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The Efficacy of Teaching Advanced Forms of Patterning to Kindergartners

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Abstract

This project tested the effects of adding instruction of trios of children in patterning, mathematics, early literacy, or social studies to ongoing instruction in kindergartens. Children were randomly assigned to trios which were randomly assigned to one of four kinds of instruction. A quarter of the trios received patterning instruction with a mixture of repeating and growing patterns. Another quarter of the trios were taught number recognition, number order, counting, comparing quantities and related early mathematics. Another quarter were taught letter recognition and sounds, simple words, and other subject matter in early literacy. The remaining quarter of the trios were taught social studies, including recognition of important figures in history and important city and federal services. The children taught patterning outscored the others on a test of patterning, but there were no other significant differences. Implications for patterning instruction as a support for early mathematics or literacy were discussed.

Keywords

Patterning, Literacy, Mathematics, Kindergarten, Five-Year-Olds

1. Introduction

A variety of cognitive abilities develop between ages four and six that involve relations between different items. Among them are the abilities to identify the odd object in a group, to insert items into series, and to recognize regular sequences of items. Educators commonly term repeating sequences (e. g. green pink green pink green pink or circle square circle square circle square) "patterns" and instruction of preschoolers and kindergartners in "patterning" has been very common in American preschools and schools for decades. Patterning instruction has been highly recommended by the National Council of Teachers of Mathematics (2006) and the National Council of Teachers of Mathematics/National Association for the Education of Young Children (2002/2010). At times it has been part of the Common Core State Standards, although it is not at present (Common Core State Standards, 2010). The main point of the present research was to determine whether teaching five-year-old children patterning is worthwhile.

The central idea behind such instruction is that it fosters children' cognitive development, especially their understanding of early mathematics (Scandura, 1971; Clements & Sarama, 2007a, 2007b, 2007c; Nguyen et al., 2016; Rittle-Johnson, Fyfe, Hofer, & Farran, 2017). The effect may be relatively direct; there are patterns in the number system. Digits repeat as in 1, 2, 3, … 11, 12, 13. Tens and hundreds also repeat. Or the effect may be indirect: some researchers have suggested that patterning instruction produces a more general improvement in reasoning (Hendricks, Trueblood, & Pasnak, 2006; Pasnak et al., 2015; White, Alexander, & Daugherty, 1998; Zippert, Clayback, & Rittle-Johnson, 2019).

The patterns used in such instruction are typically more complex than the simple ABABAB patterns described above. Patterns such as ABCABC or AABAAB or AABBAABB are usually included. A standardized test (Assessment of Basic Language and Learning Skills-Revised, for mastery of such patterns is available (Partington 2010). Recently, patterning instruction has sometimes involved "growing" patterns. Growing patterns may involve geometric shapes—a square, a configuration of four squares that make a larger square, a configuration of nine squares that make a still large square, etc. Or they may involve sequences of numbers (7, 9, 11, 13, 15) or of letters (m, k, i, g) or of coins or of time shown by clocks or rotated positions of objects or any other regularity.

Some researchers have explored the relative difficulty of different types of patterns for children. Pasnak, Thompson, Gagliano, Righi and Gadzichowski (2019) found that kindergartners were more accurate on patterns made of clock faces that showed increasing amounts of time or were made of rotating objects than on patterns made of progressively higher numbers or of letters that came progressively later in the alphabet. These researchers also found that symmetric patterns were easier for kindergartners than growing patterns.

Earlier Gadzichowski (2012a) experimented with older children (first graders) and found that whether growing patterns were made of letters, numbers, time (as shown by clock faces) or an object rotating through successive positions made no difference. A second study (Gadzichowski, 2012b) replicated this finding but showed that the pattern rule was important. Repeating patterns (ABBABB) were the easiest, and as Pasnak et al. (2019a) showed for kindergartners, growing patterns were more difficult than symmetric patterns.

MacKay and de Smedt (2019) experimented with patterns similar to those used by Gadzichowski (2012a, 2012b) and found that growing patterns of numbers, letters, and clockfaces were associated with individual differences in first graders' calculation abilities, and that the associations for each type of pattern were independent. The associations were strongest for numbers and clockfaces. Rotating patterns were not associated with calculation abilities. Performance was poor on rotating patterns, which may have been too difficult for this sample.

