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Title:
Is Patterning Helpful in Children's Education?

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Sections
(1) Classroom Instruction and Context
(2) Early Childhood Education

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Abstract Body

Background / Context:
In the USA, kindergarten and first grade children are taught to recognize patterns of objects, letters, numbers, shapes and colors (Burton, 1982; Ducolon, 2000; Jarboe & Sadler, 2003). It is believed that "patterning" instruction leads to mastery of cognitive skills that translate into better academic performance. However, this belief, and the widespread inclusion of patterning instruction in curricula, rests more on consensus than on empirical evidence.

Patterns make varying cognitive demands on children. Simple patterns require an understanding of similarities, differences and ordinal relationships. More complex patterns that utilize two dimensions require sufficient decentration to consider both dimensions, an ability that children are developing as they enter first grade. More demanding patterns using three dimensions require greater mastery of these abstract thinking abilities, as well as understanding rules previously learned while simultaneously considering a new dimension. This more complicated reasoning places demands on a child's executive control that may initially be excessive (Zelazo & Frye, 1998; Zelazo, Resnik, & Pinon, 1995). To make the leap from forming and interpreting simple patterns to doing that for more complex patterns, children must discern the more complex rules governing the pattern, and also adapt as these rules shift from pattern to pattern. Halford's relational complexity theory accounts for the difficulty imposed by adding dimensions, which change the pattern from unary to binary and beyond in his terms (Chalmers & Halford, 2003).

White, Alexander and Daugherty (1998) theorized that understanding patterns contributed to a very early form of analogical reasoning involved in mathematics, and tested their theory by a correlational study. Children's ability to extend patterns was related to their mastery of an early form of analogical reasoning, which in turn predicted their learning of mathematics. Other abilities, such as comparing quantities and recognizing numbers, although relevant, accounted for less of the difference (variance) in mathematics learning.

Only two empirical studies have directly tested patterning instruction's educational effectiveness. Herman (1973) gave children 24 lessons on very simple patterns and measured the impact on their achievement in math. Students who spoke English as their native language gained the most – an example of heterogeneity in child characteristics and intervention impact that remains unexplained. Much later, Hendricks, Trueblood, and Pasnak (2006) conducted a test of more extensive patterning instruction's effect on children's academics. They found that children receiving patterning instruction gained more in reading and mathematics than control children receiving equivalent instruction focused on academic material recommended by their teachers.

In an effort to inform critical decisions about the place of patterning in curricula and teaching, we investigated whether there were cause and effect relations between patterning instruction and academic gains that were important in terms of educational effectiveness.

Purpose / Objective / Research Question / Focus of Study:
Our purpose was to study the efficacy of patterning instruction in improving the reading and mathematics proficiency of first grade children. Patterning instruction was compared to equal time and effort spent on instruction on reading or mathematics or social studies, which are control conditions in this experiment. The question for educators was whether instruction on patterning would be produce greater overall gains than instruction on the other subject matter.

Setting:

The research was conducted in a public school system of an urban school district in Northern Virginia, which served many low income and immigrant families.

Population / Participants / Subjects:
A screening test was administered to 443 first-graders. The eight who scored lowest in each of 16 classrooms were selected to participate. After attrition 120 children remained, 64 boys and 56 girls. Of these, 52 (43%) were African American, 42 (35%) were Hispanic/Latino, 16 (13%) were Middle Eastern, 3 (2.5%) were Caucasian and 7 (5.8%) were of an unspecified ethnicity. The mean age for these children was 7 years 5.19 months, SD = 3.36.

Intervention / Program / Practice:
The patterns taught were single and double alternations, symmetrical patterns, progressive patterns involving increasing numbers of elements, sizes, or values, rotation patterns, and random repeating patterns. Note cards that showed a pattern and displayed four options for completing it were used in this instruction. Performance was scaffolded through explanation and repetition until each child was able to complete each pattern. For freshness, patterns were also displayed on minicomputers – again, a pattern and four alternatives, and the children taught to select the correct alternatives with as much coaching and assistance as needed. Teachers gradually reduced their assistance until the child made correct choices freely and independently.

