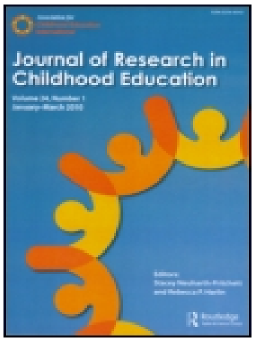

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Effects of Patterning Instruction on the Academic Achievement of 1st-Grade Children

Julie K. Kidd, Abby G. Carlson, K. Marinka Gadzichowski, Caroline E. Boyer, Debbie A. Gallington, and Robert Pasnak

George Mason University, Fairfax, Virginia

A test of the effectiveness of patterning instruction was conducted with 140 first-graders. First, 383 first-graders from 20 classes were screened on a patterning test. The eight in each class who scored worst were given individual 15-minute lessons on patterning or reading or mathematics or social studies three times weekly for a period of 6½ months. Test results for 140 children still available in May showed that the children receiving patterning instruction were generally superior on a patterning test. They also scored significantly higher on the Woodcock-Johnson (W-J) III Mathematics Concepts Scale 18A than children who received mathematics, reading, or social studies lessons. On the W-J III Mathematics Concepts Scale 18B, children who received either patterning or mathematics instruction scored significantly higher than those who received social studies instruction. There were no significant differences on the W-J III Applied Problems Scale 10, nor on three W-J III reading scales. These results suggest that instruction on understanding patterns can substantially improve 1st-graders' understanding of mathematical concepts. Such outcomes may be specific to the sort of children, primarily minority children from diverse ethnic backgrounds, who were participants in this study.

Keywords: patterning, mathematics, achievement, 1st grade

Children in the kindergartens and 1st grades of U.S. schools may be taught to recognize simple patterns of shapes, sizes, and colors, often involving alternations. Examples are red blue red blue red blue or large small small large small small large small small or oval oval disk disk oval oval disk disk oval oval disk disk. Patterns involving three elements are common. Manuals are available describing how such instruction can be done (Burton, 1982; Ducolon, 2000; Jarboe & Sadler, 2003), and it is not difficult for teachers to carry it out.

The goal of such instruction is to improve the cognitive development of the children who receive it, in the expectation that improved academic achievement will follow. The problem with this expectation is twofold. First, more theoretical support is needed for the assumption that

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Address correspondence to Robert Pasnak, Department of Psychology, George Mason University, 4400 University Drive, 3F5, Fairfax, VA 22030-4444. E-mail: rpasnak@gmu.edu

recognizing patterns is an important aspect of cognitive development; second, more evidence is needed that instruction on patterning improves academic performance.

The professionals who study cognitive development, primarily developmental psychologists, have ignored patterning. There is scant theory describing its place in the development of children's thinking, and little explanation of just how a child would be helped to reason better or achieve more if their ability to recognize patterns was better. Of course, intelligent children reason better, achieve more, and understand patterns better than less intelligent peers, but understanding patterns might well be a consequence of intelligence rather than a component or building block of thinking.

What is absent from available literature is a study of patterning as a separate component of thinking. It could be an important mode of thought that, when mastered, serves to promote overall cognitive competence and school readiness. Patterning is an ability to understand abstract relationships that incorporates much of the reasoning involved in the transition from the kind of thinking done by preschoolers to that developed by early elementary children, especially thought involving patterns of magnitudes, reversing relationships, and transitivity. However, patterns can be quite complex and may involve more than one dimension. Simple alternation of two or three elements can be understood if the child recognizes similarities and differences on familiar dimensions, such as color, shape, or size, and understands basic temporal sequences well enough to recognize when one item precedes or follows another, knowledge that most children possess before entering school. Considering two dimensions, such as size and shape or shape and color, and relating them well enough to understand such a pattern as red oval, red square, blue oval, blue square, red oval, red square, and so on is more demanding. It requires decentration (Piaget, 1963/1963) and sufficient executive control to shift focus rapidly from favored dimensions to less favored ones as appropriate.

