock patterns—also were readied for presentation via a Toshiba T1910CS laptop computer.

Types of Patterns. Patterning tasks ranged from simple linear orderings on one dimension to multidimensional sequences presented as matrices. Simple sequences of numbers increasing (or decreasing) by ones, twos, fives, or tens were presented in rows, columns, and matrices in the felt board and computer-generated formats. These formats were used to present letters in short but perfect alphabetical sequences and also in alphabetical sequences having irregular gaps. Computer-generated clock faces were presented that showed clock hands set at 60-, 30-, or 15-minute intervals. Arbitrary patterns were constructed in a variety of formats and types, in progressively more complex patterns. The simplest form (1, 2, 1, 2) was presented by using colors, letters, numbers, animal stickers, and shapes. The patterns became progressively more difficult in terms of length, number of dimensions, number of items, and number of missing items. Rotation patterns showed regular or irregular geometric shapes rotating through four or six positions. The narrative script cards, purchased commercially or prepared by an artist, used 3 to 7 cards to portray simple or complex cause-and-effect events, such as playing catch or going to the beach.

Academic "Active Control" Materials. Materials used were variable, depending on what the teachers recommended as most beneficial for their students. Flash cards were used for instruction on the alphabet, phonics, first-sight words, numbers, simple addition and subtraction, currency, shapes, colors, and time. Memory skills were addressed with a memory game for matching pictures. Cursive writing and printing was practiced by writing names, addresses, dates, time, and simple sentences. Children also worked with activity sheets designed to boost word skills and sentence structure knowledge.

Research Instruments

Standardized Tests. Brief, easily administered, reliable, and valid instruments that would not interfere with testing done in the school system were desired to measure general reasoning ability and academic achievement. The Slosson Intelligence Test-Revised (SIT-R) and the Diagnostic Achievement Battery-2 (DAB) were employed. The SIT-R (Slosson, 1996) has a reported reliability of $r = .96$ (test-retest) and a concurrent validity coefficient of $r = .84$ with the WISC-R. In the context of the present study, it correlated .72 with the DAB achievement measure. It is brief (25 minutes at age 7) and not as difficult to administer as other tests of reasoning, but is reasonably predictive as a screening instrument.

Correlations of the DAB (Newcomer, 1990) with the Detroit Tests of Learning Aptitude-Primary (DTLAP) and the Wide Range Achievement Test (WRAT) range from .47-.81, depending on sample characteristics. DAB stability coefficients for the composite scores range from .92-.98. It only takes 25 minutes to administer the DAB with 1st-graders, and it was chosen over the DTLAP and WRAT because those tests are used for nonresearch purposes in area public schools. The test-retest correlation for the children in the present study was .69. This reliability coefficient was presumably lowered by unequal changes in achievement engendered by the experimental manipulations.

Unstandardized Test. The Patterning Measure (PM) contained 60 patterns in a variety of media, including beads, felt numbers, letter and shapes, stickers, narrative sequences on cards, and dice. There were 30 patterns designed to measure near generalization and 30 for far generalization. The near generalization patterns were different in particulars but similar in form and media to those used in the instruction. Far generalization problems were made up of patterns and media not used in the instruction sessions—UNO and animal cards, dice, and dominoes. A child's score was determined by the number of correct patterns selected, and could range from 0 to 60.

The psychometric properties of this research instrument are undetermined.

Procedure

There were five instructors, two male and three female; two were graduate students and three were undergraduate students. Instructors rotated weekly, working with either the experimental or control group on alternate weeks, to minimize instructor effects. Instruction for experimental and control trios in each class was given simultaneously, for four days a week in 15-minute sessions, from the end of October to mid-March. Instruction was terminated for the experimental and control trios from the same class when the former had mastered the whole learning set.

Patterning Instruction. The children were instructed in groups of three. While two children watched, one was shown a problem and first asked to identify the objects. Pointing to several alternatives, the instructor then asked, "Which of these beads, numbers, letters, etc., belongs in this space?" The child pointed to one of the alternatives or moved it into the missing space in the pattern. The child was asked to explain the choice and the rule that described the pattern. This might require much or little coaching, depending on how well the child understood that type of pattern.

Each child in a trio was given the same number of turns at solving patterns during any session. The children progressed to more demanding patterns at their own rates. Attention to the needs, motivation, and performance of each child in the trio was central to the instructor's effort, as was emphasizing enjoyment and self-esteem.

Academic "Active Control" Instruction. Because of its nature, this instruction was highly variable. Shaping the instruction according to what the teachers thought their children needed most was deemed better for the children than prescribing preconceived instructional content. Instructors focused on the needs, motivation, and performance of each child in the trio, emphasizing enjoyment and self-esteem, while teaching the children colors, letters, numbers, phonics, first words, cursive writing, printing, arithmetic, currency equivalences, time shown by clocks, and memory skills.

Testing. In November, all children were pretested on the DAB. In May, two months after instruction was completed, all were posttested with the PM, DAB, and SIT-R by experimentally blind testers recruited for that purpose. The posttesting delay was designed to give the experimental group's new mastery of patterning time to assist their classroom learning and mastery of academics.