Manipulatives (small objects) were also used to teach children to extend patterns. Teachers would start a pattern, provide the children with more manipulatives, and request that they complete or extend it. Children were also asked to create patterns to be completed by the teacher or another child. White boards were also employed for these purposes. The only difference was that patterns were drawn on the boards instead of being made from manipulatives.

The variety of approaches used in teaching was based on the principle that multiple types of exemplars are important for producing generalization of abstractions beyond the exemplars used in instruction. Investigation of whether the use of certain materials, presentations, or patterns is most effective must await further research. Our goal was to lay a foundation: would patterning instruction be more effective, in general, than instruction in other domains?

Research Design:
Active control groups were used in an advanced design recommended by Pasnak and Howe (1993). In such designs, children in experimental and control conditions receive equal investments of instructional time, resources, and attention in activities that are expected to improve academic performance. All are expected to make gains; differences in the gains reflect differential effectiveness of the types of instruction they receive. Such a design is superior to the classic experimental group – control group designs, which are subject to Hawthorne, familiarity, and expectancy effects.

Children were given the screening test individually in October. A random numbers table was used to assign two of the eight children in each classroom who scored lowest to either the experimental (patterning) condition or one of three active control conditions (reading, mathematics or social studies). Note that the two children from each classroom, teacher, and school were assigned to each condition, to eliminate these sources of bias.

These four conditions of instruction – one experimental and three controls - give a comprehensive and very relevant picture of the efficacy of the patterning instruction, while controlling for artifacts and equalizing investment of resources. We hypothesized the following:

(a) The children receiving instruction in patterning would exceed the social studies control children in patterning, mathematics, and reading.
(b) They would exceed the mathematics group in patterning and reading.
(c) They would exceed the reading group in patterning and mathematics.
(d)The patterning children would equal or exceed the mathematics children in mathematics.
(e) They would equal or exceed the reading children in reading.
(f)The reading children would exceed the mathematics and social studies children in reading.
(g)The mathematics children would exceed the reading and social studies children in mathematics.
(h)The reading, mathematics, and social studies children would be equal in patterning.

The children had 15 minutes of instruction in the condition to which they were assigned in back to back sessions three times per week November through April during "centers time", an hour devoted to individualized or small group activities. A counterbalanced order of instruction was used so that teachers gave each form of instruction first, second, third, or fourth equally often.

Data Collection and Analysis:
In May school psychologists who were blind to the instruction the children had received, re-administered the original screening test, and gave seven more tests to each child - the Gray Oral Reading Test (GORT-4), the Test of Word Reading Efficiency (TOWRE), the Test of Reading Ability (TERA-3), the Woodcock-Johnson (W-J) Math Concepts scales A and B, the Key Math test, and a "far generalization patterning" test made of patterns quite different from those on the screening test or used in instruction. Inasmuch as differences between classrooms, teachers, and schools were controlled in our design, ANOVA followed by *a priori* comparisons were used to analyze the results for each dependent variable for overall differences and for differences between specific conditions of instruction.

Findings / Results:
Differences in the screening scores for children in the four conditions were trivial (see Table 1), indicating that the random assignment was successful. In contrast, the overall difference on the patterning posttest was large (Cohen, 1992). The patterning condition produced scores approximately twice as high as the other conditions, and p was < .001, in each pairwise comparison. Hence, the patterning instruction was effective in the sense that the children could generalize their understanding to patterns that were different from but of the same general type as those they had been taught (see Table 1). The results were similar but somewhat more modest for the far generalization problems, which involved patterns quite different from those on which the patterning instruction had been conducted. The patterning children's scores were not quite twice as high as those of the other children, the effect size was medium, and again $p < .001$ in all pairwise comparisons of patterning with the other conditions. Children who received patterning instruction applied their improved understanding to patterns quite different from those they had been taught. The three control conditions did not differ from each other.

Table 2 shows the effect of the different types of instruction on reading measures. There were no meaningful differences on the TOWRE phonemic measure, but overall differences on the TOWRE word measure were significant statistically, $p < .001$. The effect size was small. Although the patterning children made the highest scores in an absolute sense, the patterning and reading conditions did not differ significantly. Both produced significantly higher scores than the other two conditions. This indicates that both the reading and patterning instruction were effective in improving reading, as measured by this TOWRE scale. The results for the TERA 3 were similar, but overall differences were medium instead of small. The patterning children had the highest scores, those of the reading children were next, and the others were lower. There was no significant difference between the patterning and reading children; both were significantly better than the children in the other conditions on this measure.