Patterns can be much more complex—gray disk, pink L, gray triangle, pink M, gray disk, pink N, gray triangle, pink O—and may make excessive demands on children's executive control (Zelazo & Muller, 2002). When faced with excessive demands, children may turn to a rule that they used to solve simpler problems, even though it is insufficient to solve the new problems. Young children may even persist in using old rules when they encounter problems that must be solved by new rules, even though the new rule is no more difficult than the old (cf. reviews by Zelazo & Frye, 1997; Zelazo & Jacques, 1996).

Such cognitive difficulties, which are imposed by adding dimensions so as to make patterns binary, ternary, or more complex, is addressed by Halford's relational complexity theory (Halford, 1993; Halford, Andrews, Dalton, Boag, & Zielinski, 2002), and a demonstration of the theory's application to oddity problems, which were presented in a variety of dimensions, was provided by Chalmers and Halford (2003). However, new patterns are frequently encountered that do not involve additional dimensions, and if the pattern rule is relatively complex, a 5- or 6-year-old may perform like the preschoolers studied by Zelazo and his colleagues (Zelazo & Frye, 1998; Zelazo, Resnick, & Pinon, 1995).

Understanding new patterns requires effective executive function, especially that of inhibiting learned responses to patterns previously experienced, because those responses are now inappropriate. Children also must maintain attention to critical characteristics of the new pattern and shift attention between its elements as necessary. The suppression of responses previously learned is distinct from and generally precedes shifting of attention to new rules (Espy & Bull, 2005).

Both must be addressed in teaching patterning, because adhering to and applying a rule is quite different from knowing it in the first place (Zelazo & Muller, 2002).

Whatever the role of understanding patterns is in the development of thought, the question remains of how understanding patterns translates into academic performance. The account offered by Manning, Manning, Long, and Kamii (1995) of how children progressively develop expectations for the pattern of temporal and spatial correspondences between written and spoken words may point to a role for understanding patterns in reading. Children who have not yet begun to read attend primarily to nouns. According to Manning et al., such children enter the first stage of reading if, when there is no more than one functor word (auxiliaries, articles, or prepositions), they note some correspondences between the order of spoken and written words in simple declarative sentences. In Stage 2, prereaders understand better that when sentences are written down every word that is spoken should be represented, but often do not have a good understanding of where those spoken words should be in the array of written words. Prereaders advance to Stage 3 when by attending to the pattern of the spoken words, they can grasp correspondences between the words that were spoken and those that are written. The next step (Stage 4) is to combine letter-sound correspondences to the words and the pattern of the words in identifying portions of the sentences that were written. This is a long way from patterns of alternating shapes and colors but is as close as anyone has come to suggesting a way in which skill in recognizing patterns could have an impact on early reading and writing.

White, Alexander, and Daugherty (1998) offered an account of how advances in understanding patterns could lead to advances in mathematics. They explained that patterning could lead to analogical reasoning, which includes, in their formulation, recognizing patterns of relations between symbols. Their theorizing was based on the cognitive and metacognitive processes described by Sternberg (1977, 1981), and they tested it by analyzing children's performance on a test based on the processes of encoding, mapping, inferring, and application. Their analyses showed that there was a relation between extending patterns and analogical reasoning in a very primitive form. This, in turn, predicted children's learning of mathematics. More of the variance in numeracy was accounted for by children's understanding of patterns than by other components of numeracy, such as recognizing numbers and comparing quantities. White et al. posited that being able to extend a pattern depended on understanding the relations between elements of the pattern, and that this is a foundation for understanding relations between mathematical expressions and terms upon which mathematical learning is predicated. This venture into formulating theory, and the possibility suggested by Manning et al. (1995), are the only theoretical accounts of how patterning could have a role in academic achievement.

In any event, there is very little empirical evidence that improving children's ability to recognize patterns improves academic achievement. For decades, patterning instruction was carried out on the basis of an educational consensus that it had value. Only one study, an unpublished dissertation (Herman, 1973), tested whether it had an effect. Herman (1973) offered inner-city, English speaking children and non-English speaking Latino 5-year-olds 24 lessons on patterns that were simple alternations—abababab, aabaabaab, abbabbabb, or aabbaabb. The result was a small gain on the Metropolitan Readiness test for African American children but not for Latino children.