Wijns, Torbeyns, Bakker, De Smedt, and Verschaffel (2019) showed that associations between both growing and repeating patterns remained relatively constant between ages four and six years.

Longitudinal studies have supported the idea that understanding patterns predicts subsequent understanding of mathematics. Rittle-Johnson, Zippert, and Boice (2018) and Zippert, Douglas, and Rittle-Johnson (2020) showed that preschooler's understanding of repeating patterns predicted their understanding of mathematics and numeracy at the end of preschool and at the end of kindergarten. Earlier, Rittle-Johnson, Fyfe, Hofer, and Farran (2017) found that preschoolers' understanding of repeating patterns predicted mathematics achievement at the end of kindergarten and that the predictive relationship extends to fifth grade. The more recent research (Rittle-Johnson et al., 2018; Zippert et al. 2020) on children in preschool and kindergarten corroborates part of the earlier findings

Other researchers have tested the effects of teaching patterns to children on academic achievement. Results vary with the age of the children taught. Papic, Mulligan, and Mitchelmore (2011) experimented with teaching patterning to Australian preschoolers. This team offered the children 12 lessons on ABC repeating patterns, two lessons on a unique form of "hopscotch" repeating patterns, and four lessons on that involved groups of dots but not patterns. The experimental children made higher scores than control children on selected parts of a mathematics test that was widely used in Australia, but there were no tests of statistical significance. This research is also compromised because of potential pre-existing differences between the experimental and control children, who attended different preschools.

In what was apparently the earliest experimental effort at measuring the effects on mathematics of instructing children on patterning, Herman (1973) gave 24 lessons on repeating patterns to minority kindergarten children in inner city Baltimore. These children scored better on the mathematics section of the Metropolitan Readiness test than control children from another inner-city school who received no patterning instruction. This dissertation research was never published as a journal article and, like that of Papic et al. (2011) is compromised because of potential pre-existing differences between the children in the experimental and control groups.

Forty-four years later Shriver et al. (2017) also taught patterning to kindergarten children. The children were pretested on standardized tests of patterning, early literacy, and mathematics. A restricted randomization plan was used to assign the children to equivalent tutoring groups which focused on either patterning or early literacy or mathematics or social studies. The children had 20 or more sessions of instruction during the latter half of the school year. No gains in patterning from the patterning instruction were demonstrated. This failure was the result of a design flaw; the standardized patterning test employed only repeating patterns, but more complex patterns were used in the instruction. There were also no gains for the patterning group in early literacy or mathematics. There are three possible explanations for this: 1) patterning does not affect early literacy or mathematics at the kindergarten level, 2) the tests used were not sensitive to any gains that occurred, or 3) the instruction occurred during the spring semester. It may be that cognitive gains from improving from patterning must be in place for a substantial period of time in order for children to profit from their teacher's classroom instruction in literacy and mathematics.

Pasnak, Gagliano, Righi, and Kidd (2019) randomly assigned 42 kindergartners to trios. One member of each trio received instruction in patterning, one in mathematics, and one in early literacy received instruction three times per week in sessions yoked to the progress of the child in the patterning condition. Instruction began early in the school year and continued for 8 - 12 weeks, depending on the progress of the child instructed in patterning. Posttesting in late May-early June showed that the children instructed in patterning were slightly better in that, but there were no significant differences in academic performances. The analyses were compromised by low power. There were, however, significant correlations between children's patterning scores and some literacy measures.

Kidd et al. (2019) followed up this research by teaching repeating, symmetrical, and growing patterns to a much larger sample of 184 kindergartners. The instruction took place three times weekly for approximately two months, using a random assignment design similar to that of Shriver et al. (2017). As was the case with Shriver et al. the instruction was conducted primarily during the spring of the school year. The results were similar to those of Pasnak et al. (2019a). The patterning instruction produced better patterning in the late spring but had no effect on academic achievement. However, an exploratory factor analysis showed that patterning loaded on the same factor as mathematics computation and three measures of executive function (thinking abilities). Mathematics concepts and computations and several early literacy measures comprised a second factor. Hence patterning, as these researchers measured it, is primarily a measure of cognitive ability.