For the GORT-4, the overall difference was significant and patterning children again made significantly higher scores than any other group, with *p* ranging from .002 to .025, but the effect was small. No other differences were significant. Hence, the patterning instruction resulted in slightly improved reading as captured by this measure, but the reading instruction did not.

In sum, the control reading instruction was generally effective, although this did not show up on all scales. The patterning instruction was even more effective in improving reading. Effect sizes ranged from small to medium.

For the W-J III mathematics concepts measures, the overall effects of the patterning and mathematics instruction on both scale A and scale B were quite large in terms of Cohen's (1992) metric. This echoes the results Kidd, et al. (2011) reported. The patterning condition was significantly better than all of the others, the mathematics condition was significantly better than the other two, and the social studies condition was worst on both scales (see Table 3).

On most Key Math scales the patterning condition was superior, although effect sizes were always small. Overall differences were significant for the Numeration, Addition, and Algebra scales. Pairwise comparisons showed that the patterning condition was significantly better than each of the others on each of these scales. Parallel results were obtained for the Measurement scale, except that *p* for the overall difference between groups was .053; again, the patterning instruction produced significantly higher scores than any of the other types of instruction.

The overall difference on the Foundation scale was significant, but small; only the differences between the patterning and the reading and social studies conditions were significant.

For the Computation scale *p* for the overall difference was .052; differences between the patterning condition and the reading and mathematics conditions were significant.

The overall difference on the Data Problems scale was not significant. The planned pairwise comparisons showed that the patterning children scored significantly higher than the reading control children. The differences between the patterning children's scores and those of children in the other two control conditions were of similar magnitude, but p was somewhat above .05.

No differences on the Geometry and Multiplication scales were significant.

In sum, differences on the W-J III Math Concepts scales were robust and favored children receiving patterning or mathematics instruction. Differences on the Key Math scales generally favored the patterning instruction. They were small in a statistical sense but as large as eight months in grade equivalencies (see Table 3).

Conclusions:

Although small in a statistical sense, many of the gains were large enough – 2 to 8 months in grade equivalencies – to be very welcome to educators charged with improving academic achievement. A great advantage of patterning instruction was that it improved both reading and mathematics, as opposed to only one or the other. Much more research is needed, especially to determine the characteristics of children who benefit most from incorporating such extensive patterning instruction in the curriculum, and how long such gains last.

Appendices

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Appendix A. References

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Appendix B. Tables and Figures
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Table 1
Descriptive Statistics and Statistical Comparisons for Patterning

Patterning Screening Test

Group	Mean	SD
Patterning	11.32	3.93
Reading	11.35	3.69
Mathematics	11.27	3.24
Social Studies	10.69	2.88

	df	Mean Square	F	p	partial eta squared
Group	3	2.97	.24	>.05	.006
Error	116	12.03			

	Mean Difference	Standard Error	p
Pattern vs. Reading	-.03	.88	> .05
Pattern vs. Math	.06	.89	> .05
Pattern vs. Soc . St.	.64	.90	> .05
Reading vs. Math	.09	.89	> .05
Reading vs. Soc. St.	.67	.90	> .05
Math vs. Soc St..	.58	.90	> .05

Patterning Posttest

Group	Mean	SD
Patterning	27.68	8.34
Reading	15.61	5.01
Mathematics	12.60	3.42
Social Studies	14.66	6.59

	df	Mean Square	F	p	partial eta squared
Group	3	1423.37	37.88	.001	.49
Error	116	12.03			

	Mean Difference	Standard Error	p
Pattern vs. Reading	12.06	1.56	.001
Pattern vs. Math	15.08	1.57	.001
Pattern vs. Soc . St.	13.02	1.58	.001
Reading vs. Math	3.01	1.57	> .05
Reading vs. Soc. St.	.96	1.58	> .05
Math vs. Soc. St.	2.06	1.60	> .05