More recently, Hendricks et al. (1999), in a multiple baseline study of four boys who were learning English as a second language (one Asian and three Mideastern), provided some evidence that the instruction might be valuable. Instruction on both class inclusion and patterning—Hendricks et al. termed the latter "sequencing"—was followed by gains on the Slosson Intelligence Test (SIT-R) and the Diagnostic Achievement Battery-2 (DAB-2) when the boys were tested 2 to 5 months later. However, the multiple baseline design demonstrates only that the boys improved on patterning and class inclusion. It does not prove that the SIT-R and DAB-2 gains were due to this instruction, and there are in fact many reasons why children learning English might improve on standardized tests over a period of months.

A much better demonstration was provided by Hendricks, Trueblood, and Pasnak (2006). They taught 440 patterns ranging from simple alternations to complex multidimensional patterns presented in matrices to 33 English speaking children from three schools for a period of 3 months. They found limited but statistically significant overall differences on the DAB-2 when these children were compared with classmates who had matched sessions of academic instruction. This study and those of Herman (1973) and Hendricks et al. (1999) comprise the total database for a large academic enterprise in American schools. A better database is needed, and this study is an effort to address that need. Does patterning instruction, whatever its effect on cognitive development may or may not be, improve academic achievement? That is the central question for educators.

METHOD

Participants

The research was conducted in six schools in an urban system in the Virginia suburbs of Washington, D.C., which served many low-income and immigrant families. For this study, 383 1st graders from 20 classes in these schools were screened on a 42-problem patterning test in October. The eight children in each class scoring lowest ($M = 17.76$, $SD = 3.98$) comprised the sample for the study. In May, after attrition, there remained 76 boys and 64 girls. Thirty-six were African American, 19 were West African, 47 were Latino/Hispanic, 27 were Mideastern, 8 were other White, and 3 were East Asian. Average age was 6.63 months, $SD = 1.89$.

Design

The central research question was whether teaching children patterning produced better achievement than equivalent investment of time and instructional resources teaching them reading or mathematics. Accordingly, an active control design was employed. In such advanced designs (Pasnak & Howe, 1993), children in control groups receive as much investment of time and resources in productive activities as children in experimental groups. The control activities are different from those of the experimental group, and hence differences in the outcomes for the experimental and control groups provide a direct test of the relative effectiveness of differences in whatever has been done for or to the children in the experimental and control conditions. The advantage of such designs is that spurious results from Hawthorne effects, expectations, familiarity, and related factors are avoided, as all children receive equal investments of time, attention, and resources in activities expected to be fruitful.

In this research, eight children per classroom were randomly assigned to four instructional conditions, with the restriction that two children be in each condition, to control teacher and classroom effects. In each classroom, two children were taught patterning, two were taught reading, two were taught mathematics, and two were taught social studies. Instructional sessions were matched in timing, number, and duration, so that in each classroom each child received the same amount of special attention and was expected to make progress. Social studies were viewed as a control subject matter that would not lead to as much improvement in reading or mathematics as instruction directly on those subject matters. The hypotheses were that, subsequent to instruction:

1. Children in the patterning condition should make higher scores on a test of patterning than the children in the other conditions. This is a unidirectional hypothesis.
   patterning condition > reading condition = mathematics condition = social studies condition
2. Children in the patterning condition should make scores higher than those in the mathematics or social studies condition on a test of *reading*. This was a unidirectional hypothesis.
   patterning condition > mathematics condition = social studies condition
3. Children in the patterning condition should make scores higher than those in the social studies condition on a test of mathematics. This was a unidirectional hypothesis.
   patterning condition > reading condition = social studies condition
4. Children in the reading condition should make higher scores on a test of reading than the children in the mathematics or social studies conditions. This was a unidirectional hypothesis.
   reading condition > mathematics condition = social studies condition
5. Children in the mathematics condition should make higher scores on a test of mathematics than the children in the reading or social studies conditions. This is a unidirectional hypothesis.
   mathematics condition > reading condition = social studies condition
6. Children in the patterning condition might make scores as high as, higher than, or lower than those in the reading condition on a test of reading. This is a bidirectional hypothesis.
   patterning condition >, =, or < reading condition
7. Children in the patterning condition might make scores as high as, higher than, or lower than those in the mathematics condition. This is a bidirectional hypothesis.
   patterning condition >, =, or < mathematics condition