Results

Posttest scores on the DAB Total Achievement measure correlated with the children's scores on the patterning measure (PM), *r*

(60) = .40, $p < .01$. The correlation for the subscales was similar (mathematics, r (60) = .42, p <.01; written language, r (60) = .35, p < .01; spoken language, r (60) = .38, p < .01). These are medium effect sizes (Cohen, 1992). Hence, it seems clear that the children's academic achievement was related to their ability to understand patterns. This could be due to intelligence, which would be expected to influence both academic achievement and understanding patterns. Or, it might reflect some special contribution from the ability to understand patterns, above and beyond the effect of a child's general intelligence. If the latter is the case, increasing children's mastery of patterning, as was attempted with the experimental group, should increase their academic achievement. Hence, the key questions are whether the experimental instruction helped the experimental group become better at patterning than the control group, and whether that superiority, in turn, produced greater academic achievement than would be predicted from their intelligence test scores.

Table 1 provides the means and standard deviations for both groups on all measures. Scores on the patterning measure were significantly better for the experimental group than for the control group, both for problems similar in format but different in particulars from those on which they had been instructed (near generalization), and also on patterns that had quite different formats (far generalization). However, although the experimental group consistently scored better than the control group, neither DAB posttest scores nor gain scores (differences between pretest and posttest scores) differed significantly for the two groups.

The SIT-R scores for the two groups suggest an explanation for the absence of group differences on the DAB scale. The descriptive statistics reported in Table 1 show that despite the random assignment of children to groups, there was a 5-point difference between the groups on average intelligence (95.67 versus 100.41), with unequal variances (12.68 vs. 18.78). Since IQ favored the control group, the correlation between IQ and DAB Total Achievement scores (r = .72 in this case) may have attenuated any superiority of the patterning group on the DAB. Furthermore, the Bartlett-Box F was significant, F (1,10673) = 4.49, p = .03, indicating that the variance was not homogeneous.

Accordingly, a MANCOVA was conducted,

Table 1
Descriptive Statistics and t Tests for Direct Comparisons of Group Scores

Measure	Group	Mean	SD	t	df	p
Patterning						
Total	Experimental	35.15	8.34	4.31	60	< .001
	Active Control	26.79	6.70			
Near	Experimental	8.52	3.99	4.52	60	< .001
	Control	14.34	3.15			
Far	Experimental	12.31	4.14	3.64	60	< .001
	Control	14.34	3.15			
DAB Gain Scores						
Total	Experimental	9.48	5.98	0.45	60	> .05
	Active Control	8.31	8.35			
Math	Experimental	7.57	6.41	0.39	0	> .05
	Active Control	6.90	7.48			
Spoken	Experimental	3.18	8.35	0.48	60	> .05
	Active Control	.97	11.58			
Written	Experimental	30.48	10.56	0.71	60	> .05
	Active Control	28.10	14.64			
SIT	Experimental	95.67	12.68	1.18	60	> .05
	Active Control	100.41	18.78			

employing the SIT-R scores as a covariate. When the groups were statistically equated on the SIT-R reasoning measure, the experimental group improved significantly more than the control group on the DAB Total Achievement measure. The error term for the DAB was also reduced, from 51.71 to 43.56, indicating that individual differences in learning ability revealed by the SIT-R were inflating the amount of experimental error. The results for the DAB subscales for mathematics, written language, and spoken language showed that the children taught patterning improved significantly more from pretest to posttest than the control children on the first two measures, but not on the third (see Table 2). Effect sizes for total achievement (.19) and mathematics (.18) are medium; that for written language (.47) is large.

Hence, after instruction on patterning, children were able to recognize and interpret patterns significantly better than children who were not so instructed. When the groups were equated on IQ, the children whose understanding of patterns was better made significantly greater gains in mathematics and written language than children who were instructed directly on academic material.

Discussion

This research demonstrates that patterning can be successfully taught in small groups. At the end of the year, children in the group taught patterning were significantly better than the control group on patterns that were similar to those included in the instruction (i.e., beads, felt, loose leaf, and card patterns) and also on patterns composed from materials not presented during the intervention (i.e., dice, dominoes).

This result supports the theoretical position (Gagné, 1968; Gagné & Paradise, 1961) that learning sets, in which scores of differing problems representing an overall concept or abstraction are presented in a variety of media, can successfully strengthen and build on existing abilities to facilitate more advanced conceptualization. The use of multiple problems with varying degrees of complexity also serves to suppress or eliminate common error-producing tendencies, such as pre-existing tendencies to attempt particular types of erroneous solutions, and confusion resulting from ambiguous cues (Harlow, 1949). Instead of merely helping participants learn to solve individual problems and memorize solutions to many separate pattern problems, the learning set serves to promote overall concept formation, or as Harlow stated, "learning how to learn" (p. 53). The success of the learning set method in teaching advanced concepts to young children was previously shown by Gelman (1969) for number conservation, Kingsley and Hall (1967) for length and weight conservation, and Pasnak et al. (1987) for

Table 2
Analysis of Covariance for Experimental-Control Group Differences in DAB Gain Scores

Source	*df*	Mean Square	*F*	*p*
DAB Gain Scores				
Total Achievement	1	509.91	11.71	< .001
Mathematics	1	442.80	10.85	< .002
Spoken Language	1	37.81	.38	> .05
Written Language	1	3102.58	28.41	< .001
Error				
Total Achievement	1	43.56		
Mathematics	1	40.82		
Spoken Language	1	99.52		
Written Language	1	109.20		

teaching number and substance conservation, the oddity concept, and operational seriation.