Pattern Far Generalization Test

Group	Mean	SD
Patterning	7.90	2.89
Reading	4.58	2.28
Mathematics	4.37	1.71
Social Studies	4.55	2.35

	df	Mean Square	F	p	partial eta squared
Group	3	89.29	16.16	.001	.29
Error	116	5.53			

	Mean Difference	Standard Error	p
Pattern vs. Reading	3.32	.60	.001
Pattern vs. Math	3.54	.60	.001
Pattern vs. Soc . St.	3.35	.61	.001
Reading vs. Math	.21	.60	>.05
Reading vs. Soc. St.	.03	.61	>.05
Math vs. Soc. St.	.19	.61	>.05

Table 2
Descriptive Statistics and Statistical Comparisons for Reading

TOWRE Word

Group	Mean	SD	Grade Equivalent
Patterning	49.52	13.22	2.8
Reading	42.45	15.19	2.4
Mathematics	32.93	13.31	2.0
Social Studies	33.31	17.33	2.0

	df	Mean Square	F	p	partial eta squared
Group	3	1926.46	8.76	.001	.18
Error	116	219.81			

	Mean Difference	Standard Error	p
Pattern vs. Reading	7.06	3.76	>.05
Pattern vs. Math	16.58	3.80	.001
Pattern vs. Soc . St.	16.21	3.83	.001
Reading vs. Math	9.52	3.80	.014
Reading vs. Soc. St.	9.14	3.83	.019
Math vs. Soc. St.	.37	3.86	>.05

TOWRE Phonemics

Group	Mean	SD	Grade Equivalent
Patterning	16.26	12.19	2.2
Reading	15.10	9.98	2.0
Mathematics	13.03	10.04	2.0
Social Studies	15.59	112.64	2.0

	df	Mean Square	F	p	partial eta squared
Group	3	58.45	.46	>.05	.01
Error	116	126.91			

	Mean Difference	Standard Error	p
Pattern vs. Reading	1.16	2.86	>.05
Pattern vs. Math	3.22	2.89	>.05
Pattern vs. Soc . St.	.67	2.91	>.05
Reading vs. Math	2.06	2.89	>.05
Reading vs. Soc. St.	-.49	2.91	>.05
Math vs. Soc. St.	-2.55	2.93	>.05

GORT

Group	Mean	SD	Grade Equivalent
Patterning	13.71	6.78	2.0
Reading	8.42	6.20	1.4
Mathematics	9.97	6.08	1.6
Social Studies	9.83	6.68	1.6

	df	Mean Square	F	p	partial eta squared
Group	3	158.40	3.82	.012	.09
Error	116	41.48			

	Mean Difference	Standard Error	p
Pattern vs. Reading	5.29	1.64	.002
Pattern vs. Math	3.74	1.65	.025
Pattern vs. Soc . St.	3.88	1.66	.021
Reading vs. Math	-1.55	1.65	>.05
Reading vs. Soc. St.	-1.41	1.66	>.05
Math vs. Soc. St.	.14	1.68	> .05

TERA Meaning

Group	Mean	SD	Grade Equivalent
Patterning	19.58	4.95	1.4
Reading	17.35	5.02	1.2
Mathematics	14.27	4.74	1.0
Social Studies	13.17	4.43	1.2

	df	Mean Square	F	p	partial eta squared
Group	3	257.79	11.20	.001	.22
Error	116	23.01			

	Mean Difference	Standard Error	p
Pattern vs. Reading	2.23	1.22	>.05
Pattern vs. Math	5.31	1.23	.001
Pattern vs. Soc . St.	6.41	1.24	.001
Reading vs. Math	3.09	1.23	.013
Reading vs. Soc. St.	4.18	1.24	.001
Math vs. Soc. St.	1.09	1.25	> .05

Table 3
Descriptive Statistics and Statistical Comparisons for Mathematics

W-J Mathematics Concepts (A)

Group	Mean	SD
Patterning	15.00	.73
Reading	10.87	2.45
Mathematics	13.90	1.35
Social Studies	8.76	2.10

	df	Mean Square	F	p	partial eta squared
Group	3	242.62	76.41	.001	.66
Error	116	3.18			