Procedure

Throughout the course of the school year, each child received direct instruction in the topic to which they had been randomly assigned for 15 minutes a day, three days per week. At the end of the year, a patterning test was administered to all of the children, as were three W-J III Achievement subtests designed to measure reading and three more designed to measure mathematics (Woodcock, McGrew, & Mather, 2001).

Patterning. Instructors used interactive computer slideshows to teach children a variety of patterns. Each slide displayed a different pattern, and children were required to identify the object needed to complete each pattern. Slides advanced when children clicked on the correct answer and remained on the same page when they selected the wrong one. Performance was scaffolded on this task through explanation and repetition until children were able to demonstrate mastery of each pattern type. A similar approach was used with note cards; each note card showed a pattern and displayed four options for completing the pattern.

Small objects (manipulatives) were also used to teach similar patterns. Researchers would start a pattern, provide the children with more manipulatives, and request that they complete or extend it. Children also had the opportunity to create patterns for the researcher or another child to complete. White boards were used in a similar fashion, with the patterns being drawn instead of created from manipulatives.

The patterns had symmetrical, random, alternating, rotating, or regularly increasing numbers of elements; the elements were colors, shapes, letters, numbers, and everyday objects.

Mathematics. Mathematics instruction consisted of a different math-related activity for each day. Each activity addressed one or more specific skills, such as counting by 5, adding, shapes, and basic fractions. A number of materials were utilized, including coins, manipulatives, number cards, and various activity pages.

Each activity began with a quick review of the skill being covered to ensure that the child had the fundamental abilities needed to do the chosen task. The tasks all had optional "back up here" and "go ahead to here" options that instructors could use to better tailor each activity to the children's abilities. If the initial task was too difficult, the instructors would fall back to a simplified version; if the initial task was easy and completed quickly, they could move ahead to a more challenging extension. All activities ended with a concluding question or task that addressed the overall focus of the activity.

For example, an activity that focused on counting began with a review session in which children counted to 100 as quickly as they could. The basic activity involved a series of 100 number cards that students dropped onto the table and then were instructed to pick up in order of smallest to greatest. If this was too difficult, the number cards 1 through 20 could be used. If this was too simple, children were instructed to pick up the cards in order from greatest to smallest after they finished the initial activity. At the end of the session, the children were helped to put the cards away by 40s, 50s, 60s, and so on.

Reading. Each week, the reading activities focused on one poem with a specific phonetic ending (i.e., -ay, -ed, -est, -ump). The 15-minute session began with one minute of warm-up conversation, designed to improve oral vocabulary and conversation skills through basic back-and-forth conversation between the children and the instructor.

The warm-up conversation was followed by 3 minutes of familiar reading, in which the children read the focus poem from the previous week. During this activity, the students used Whispy Readers, small curved tubes that a child held to his or her mouth and ear like an old fashioned telephone receiver. These tubes allowed the children to say the words orally as they read and hear what they said without disturbing any other child. The familiar reading activity was targeted to improve fluency and teach decoding, sight words, and comprehension strategies.

While the children were reading, the instructors helped them as was needed. After each child finished the poem, the instructor asked them basic questions about what they had just read, such as "Where did the owl live?" or "Why do you think the truck never got stuck?" This final step was intended to aid in reading comprehension.

Familiar reading was followed by 6 minutes of reading and discussion related to the week's new poem. This portion of the activity had three facets, with each one administered in rotating order on separate days of the week throughout the year. On the first day, instructors focused on improving comprehension by reading the poem aloud and talking with the children about what they had heard. On the second day, the children read along with the instructor in order to emphasize fluency. They also worked on vocabulary by discussing different words in the poem. On the third day, all three of these skills were reinforced with additional reading, discussion, and questioning.