Hendricks, Trueblood, and Pasnak (2006) also experimented with instruction utilizing complex patterns but offered it to older (first grade) children. Children were randomly assigned to receive instruction on either patterning or subject matter recommended by their teachers. Repeating patterns and more complicated patterns, including matrices of letters and numbers patterns of objects and stickers, temporal and causal cartoon sequences, and patterns of 6 - 8 colors were employed. The children receiving the patterning instruction made gains in both mathematics and written language.

Kidd et al. (2013) experimented with first graders using a randomized assignment design similar to that which both Shriver et al. (2017) and Kidd et al. (2019) employed with kindergartners. The children were instructed on complex patterns (increasing or decreasing sequences of letters or numbers or time as shown on clock faces or objects rotating through a sequence of positions). The instruction took place in the fall and early spring, and the patterning instruction produced gains in mathematics but not literacy as measured by the Woodcock-Johnson scales 1, 2, and 9. Kidd et al. (2014) replicated this experiment but used different literacy tests. All three of these tests (Test of Early Reading Ability, Gray Oral Reading Test, and Test of Word Recognition Efficiency) showed that the patterning instruction produced literacy gains. The finding that patterning instruction beginning early in the kindergarten year also produced mathematics gains as measured by the Woodcock-Johnson was confirmed. This research was essentially replicated by Pasnak et al. (2015). Hence, for first graders, instruction on complex patterns produce mathematics and literacy gains, but detecting the latter depends on the measurement used. The results of these four studies of instructing first graders are effectively summarized by Burgoyne, Witteveen, Tolan, Malone, and Hulme (2017).

More recently, Luken and Kampmann (2018) taught both repeating, spatial, and growing patterns to first graders for five months. On a subsequent test of numerical ability the children taught patterning outscored a control group of children who had received only ordinary classroom instruction. However, this experiment was compromised by nonrandom assignment of the children to experimental and control groups.

Hence, there are two studies testing the effect on mathematics of instructing preschoolers on patterns. Because children were not randomly assigned to experimental and control groups, these studies are inconclusive as to whether the instruction produced improvement in early academic achievement, although the results favored the preschoolers who were taught patterning. There are four studies of instructing first grade children on complex patterns and all show that the instruction produced academic gains. Two studies of instructing kindergartners on patterns appear to show gains in mathematics but are not conclusive because of nonrandom formation of experimental and control groups. Two experiments in which children *were* randomly assigned to experimental and control groups indicate that instructing kindergartners on patterns produced no academic gains. However, one is compromised by low power and the other because the instruction occurred late in the kindergarten year. So, that research which has been published does not demonstrate definitively whether the instruction of kindergartners on patterns which is so common in the USA really produces academic gains. It is possible that patterning instruction is profitable only with older children who have made more academic progress than is typical of kindergartners.

Because the previous studies of kindergartners have been compromised, the present study was undertaken with kindergartners, employing different measures of academic achievement in an effort to produce a resolution of whether instructing kindergartners on patterning produces academics gains.

The hypotheses tested were:

1) Kindergartners taught patterning will score higher on patterning than

children taught other subject matter.

2) Kindergartners taught mathematics will score higher on mathematics than children taught other subject matter.

3) Kindergartners taught literacy will score higher on literacy than children taught other subject matter.

4) Kindergartners taught patterning will score higher on mathematics than children taught other subject matter.

5) Kindergartners taught patterning will score higher on literacy than children taught other subject matter.

2. Method

2.1. Participants

The participants were 189 boys and 168 girls from kindergartens in five public schools serving an urban mid-Atlantic region of the United States. Kindergarten is the first year of public schooling in the USA. Six per cent of these children were Asian, 28% were African-American, 35% were Hispanic/Latino, 23% were other white, primarily mid-Eastern, and 7% were of mixed or unknown ethnicity according to the information available. The school district reported that the students were from 120 different countries and spoke 121 languages. Free or reduced-price lunches were available to 56%, and 31.7% received services for English as a second language.