	Mean Difference	Standard Error	p
Pattern vs. Reading	4.13	.45	.001

Pattern vs. Math	1.10	.46	.017
Pattern vs. Soc . St.	6.24	.46	.001
Reading vs. Math	-3.03	.46	.001
Reading vs. Soc. St.	2.11	.46	.001
Math vs. Soc. St.	5.14	.36	.001

W-J Mathematics Concepts (B)

Group	Mean	SD
Patterning	16.48	1.88
Reading	10.68	3.50
Mathematics	12.87	2.46
Social Studies	9.21	1.05

	df	Mean Square	F	p	partial eta squared
Group	3	303.66	52.34	.001	.57
Error	116	5.80			

	Mean Difference	Standard Error	p
Pattern vs. Reading	5.81	.61	.001
Pattern vs. Math	3.62	.62	.001
Pattern vs. Soc . St.	7.28	.62	.001
Reading vs. Math	-2.19	.62	.001
Reading vs. Soc. St.	1.47	.62	.02
Math vs. Soc. St.	3.66	.63	.001

Key Math Numeration

Group	Mean	SD	Grade Equivalent
Patterning	13.19	3.40	2.0
Reading	10.29	3.90	1.4
Mathematics	10.83	4.25	1.6
Social Studies	10.79	3.54	1.6

	df	Mean Square	F	p	partial eta squared
Group	3	52.58	3.67	.014	.09
Error	116	14.35			

	Mean Difference	Standard Error	p
Pattern vs. Reading	2.90	.96	.003
Pattern vs. Math	2.36	.97	.016
Pattern vs. Soc . St.	2.43	.98	.014
Reading vs. Math	-.54	.97	>.05
Reading vs. Soc. St.	-.47	.98	>.05
Math vs. Soc. St.	.08	.99	>.05

Key Math Addition

Group	Mean	SD	Grade Equivalent
Patterning	10.09	2.87	2.2
Reading	7.32	2.86	1.6
Mathematics	7.80	3.31	1.9
Social Studies	7.93	3.02	1.6

	df	Mean Square	F	p	partial eta squared
Group	3	47.05	5.17	.002	.12

Error	116	9.10			

	Mean Difference	Standard Error	p
Pattern vs. Reading	2.77	.76	.001
Pattern vs. Math	2.30	.77	.004
Pattern vs. Soc . St.	2.17	.78	.006
Reading vs. Math	-.47	.77	>.05
Reading vs. Soc. St.	-.61	.78	>.05
Math vs. Soc. St.	-.13	.79	>.05

Key Math Algebra

Group	Mean	SD	Grade Equivalent
Patterning	9.16	3.44	2.4
Reading	7.03	3.22	1.8
Mathematics	6.90	3.35	1.8
Social Studies	7.24	3.81	1.8

	df	Mean Square	F	p	partial eta squared
Group	3	34.66	2.90	.038	.07
Error	116	11.96			

	Mean Difference	Standard Error	p
Pattern vs. Reading	2.13	.88	.017
Pattern vs. Math	2.26	.89	.012
Pattern vs. Soc . St.	1.92	.89	.034
Reading vs. Math	.13	.89	>.05
Reading vs. Soc. St.	-.21	.89	>.05
Math vs. Soc. St.	.34	.90	>.05

Key Math Measurement

Group	Mean	SD	Grade Equivalent
Patterning	11.51	4.43	2.3
Reading	8.71	4.42	1.6
Mathematics	9.00	4.72	1.7
Social Studies	8.93	4.54	1.7

	df	Mean Square	F	p	partial eta squared
Group	3	53.97	2.64	.053	.06
Error	116	20.48			

	Mean Difference	Standard Error	p
Pattern vs. Reading	2.81	1.15	.016
Pattern vs. Math	2.52	1.16	.032
Pattern vs. Soc . St.	2.59	1.17	.029
Reading vs. Math	-.29	1.16	>.05
Reading vs. Soc. St.	-.22	1.17	>.05
Math vs. Soc. St.	.07	1.18	>.05

Key Math Foundation

Group	Mean	SD	Grade Equivalent
Patterning	8.26	2.32	2.3
Reading	6.35	2.18	1.6
Mathematics	7.37	3.23	1.9