After completion of reading and discussion, 4 minutes were used for a phonics activity. Rhyming word flashcards with the same phonetic ending as the week's poem were used to quiz the children. The instructors helped the children make connections between the words they were reviewing and the poem they were reading that week.

The final minute of the reading intervention was spent in conversation, as the instructor and the children summarized what they had done during the session.

Social studies. Social studies activities changed daily and featured a variety of activities that highlighted civics, geography, and important people and events in history. The instructor would join the children in different activities, such as coloring activity sheets, doing puzzles, filling in maps, completing mazes, and making different objects from cut-and-paste materials.

Measures

The patterning test and six scales from the W-J Tests III Tests of Achievement (W-J III) were administered in May of the school year. This test provides an estimate of an individual's school-based skills and achievement. In this study, children were administered subtests comprising the Broad Reading and Math Reasoning clusters. The reading cluster includes subtests that measure a child's ability to recognize and identify isolated letters and words (Scale 9 Letter-Word Identification), reading speed and fluency (Scale 2 Reading Fluency), and completing short passages with key words missing (Scale 1 Passage Comprehension).

Children's ability to apply skills of mathematical knowledge was measured by three subtests composing the Math Reasoning cluster. These are Applied Problems (Scale 10) and Quantitative Concepts (Scales 18A and18B).

RESULTS

Descriptive statistics for the outcomes are shown in Table 1. An ANOVA (see Table 2) showed that the instructional conditions produced significantly different outcomes on the patterning test, $F(3, 136) = 3.21$, $p < 0.025$. A priori Least Significant Differences (LSD) tests yielded $p < 0.05$ and $p < 0.01$ for the comparisons of the patterning children with the control children in the reading and social studies conditions, respectively. The difference between the mathematics condition and the patterning condition on this scale was in the same direction. Hence, we conclude that the patterning instruction was effective in teaching patterning.

However, ANOVAs showed that there were no significant differences on any of the three W-J III reading scales, even when LSD tests were applied to test for hypothesized differences.

TABLE 1
Descriptive Statistics for Patterning, Reading, Mathematics, and Social Studies Conditions

		Patterning	*Reading*	*Mathematics*	*Social Studies*
Patterning	*M*	26.15	23.44	25.51	22.65
	SD	5.09	5.53	4.82	6.23
1 Letter-Word	*M*	32.94	32.97	33.09	31.09
	SD	5.93	4.97	4.53	5.60
2 Fluency	*M*	18.33	19.79	18.37	16.91
	SD	8.70	11.27	8.91	7.82
9 Comprehension	*M*	16.15	16.26	16.17	15.82
	SD	2.94	2.47	2.44	2.53
10 Applied Problems	*M*	24.91	23.69	23.83	25.26
	SD	3.72	3.74	4.11	3.51
18A Concepts	*M*	15.94	14.44	14.57	14.79
	SD	2.08	1.80	2.27	2.19
18B Concepts	*M*	10.15	9.42	10.03	8.91
	SD	1.96	2.30	1.98	1.69

These data provide no support for the hypothesis that there is a relation between competence in patterning and competence in reading

Table 3 shows that there were also no significant differences on the W-J III Applied Problems Mathematics Scale (Scale 10). In contrast, the patterning children outscored the children in the other instructional conditions on Quantitative Concepts scale 18A, $F(3,136) = 3.71$, $p < 0.02$. LSD tests showed that the patterning group was significantly better than the reading group ($p < 0.01$), mathematics group ($p < 0.01$), and social studies group ($p < 0.05$). There were also significant differences on Quantitative Concepts scale 18B, $F(3, 136) = 2.80$, $p < 0.05$. LSD tests showed that the children in the patterning condition and also those in the mathematics condition outscored the social studies condition, $p < 0.05$ in both comparisons.