Despite its advantages and track record, the learning set produced only a 31 percent advantage for the experimental group on the patterning posttest. This may be evidence that patterning is truly a significant cognitive challenge for 1st-graders. Piaget (1967) posited that changes in the *abstract level* of one's thinking would be greatly hindered by the process of assimilation, whereas conventional instruction could easily induce improvements on lower order skills like those involved in computation or writing if one already had the requisite conceptual abilities. Despite 17 weeks of instruction in small groups, the experimental group averaged only 59 percent correct, while 1st-graders instructed individually by Hendricks et al. (1999) averaged 84 percent correct. The reduced gain may well be due to sharing attention when the children were instructed in trios, instead of having the instructor's whole effort focused on each child individually. Learning by watching others for 10 minutes out of every 15 is presumably not as effective as 15 minutes of one's own efforts with individual coaching and scaffolding. This suggests that the relatively short-term teaching of patterning in the classroom, under conditions in which a teacher's attention is widely distributed among children, may not produce much improvement in children's patterning ability. There is no published evidence for the effectiveness of patterning instruction under normal conditions in the classroom.

The incomplete mastery of patterning by the experimental group (41 percent error rate) in this study failed to produce sufficient automaticity in patterning to offset the control group's SIT-R advantage when it came to learning academic material presented in the classroom. When the groups were equated on the SIT-R measure of general reasoning, however, the experimental group significantly outgained the control group in academic achievement. This is an important finding, *because the control group was instructed in areas directly assessed by the DAB*. Since instruction in patterning was more effective in promoting academic achievement than an equal amount of time spent in providing additional small-group tutoring in academic material, it appears that even a moderately improved understanding of patterns is helpful for children. The notion that patterning is an important thinking ability for this age group and belongs in the curriculum because it facilitates a better understanding of the academic challenges faced by 1st-graders appears to have merit. Had the control group been one in which children received no special instruction, or instruction in some useful but nonacademic skill (such as art, music, or physical education), the patterning group would presumably have had an even greater advantage on the DAB. The control group used in this research is an especially stringent one, because it involves direction instruction in the kind of academic material on which the children were tested.

Why would the ability to understand patterns be an important cognitive ability that is deficient in children who are struggling in many areas of academic performance? One reason may be that comprehending patterns requires many of the thinking skills acquired in the transition from preoperational thought to the concrete operational thought central to school readiness. First, comprehension of patterns requires attention to the relations between and among the items in the pattern. Second, many of the more complex patterns require the child to attend to more than one dimension (e.g., both color and shape), a necessary skill in advanced classification. Third, incorporated into recognition of patterns is the notion of reversibility, which Piaget posited as the sine qua non of early mental operations (Piaget, 1924/1969). The ability to understand that a pattern of 1, 3, 5 has the same underlying logic as one of 5, 3, 1 is an example of being able to mentally reverse a relation. In order to recognize a pattern, attention must be paid to relations among and between the objects within the pattern. For example, to solve a more difficult sequence like red square, yellow circle, green triangle, blue diamond, blue diamond, green triangle, yellow circle, red square, one must see that there is an orderly progression of both color (red, yellow, green, blue) and shape (square, circle, triangle, diamond) and that the order of presentation reverses. Strengthening these cognitive abilities by teaching children to understand the relations involved in patterns may help them progress towards the level of abstract thinking required for success in the early grades. Instruction in patterning may offer an additional way to support and strengthen the development of age-appropriate mental abilities and provide help in boosting children's overall intellectual growth. Such assistance would be especially useful for children who are slow in reaching their cognitive potential. Increased cognitive ability could lead to better mastery of classroom material, which can be accompanied by improved self-images (Dudek, Strobel, & Thomas, 1987).

It is noteworthy that the children whose patterning was improved by the intervention improved on the written language scale as much or more than they improved on the mathematics scale. Previous researchers have focused on numeracy in the early grades (Burton, 1982; Ducolon, 2000; Herman, 1973; Jarboe & Sadler, 2003). However, Manning (1995) presented a model that applied patterning to reading in kindergarten. Her results suggested that children's initial successes are in noticing how the temporal patterns of spoken words are linked to the spatial patterns of written words. The results of the present research implicate the second half of this model as the locus of the main effect of differences in patterning abilities. Whether this model, or some other, accounts for the effect of patterning on written language awaits further research.

In sum, although there has been little research on its effectiveness, instruction in comprehending patterns seems to deserve its place in the school curriculum. It may be an effective form of assistance for not only 1st-graders who are not performing at their optimum level, but also other children who are entering the period of concrete operational thought. Identifying which children can profit the most is a worthy goal for further experimentation.

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