Social Studies	6.48	2.96		1.6	

	df	Mean Square	F	p	partial eta squared
Group	3	23.97	3.29	.023	.08
Error	116	7.29			

	Mean Difference	Standard Error	p
Pattern vs. Reading	1.90	.69	.006
Pattern vs. Math	.89	.69	>.05
Pattern vs. Soc . St.	1.78	.70	.012
Reading vs. Math	-1.01	.69	>.05
Reading vs. Soc. St.	-.13	.70	>.05
Math vs. Soc. St.	.88	.70	>.05

Key Math Computation

Group	Mean	SD	Grade Equivalent
Patterning	8.39	3.47	2.2
Reading	6.23	3.77	1.0
Mathematics	6.00	3.45	1.0
Social Studies	6.79	3.96	1.2

	df	Mean Square	F	p	partial eta squared
Group	3	35.69	2.66	.052	.06
Error	116	13.43			

	Mean Difference	Standard Error	p
Pattern vs. Reading	2.16	.93	.022
Pattern vs. Math	2.39	.94	.012
Pattern vs. Soc . St.	1.59	.95	>.05
Reading vs. Math	.26	.94	>.05
Reading vs. Soc. St.	.32	.95	>.05
Math vs. Soc. St.	.79	.95	>.05

Key Math Data Problems

Group	Mean	SD	Grade Equivalent
Patterning	9.84	4.47	2.0
Reading	7.68	3.71	1.4
Mathematics	7.83	4.11	1.4
Social Studies	7.76	4.50	1.4

	df	Mean Square	F	p	partial eta squared
Group	3	33.48	1.89	.135	.05
Error	116	17.71			

	Mean Difference	Standard Error	p
Pattern vs. Reading	2.16	1.07	.045
Pattern vs. Math	2.01	1.08	>.05
Pattern vs. Soc . St.	2.08	1.09	>.05
Reading vs. Math	-.16	1.08	>.05
Reading vs. Soc. St.	-.08	1.09	>.05
Math vs. Soc. St.	.07	1.10	>.05

Key Math Geometry

Group	Mean	SD	Grade Equivalent

Patterning	11.81	2.74	1.7	
Reading	10.81	3.31	1.5	
Mathematics	10.60	3.45	1.4	
Social Studies	11.10	2.46	1.5	

	df	Mean Square	F	p	partial eta squared
Group	3	8.54	.93	.43	.02
Error	116	9.14			

	Mean Difference	Standard Error	p
Pattern vs. Reading	1.00	.77	>.05
Pattern vs. Math	1.21	.77	>.05
Pattern vs. Soc . St.	.70	.78	>.05
Reading vs. Math	.21	.77	>.05
Reading vs. Soc. St.	-.30	.78	>.05
Math vs. Soc. St.	-.50	.79	>.05

Key Math Multiplication

Group	Mean	SD	Grade Equivalent
Patterning	1.03	1.28	2.4
Reading	.42	1.29	2.0
Mathematics	.77	1.33	2.3
Social Studies	.59	1.18	2.1

	df	Mean Square	F	p	partial eta squared
Group	3	59.43	1.31	.273	.03
Error	116	2.12			

	Mean Difference	Standard Error	p
Pattern vs. Reading	.61	.32	>.05
Pattern vs. Math	.27	.33	>.05
Pattern vs. Soc . St.	.45	.33	>.05
Reading vs. Math	-.35	.33	>.05
Reading vs. Soc. St.	-.17	.33	>.05
Math vs. Soc. St.	.18	.33	>.05

Key Math Applied Problems

Group	Mean	SD	Grade Equivalent
Patterning	8.90	3.29	2.0
Reading	7.16	3.41	1.5
Mathematics	8.03	3.59	1.7
Social Studies	7.07	2.99	1.5

	df	Mean Square	F	p	partial eta squared
Group	3	22.50	2.03	.114	.05
Error	116	11.09			

	Mean Difference	Standard Error	p
Pattern vs. Reading	1.74	.85	.042
Pattern vs. Math	.87	.85	>.05
Pattern vs. Soc . St.	1.83	.86	.035
Reading vs. Math	-.87	.85	>.05
Reading vs. Soc. St.	.09	.86	>.05
Math vs. Soc. St.	.96	.87	>.05