DISCUSSION

The first major finding is that the patterning instruction did improve patterning scores. We note that the instruction was much more extensive than that usually offered to elementary schoolchildren and involved multiple presentations of increasingly complex patterns treated in different ways in four different media. This is in keeping with findings that date from as far back as the middle of the last century—when one is teaching an abstraction that requires a conceptual advance on the part of the learner, multiple exemplars and formats increase understanding of the abstraction (Gagné, 1968; Gagné & Paradise, 1961)—and is in keeping with modern educational practice. It is particularly important when attempting to teach children abstractions that are over their heads, because this approach can strengthen existing abilities that are the foundation needed to develop higher level conceptualizations. Repeatedly rising to the challenge of progressively solving a large number and variety of problems also extinguishes preexisting tendencies to attempt

TABLE 2
Analysis of Variance and Least Significant Differences for Patterning and Reading

Patterning Test				
Source	*df*	*MS*	*F*	*p*
Group	3	95.14	3.21	.025
Error	136	29.64		
Group Comparisons	*Mean Difference*		*SE*	*p*
Pattern vs. Reading	2.72		1.29	.037
Pattern vs. Math	.64		1.32	>.05
Pattern vs. Social Studies	3.50		1.33	.009
Reading vs. Math	−2.08		1.27	>.05
Reading vs. Social Studies	.79		1.28	>.05
Math vs. Social Studies	2.87		1.31	.030
W-J Scale 1 Letter Word				
Source	*df*	*MS*	*F*	*p*
Group	3	31.57	1.14	>.05
Error	136	29.64		
Group Comparisons	*Mean Difference*		*SE*	*p*
Pattern vs. Reading	−.03		1.25	>.05
Pattern vs. Math	−.15		1.28	>.05
Pattern vs. Social Studies	1.35		1.29	>.05
Reading vs. Math	−.11		1.23	>.05
Reading vs. Social Studies	.79		1.28	>.05
Math vs. Social Studies	2.00		1.27	>.05
W-J Scale 2 Reading Fluency				
Source	*df*	*MS*	*F*	*p*
Group	3	50.45	.58	>.05
Error	136	87.32		
Group Comparisons	*Mean Difference*		*SE*	*p*
Pattern vs. Reading	−1.46		2.21	>.05
Pattern vs. Math	−.04		2.27	>.05
Pattern vs. Social Studies	1.42		2.28	>.05
Reading vs. Math	1.42		2.18	>.05
Reading vs. Social Studies	2.88		2.19	>.05
Math vs. Social Studies	1.46		2.25	>.05

(*Continued*)

TABLE 2
(Continued)

W-J Scale 9 Passage Comprehension				
Source	*df*	*MS*	*F*	*p*
Group	3	1.27	.19	>.05
Error	136	6.73		
Group Comparisons		*Mean Difference*	*SE*	*p*
Pattern vs. Reading		−.10	.61	>.05
Pattern vs. Math		−.02	.63	>.05
Pattern vs. Social Studies		.33	.63	>.05
Reading vs. Math		.08	.60	>.05
Reading vs. Social Studies		.43	.61	>.05
Math vs. Social Studies		.35	.63	>.05

Note. W-J = Woodcock-Johnson.

particular types of erroneous solutions. In essence, the child is given multiple opportunities for "learning how to learn" (Harlow, 1949, p. 53). The success of this approach in teaching young children concepts that were previously too abstract for them was shown initially by Gelman (1969) and Kingsley and Hall (1967), and more recently by Kidd, Pasnak, Gadzichowski, Ferral-Like, and Gallington (2008) and Pasnak et al. (2007). It is in fact embodied in most teaching, whether the content is abstract or simply factual. The point is that this was not a brief unit on simple alternations, such as is usually employed when teaching patterning in U.S. schools.

That said, the result of the patterning instruction was improvement in patterning, not complete mastery. This was the result obtained by Herman (1973), Hendricks et al. (1999), and Hendricks et al. (2006) for patterning, and more recently by Pasnak et al. (2007) and Kidd et al. (2008) for lower level abstractions. At any age, it is very challenging to master principles more abstract than those you have understood on your own, and then to apply these principles to new problems.