2.2. Materials

Patterning test. Patterns were displayed horizontally, each at the top of a page in a flipbook with four answer choices below it. Six patterns were ABABA? Six were ABBAB? Six were ACEFH? (skip-one) Six were ABCCB? (symmetric) and six were ABABBABB? (growing) The patterns were comprised of clock faces, letters, numbers, pictures of objects, and shapes. The item needed to complete the pattern was at the end or beginning equally often. Administration of this test took approximately 15 minutes. See **Figure 1** for examples.

Mathematics tests. The Kaufman Test of Educational Achievement (KTEA-3). The K-TEA (Kaufman & Kaufman, 2014) was used for the mathematics posttest. This test has a scale for computations and another for concepts and applications. Each requires about ten minutes at the kindergarten level. Concurrent validity coefficients with the Wechsler Individual Achievement Tests, Third Edition (WIAT-III) were as high as 0.95. Kaufman and Kaufman (2014) reported split-half reliability of 0.54 - 0.99.

Early literacy tests. Literacy skills were measured with the Test of Word Reading Efficiency (TOWRE) and the DIBELS Initial Sound Fluency (ISF) scale. The TOWRE (Torgesen, Wagner, & Rashotte, 2012) Sight Word Efficiency (SWE) scale measures the number of simple words children can read in 45 seconds. Their mastery of phonetics (Phonetic Decoding Efficiency, or PDE) is measured with another 45 second scale. The TOWRE manual indicates that

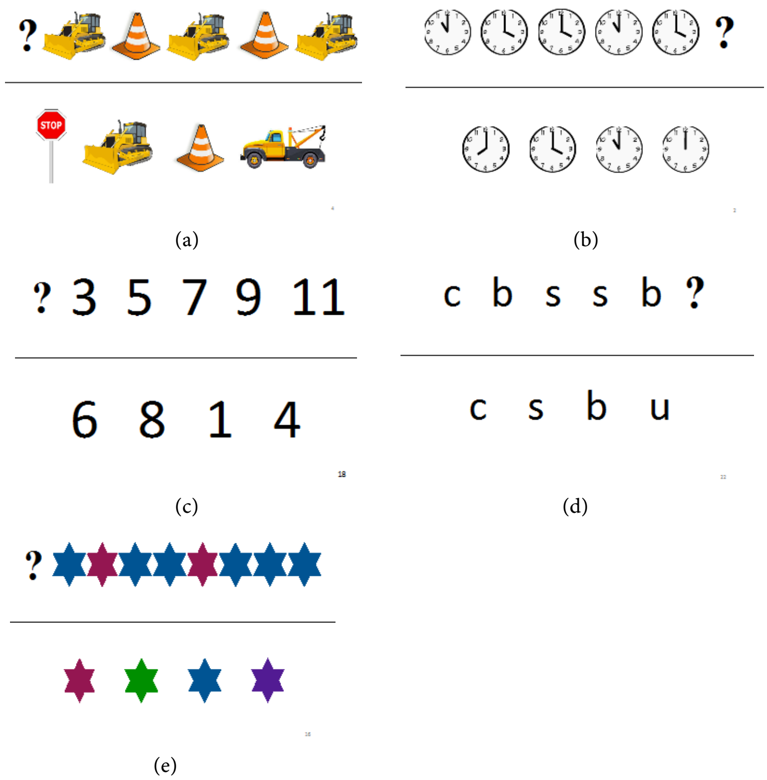

Figure 1. Examples of patterning from the patterning test. Examples of patterns that were used in the patterning test are given above. (a) An ABAB repeating pattern made of pictures of objects; (b) An ABBABB repeating pattern made of clock faces; (c) A skip-one pattern made from numbers; (d) An ABCCBA (symmetric) pattern made of letters; (e) An ABABBABBB (growing) pattern made of colored shapes.

Concurrent validity with the Woodcock Reading Mastery Tests-Revised is 0.85 - 0.98, and reliability is 0.90 - 0.99 according to the TOWRE manual.