Nevertheless, the 1st-graders taught patterning did better than any other group on the test of conceptual knowledge of mathematics. Their score in the ninth month of 1st grade is equivalent to that made by children in the 6th month of 2nd grade, according to the national norms on the W-J III, which is for Scales 18A and 18B combined. They even outscored (in an absolute sense) the children who were instructed specifically in mathematics, who themselves had an excellent average on the conceptual scales, equivalent to that made by 2nd-graders in their 3rd month. The scores of the reading and social studies groups on the same scale were more grade appropriate (e.g., Grade 1 9 months and Grade 2 1 month, respectively). Hence, it seems clear that, at least within the parameters of this research, extensive instruction in patterning is justified by a resultant gain in mathematics. This gain is limited, however, to conceptual advances, as all groups scored about as they should (year 1 month 8 – year 2 month 1) on W-J III Scale 10.

There was no indication when scores on the reading tests were compared that either the patterning or reading lessons offered to the children helped them with reading. Although it seems likely that the control reading instruction at least benefited the children in some aspects of reading, it was not captured by the W-J III reading scales. In contrast, the superiority of the mathematics group to the social studies group on the W-J III scale that measured concepts shows that

TABLE 3
Analyses of Variance and Least Significant Differences for Mathematics

W-J Scale 10 Applied Problems				
Source	*df*	*MS*	*F*	*p*
Group	3	21.64	1.52	>.05
Error	136	14.25		
Group Comparisons	*Mean Difference*		*SE*	*p*
Pattern vs. Reading	1.22		.89	>.05
Pattern vs. Math	1.08		.92	>.05
Pattern vs. Social Studies	−.36		.93	>.05
Reading vs. Math	−.14		.88	>.05
Reading vs. Social Studies	−1.57		.89	>.05
Math vs. Social Studies	−1.44		.91	>.05
W-J Scale 18 Quantitative Concepts A				
Source	*df*	*MS*	*F*	*p*
Group	3	16.07	3.71	.013
Error	136	4.33		
Group Comparisons	*Mean Difference*		*SE*	*p*
Pattern vs. Reading	1.50		.49	.003
Pattern vs. Math	1.37		.51	.008
Pattern vs. Social Studies	1.15		.51	.026
Reading vs. Math	−.14		.49	>.05
Reading vs. Social Studies	−.36		.49	>.05
Math vs. Social Studies	−.22		.50	>.05
W-J Scale 18 Quantitative Concepts B				
Source	*df*	*MS*	*F*	*p*
Group	3	11.24	2.80	.001
Error	136	4.01		
Group Comparisons	*Mean Difference*		*SE*	*p*
Pattern vs. Reading	.73		.48	>.05
Pattern vs. Math	.12		.49	>.05
Pattern vs. Social Studies	1.24		.49	.012
Reading vs. Math	−.61		.47	>.05
Reading vs. Social Studies	.51		.47	>.05
Math vs. Social Studies	1.12		.48	.022

Note. W-J = Woodcock-Johnson.

the control mathematics lessons were effective. However, the patterning lessons were even more effective in improving mathematics, a somewhat surprising result.

An important consideration is that mathematics instruction was a regular activity for all children in these 1st-grade classrooms. The effect of the patterning instruction may have been that it enabled the children in the patterning group to profit more from the mathematics instruction that all children received from their 1st-grade teacher. If White et al. (1998) were correct in their conclusion that pattern instruction improved analogical reasoning and understanding the relation between symbols, the children would have been better able to profit from their classroom teacher's delivery of the school system's mathematics curriculum.

Comprehending patterns requires that children understand how the components of the pattern relate to one another. This may require the child to attend to more than one dimension as the items change on both dimensions progressively from the beginning to the end of the pattern. It may be particularly important that children become able to reverse the rule that governs the pattern, acquiring the understanding that the rule governing a pattern of 10, 20, 30, 40 is very similar in logic to one of 70, 60, 50, 40, and that if a pattern is red blue tan pink pink tan blue the next item would be red. This element of reversibility, which Piaget (1936/1963) emphasized as very important in the development of thought in children of early elementary school age, is central to the understanding that $2 \times 4 = 4 \times 2$, and that if $8 - 3 = 5$, then $5 + 3 = 8$. Whether these or some other considerations underlie the relations between improved understanding of patterns and improved understanding of mathematics concepts remains to be determined. The goal of this project was to establish empirically whether improving understanding of patterns could in fact improve understanding of mathematics, and the data indicate that it did. Just what mental mechanisms are involved awaits different types of investigations and the attention of theorists.