The DIBELS ISF scale requires children to identify which picture in a set of pictures begins with a certain sound. The children are scored on the number of correct answers and the number they have gotten correct per second. The predictive validity of kindergartners' ISF for the Woodcock-Johnson Broad Reading Cluster averages 0.36 (Good et al., 2004). Coefficients of validity obtained by the same researchers for the DIBELS were 0.34 (December) and 0.44 (April) with the Woodcock Johnson Readiness Cluster Score.

2.3. Instructional Materials

Growing patterns, repeating AB and ABB patterns, random repeating patterns, rotation patterns, and symmetrical patterns were presented horizontally with four answer choices below them, and used to teach patterning to the children in that instructional condition. The patterns were made of clocks, colors, letters, numbers, pictures of objects, (e.g., animals, fruits, etc.), and shapes. These were shown to the children via whiteboards and flip charts, and also with foam letters, numbers, small objects (manipulatives) and shapes. Please see Figure 2 for examples.

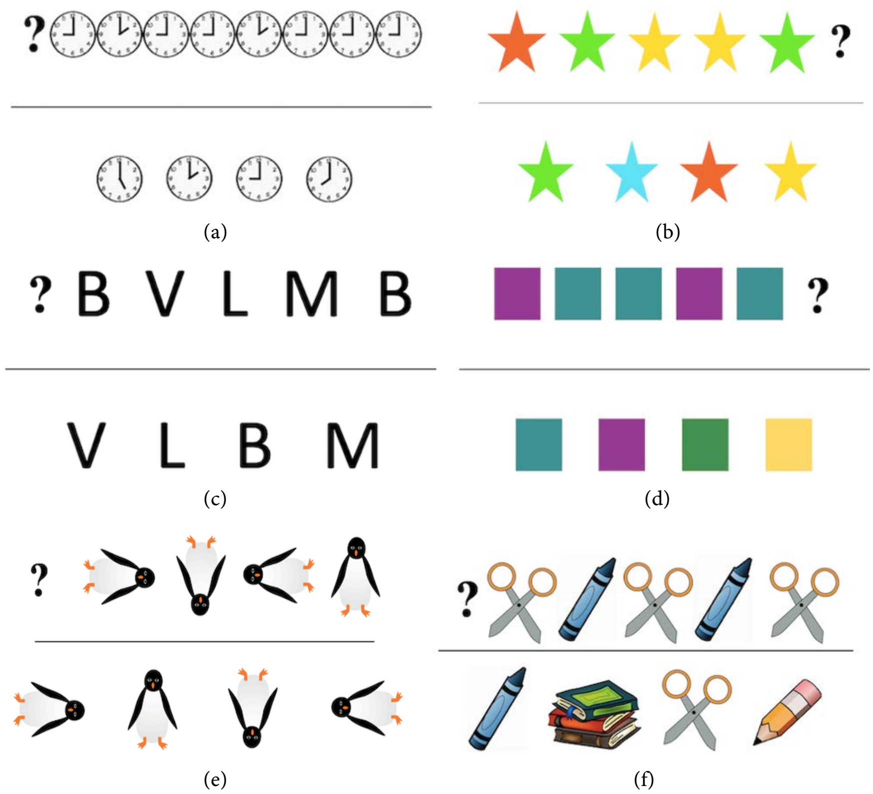

Figure 2. Materials used for patterning instruction. Examples of patterns used in instruction. (a) A growing pattern of clocks; (b) A symmetrical pattern of colored stars; (c) A random repeating pattern of capital letters; (d) An ABB pattern of colored squares; (e) A pattern of rotating penguins; (f) An AB pattern of scissors and crayons.

Children in the mathematics condition were taught early mathematics with foam numbers and manipulatives, number bingo games, and whiteboards.

Whiteboards, foam letters, letter bags and notecards were used to teach literacy to children in the literacy condition. Letter bags were labeled with letters or letter combinations and contained small object or pictures of objects that began with that letter or combination. Sets of words having the same root—fat, rat, pat, sat—were presented on the note cards.

Pictures expressing topics which were part of the Standards of Instruction for the cooperating school system (e.g., USA map of states, Abraham Lincoln, libraries, police and fire personnel and uniforms, post offices, etc.) were used with the children in the social studies condition along with crayons, water colors, and stickers.

2.4. Instructional Procedures

The children in each class routinely received "centers" instruction during part of the school day. During centers instruction small groups of children received about 15 minutes of instruction on different topics. One center was designated for the research. The patterning test was given to all of the children who returned signed permission letters. Some children showed a good understanding of patterning. Hence, the 12 children from each class who scored lowest were selected for the research, as they were deemed the most in need of extra instruction and most likely to profit from it. These children formed into trios and the trios were randomly assigned to be taught either literacy or mathematics or patterning or social studies for 15 minutes three days a week in this center. The instruction of the four trios was given in a counterbalanced order by the same teacher. For example on one day the mathematics lessons were given to the trio in the mathematics instructional condition, then the patterning lessons were given to the trio of children in the patterning condition, then the literacy lessons were given to the trio in the literacy condition, and last the social studies lessons to the trio in the social studies condition. A Latin square design was used to determine the order of instruction each day.

A specialist in early childhood education who had more than a decade of experience in the cooperating school system designed all of the instruction. A site manager at each center observed the instruction to maintain fidelity with the lesson plans, making corrections and suggestions when needed, made sure that the counterbalanced order of conditions was followed, and kept progress records. Each site manager had previous experience with this type of research.

Patterning instruction. A variety of patterns, including random repeating patterns, symmetrical patterns, AB patterns, ABB patterns, growing patterns, and rotation patterns were included in patterning instruction. Patterning problems were presented to the children one at a time on flip charts. Each pattern was a horizontal row of items that had one missing item at the beginning or end of the pattern, and the children were asked to select one of four choices to complete the pattern. Each flip chart was turned over to the next page when the child selected the correct answer and remained on the same page if the child picked the wrong one. Performance was scaffolded through explanation and repetition until each child was able to demonstrate mastery of each pattern type.

Whiteboards and manipulatives (e.g., beads, bells, cubes, etc.) were used to enhance each child's ability to identify, create, and extend patterns. Children would be shown a pattern that had been started but was incomplete. They would then be helped to identify, complete or extend it. Small objects were used in a similar way.

Mathematics instruction. Mathematics instruction featured a variety of mathematics-related activities for each day. Foam numbers, bingo games, whiteboards, and manipulatives were utilized in math activities. Specific math concepts or skills, such as numeral recognition, quantifying/counting, number order/spans, and comparisons, were addressed in daily sessions. Each mathematics session began with a brief informal assessment to determine the children's mastery of the skill or concept needed in the given task. Children were taught to recognize numerals, which were presented to them in a variety of formats. They were taught to count small objects and to count aloud by ones, twos, fives, and tens. They were also taught such mathematical terms as greater, less, plus. All mathematics activities had elementary or advanced options that could be used to individualize the instruction to meet the needs of the child.

Literacy instruction. Letter recognition and identification, building letter/sound correspondence, and distinguishing sounds were addressed in this instruction. Each child was given an alphabet chart and was instructed to read each letter. Then the focus letters (both upper and lowercase) for that day were presented and the children asked to point to a specific letter and to name it. They would be asked which classmates had names that began with the focus letter and what other words they knew that began with it.

Letter bags were utilized to help children build letter and sound correspondences and to distinguish between different beginning sounds. Some objects or pictures of objects that began with the focus letter and some that didn't begin with it were shown to the children, and the focus letter's beginning sound would be emphasized as the corresponding objects were placed in the bag. Letter bags were also used to teach students distinguish between different beginning sounds. Children were asked to sort objects or pictures that began with two previously learned letters (e. g. A and B) by placing those that begin with A in the A bag and the words that begin with B in the B bag. In addition, note cards were used to teach children phonics with a group of words with the same root (e.g., air family consisted of cards such as chair, hair, lair, pair, and stair.

Social studies. A variety of topics that highlighted historical events and people, geography, and civics were featured in social studies activities. These were described and discussed, and the children on engaged in various activities, such as coloring sheets that illustrated the different topics, and decorating them with stickers.

2.5. Posttests

From mid-April to early May, the four tests were administered to the 172 children still available. These were the patterning test used in pretesting, the TOWRE, the ISF, and the KTEA. These tests were administered in a counterbalanced order and supervised by the site managers.