PRACTICAL APPLICATIONS AND LIMITATIONS

There are some important issues for educators who wish to use patterning instruction as a means for improving mathematics achievement. First is the amount of instruction the children received. Forty-five minutes per week for most of the school year is a substantial investment of instructional time. Second, the instruction in this research was individual. A teacher could conceivably spend 15 minutes with a needy child 3 times weekly, but such attention for as many as four children would probably be prohibitive. Consequently, all of the patterning instruction would probably have to be delivered via computers. In all local school systems, 1st-graders (and kindergartners) have individual instruction sessions via computer on mathematics and other subject matter routinely, and manage these sessions themselves with little difficulty after some initial instruction, so this may be a practical solution. An alternative might be small-group instruction during a time when children go to different activity centers within their classroom.

A third concern is that patterns should be more complex than those commonly used in U.S. classrooms. These children, who scored lowest on the screening test, progressed through patterns with alternating elements very rapidly. Patterns that were symmetrical or involved increasing numbers of elements or were random but repetitive were necessary to challenge them. Another issue with this research is the subject population chosen. These 1st-grade children were generally from low-income families, many of them immigrant families, with the attendant challenges that such children face. It is apparent from the scores the children in the reading and social studies groups made on the W-J tests that their performance in reading and mathematics were normal for children at the end of 1st grade, so these challenges had been in large part overcome. However, they scored below their classmates on the patterning screening test. It is by no means clear that all children would have benefited had the patterning instruction been offered to the whole class, which is a common practice. What of the children who already understood patterning pretty well?

It already has been shown that cognitive interventions do not work well for children who already understand most of what is to be taught (Waiss & Pasnak, 1991). It also has been shown that the same cognitive intervention conducted simultaneously in two school systems can work very well in one, where the children are at the stage of development appropriate for it, and not well at all for the other, where the children are too far below that stage (Pasnak, Hansbarger, Dodson, Hart, & Blaha, 1996). Hence, although this study has shown that patterning instruction can be effective, the same instruction that worked in 1st grade here might best be offered in kindergarten or 2nd grade in other school systems.

Another issue is that any increase in cognitive competence is not likely to show up immediately in academic performance (Pasnak, 1987). Children who improve in the abstract thinking that patterning requires must have a chance to apply their newly improved abilities to the mathematics instruction the teacher offers all children as a part of regular classroom instruction. It is a better understanding of the conventional mathematics instruction that must underlie any gains in mathematics concepts, because patterning instruction does not teach the latter directly. Hence, a teacher who wishes to be able to show in his or her class results on standardized tests from teaching patterning must begin the patterning instruction in the fall, continue it in brief sessions through most of the year, and look for results in the spring—on tests that measure mathematics concepts.

In some respects, these limitations echo those that educators routinely face and overcome. Instruction for the whole class will not be equally effective for all children who show a broad spectrum of abilities. What is taught must be adapted to the children from the particular school attendance district. Instruction must frequently be relatively long term when the principles are not those that children easily grasp. Instruction in the fall is usually carried out as a foundation for gains on standardized tests at the end of the school year, so patterning instruction is hardly unique in any of these respects.

CONCLUSION

What we have here is the best evidence to date that patterning instruction actually improves academic performance, and some indication of the potential magnitude of the gains and what their nature is likely to be. Several issues remain to be resolved. One is the issue of efficiency. How well can such instruction be carried out entirely via a computer program or in a small-group format? Another is the issue of the generality of results. The W-J III is a well respected test, but it is far from the only one. On what other measures will patterning instruction produce gains, or fail to show gains? And, of course, children vary widely in abilities. For how broad a spectrum of 1st-grade children can patterning instruction be effective? These issues are easily identifiable; others will in all probability emerge as empirical investigation of patterning instruction continues.

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