3. Results

A linear mixed effects model indicated that there were significant main effects for the patterning condition. Furthermore, the same effects were shown when a standard linear model (i.e., regression with dummy codes) was conducted as a check. Table 1 shows these results.

The analyses that follow show the results when the children's patterning pretest scores were used as a covariate. The treatment groups were treated as dummy variables in a fixed effects model. Thus, the intercept represents the mean effect of the patterning instruction.

The significant intercept in Table 2 shows that the children taught patterning outscored the other children on patterning. The low and nonsignificant b values for the other instructional conditions indicate that they did not differ on patterning (see Table 2).

The nonsignificant intercept in Table 3 shows that there was no significant overall difference on mathematics. The *b* values comparing the children taught mathematics with those in each of the other instructional conditions are small and nonsignificant for mathematics (see Table 3).

Table 1. Linear mixed model fit by REML.

Random effects:					
Groups	Variance	Standard. Deviation			
Teacher	5.501	2.345			
Residual	25.727	5.072			
Fixed effects:	Estimate Std.	Error	df	t value	p
Instructional Condition	18.0103	0.6867	105.5545	26.229	<0.001
Mathematics vs Patterning	−2.1173	0.7636	324.3895	−2.773	<0.01
Literacy vs Patterning	−1.9486	0.7698	324.117	−2.531	<0.05
Social Studies vs Patterning	−3.1213	0.7638	327.7583	−4.086	<0.001

Table 2. Regression results using the patterning posttest as the criterion (dependent variable).

Predictor	*b*	*b* 95% CI [LL, UL]	sr^2 sr^2 95% CI [LL, UL]	Fit
(Intercept)	13.31**	[10.75, 15.88]		
Mathematics	0.05	[-0.29, 0.38]	0.00 [−0.00, 0.00]	
Literacy	−0.15	[−0.49, 0.18]	0.00 [−0.01, 0.01]	
Social Studies	0.04	[−0.29, 0.38]	0.00 [−0.00, 0.00]	
				R^2 = 0.195**
				95% CI [0.11, 0.25]

Note: A significant b-weight indicates the semi-partial correlation is also significant. *b* represents unstandardized regression weights. sr2 represents the semi-partial correlation squared. LL and UL indicate the lower and upper limits of a confidence interval, respectively. * p < 0.05. ** p < 0.01.

Table 3. Differences between instructional conditions using mathematics as the criterion.

Predictor	*b*	*b* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	Fit
(Intercept)	−0.35	[−0.73, 0.04]			
Patterning	0.02	[−0.03, 0.08]	0	[−0.01, 0.01]	
Literacy	0	[−0.05, 0.05]	0	[−0.00, 0.00]	
Social Studies	0.01	[−0.04, 0.06]	0	[−0.00, 0.00]	
					R^2 = 0.113**
					95% CI [0.04, 0.16]

Note: A significant *b*-weight indicates the semi-partial correlation is also significant. *b* represents unstandardized regression weights. sr^2 represents the semi-partial correlation squared. LL and UL indicate the lower and upper limits of a confidence interval, respectively. ** p < 0.01.

Likewise, there were no significant differences overall in literacy and no significant differences between instructional conditions on literacy (see **Table 4**). The *b* for the overall comparison on literacy and also those for comparisons on literacy of the children instructed on literacy with children in each of the other instructional conditions were small and nonsignificant.

4. Discussion

The first hypothesis was supported: the kindergartners taught patterning became better at patterning than the kindergartners who received control instruction. However, the patterning instruction did not produce gains in mathematics or literacy. Hence, the results are similar to those obtained in previous studies with smaller numbers of kindergartners (Kidd et al., 2019; Pasnak et al., 2019b; Shriver et al., 2017). It seems clear that improvement in patterning per se does not produce mathematics or literacy gains for kindergartners, or at least that any gains produced are not so large as to be easily detectable. The practical implication of these results is that the common practice of teaching patterning to kindergartners is probably not worthwhile.

There are several possible reasons for the difference in the results obtained for kindergartners and those obtained with first graders, for whom patterning instruction did produce gains in both mathematics and literacy. One may be that the tests employed for kindergartners are not sensitive to the gains. It is noteworthy in this context that Kidd et al. (2013) did not find literacy gains when employing Woodcock-Johnson literacy scales 1, 2 and 9 but Kidd et al. (2014) did find them when employing the TERA, TOWRE, and Gray Oral Reading Test in what was essentially a replication of the procedures of Kidd et al. (2013). Further, Kidd et al. (2013) did not find significant effects for patterning on Woodcock-Johnson III Applied Problems mathematics scale (scale 10) but did find them on Woodcock-Johnson III Quantitative Concepts scales 18A and 18B.

Table 4. Regression results using literacy as the criterion.

Predictor	*b*	*b* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	Fit
(Intercept)	−0.4	[−0.83, 0.02]			
Patterning	0.02	[−0.04, 0.08]	0	[−0.01, 0.01]	
Mathematics	0.04	[−0.02, 0.09]	0	[−0.01, 0.02]	
Social Studies	0.01	[−0.04, 0.07]	0	[−0.00, 0.01]	
					$R^2 = 0.117^{**}$ 95% CI [0.05, 0.17]

Note. A significant *b*-weight indicates the semi-partial correlation is also significant. *b* represents unstandardized regression weights. sr^2 represents the semi-partial correlation squared. LL and UL indicate the lower and upper limits of a confidence interval. * $p < 0.05$. ** $p < 0.01$.

Kidd et al. (2014) also found discrepancies between results on different KEY-math scales: patterning instruction was effective in raising scores on some scales but not others. Hence, whether or not patterning instruction produces mathematics or literacy gains on standardized tests has repeatedly been found to depend upon the tests used.

Another possibility is, of course, that a different sample of kindergartners might yield different results. The participants in the present study were those who scored lowest on the patterning pretest, and were from primarily low-income families, many of them immigrant families, in an urban neighborhood. Kindergartners from a middle class or high-income neighborhood might well yield different results. It is possible that children must have reached a sufficient level of proficiency in mastery in mathematics and literacy to be able to profit from patterning instruction. In the case of growing numerical and clock patterns, a basic understanding of addition and subtraction are necessary to determine the unit of change. Perhaps it is necessary for children to be sufficiently proficient in supporting abilities before improvement in patterning can produce academic improvement. It may be that patterning instruction can be effective in supporting the thoughts that children already have begun to develop about relationships in mathematics, and between letters and sounds, if such thinking is sufficiently developed, but not otherwise. We note in this context that Gadzichowski, O'Brien, and Pasnak (2014) reported that growing letter patterns were much easier for first-graders when presented in the horizontal sequences in which children usually encounter letters, whereas growing numerical patterns were much easier in the vertical orientations in which numbers most commonly presented in kindergarten arithmetic instruction. Pasnak, Thompson, Gagliano, Righi, and Gadzichowski (2019) replicated this result with kindergartners. The possibility that the effects of patterning instruction depend on the proficiencies children bring to the situation is suggested by such findings.

Another complication is that all of the children in the present experiment received instruction on repeating patterns as part of whole classroom curricular instruction. This complication was not foreseen, but probably should have been. This commonality in the experience of all children is likely to have muted the impact of the experimental instruction on both repeating and growing patterns. This will be a difficult problem to resolve in American kindergartens, in which patterning instruction is traditional and ubiquitous, or in any non-American kindergartens in which some form of patterning is taught to all kindergartners.

Hence, it is certainly possible that instructing kindergartners on patterning has no effect on their subsequent literacy or mathematics. However, a decisive test of this possibility must meet several conditions. 1) Children must be randomly assigned to receive instruction on patterns or not to receive it, 2) The patterning instruction must be extensive enough to produce mastery, and 3) The patterning instruction must be delivered early in the school year. Beyond these necessary conditions, researchers must make insightful or fortunate choices in the measuring instruments they choose, the sample to be involved in the experiment, and the patterns to use in instruction, which might be repeating, growing, or both. Securing sufficient cooperation from schools which do not teach patterning as part of their curricular may be difficult but must be accomplished before definitive research can be conducted.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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