

AERA Submission to Division C, Section 3 (Mathematics)

Title: Learning from Explanations: Does It Matter Who Provides Them?

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Abstract

Patterning is an activity preschoolers commonly engage in and is considered a form of early algebraic thinking. In the current study, we explored the impact of combining two learning approaches, exploration and explicit instruction, on repeating pattern knowledge. Specifically, we focused on the effect of varying the source of explanation (the self, an expert, or both). 124 four-year-olds completed a pretest, brief patterning intervention, and immediate posttest. During the intervention, children studied correct examples and either self-explained, received instructional explanations, or alternated between the two. While all students' abstract pattern knowledge improved, no significant differences were found by condition. Although the source of explanation may not have impacted learning, we found that even four-year-olds can generate self-explanations that promote learning.

Keywords: cognitive processes/development, mathematics education, preschool

Word count: 1,861

Learning from Explanations: Does It Matter Who Provides Them?

Objectives

Patterning is a common activity that young children engage in (Ginsburg, Inoue, & Seo, 1999; Ginsburg, Lin, Ness, & Seo, 2003) and is a central component of early mathematics knowledge (e.g., National Council of Teachers of Mathematics, 2000). We examined the impact of instructional- and self-explanations on preschoolers' knowledge of repeating patterns (i.e., linear patterns that have a unit that repeats). In particular, we focused on their understanding of the pattern unit (i.e., the sequence that repeats over and over), as this is the most mathematically-meaningful aspect of repeating patterns (e.g., Economopoulos, 1998; Papic, Mulligan, & Mitchelmore, 2011).

Empirical evidence is limited, but knowledge of patterns has been shown to support other areas of mathematics, such as ratios (Warren & Cooper, 2007) and early algebra (Papic et al., 2011). Past research on preschooler's patterning knowledge has shown that prompting children to generate explanations can improve knowledge of patterns (Rittle-Johnson, Saylor, & Swygart, 2008) and that the quality of self-explanation improves after an instructional-explanation is provided (Rittle-Johnson, Fyfe, McLean & McEldoon, 2013). What remains unknown is the relative merits of combining the two sources of explanations for learning.

Theoretical Framework

Several theories of learning focus on the benefits of learning through exploration and self-discovery of the environment without explicit instruction from a more knowledgeable person ("exploration"; Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009; Piaget, 1973; Schulz & Bonawitz, 2007; Sylva, Bruner & Genova, 1976). Others focus on the benefits of learning through guidance and instruction from experts such as parents and teachers ("explicit instruction"; Csibra & Gergely, 2009; Kirschner, Sweller, & Clark, 2006; Tomasello, Carpenter, Call, Behne, & Moll, 2005; Vygotsky, 1978). Both exploration and explicit instruction are thought to benefit learning in numerous ways. For example, providing the opportunity to explore a new environment or topic may increase learners' motivation, encourage broad hypothesis testing, and improve depth of understanding (e.g., Bonawitz et al., 2010; Piaget, 1973; Sylva et al., 1976; Wise & O'Neill, 2009). However, children learn extensively from social partners, and teaching children new information directly can lessen the burden on cognitive resources and support the development of accurate knowledge (Kirschner et al., 2006; Klahr & Nigam, 2004; Koenig & Harris, 2005; Sweller, van Merriënboer, & Paas, 1998; Tomasello et al., 2005).

One context in which to study ways of combining explicit instruction and exploration is explanation, an important knowledge source during learning activities. Two common forms of explanation are self-explanation and instructional explanation, which vary according to the source of the explanation. The learner generates self-explanations in an attempt to make sense of study materials (Chi, 2000), while an expert (e.g., teachers or parents) provides instructional explanations with the goal of elucidating why or how something works. Past research has shown that prompting even young children to self-explain can improve their learning (e.g., Amerstlaw & Wellman, 2006; Pillow, Mash, Aloian, & Hill, 2002; Rittle-Johnson et al., 2008). Additionally, it is common for parents to provide explanations, which are associated with greater knowledge in young children (Dunn, Brown, Slomkowski, Tesla, & Youngblade, 1991; Hughes & Dunn, 1998; Ruffman, Slade, & Crowe, 2002). Thus, both sources of explanation have been shown to support learning.

Research contrasting instructional and self-explanations with young children is sparse. One study found that four-year-olds who self-explained were better able to transfer a solution strategy to an analogous problem than children who were provided with an instructional explanation (Brown & Kane, 1988). However, ninety percent of the children who self-explained were able to generate an appropriate explanation, and the two children who did not failed on the transfer problems. Thus, these findings may not generalize to many domains for young children who often struggle to give appropriate explanations (e.g., Honomichl & Chen, 2006; Rittle-Johnson et al., 2008). Another study found that 5- to 8-year-olds' emotion understanding improved (relative to controls) when they were asked to either provide self-explanations or were given instructional explanations to picture-book vignettes, but no difference in improvement was found between explanation conditions (Tenenbaum, Alfieri, Brooks, & Dunne, 2008).

Combining both instructional and self-explanations could optimize learning for young children. For example, Rittle-Johnson (2006) found that both self-explanation prompts and direct instruction on a correct procedure helped elementary school children learn and remember a correct procedure. Additionally, self-explanation promoted transfer of the procedure regardless of instructional condition. Findings are mixed in terms of combining instructional and self-explanations with young children. Crowley and Siegler (1999) found that providing instructional explanations as well as self-explanation prompts did not improve strategy generalization relative to self-explanation alone (although it did improve the quality of the self-explanations). In contrast, Calin-Jageman and Ratner (2010) found that the combination improved kindergartners' learning on addition problems relative to self-explanation only and to no explanation.

Current Study. We contrasted whether explanations about correct examples were generated by the learner (*self-explanation*), were provided by a more knowledgeable other (*instructional explanation*), or were used in combination (*instructional and self-explanation*). Specifically, we explored whether instructional explanations were more beneficial by themselves or in combination with self-explanation.

Method

Participants. Participants were 124 children (53 female) attending preschool at one of ten preschools in Tennessee. Approximately 23% of the participants were racial or ethnic minorities and the average age was 4.59 years (range: 4.0-5.8 years). None of the participating preschools were using a specialized curriculum focused on patterning.

Design and Procedure. All children participated in two one-on-one sessions on consecutive days. In the first session, children completed the pretest pattern assessment and the first half of the intervention. In the second session, children completed the second half of the intervention and the posttest pattern assessment. Each session lasted approximately 30 minutes and included a short break halfway through. Children were randomly assigned to one of three conditions: instructional explanation ($n = 41$), self-explanation ($n = 41$), or instructional and self-explanation ($n = 42$).

During the intervention, all children alternated between solving abstract pattern problems and studying correct examples of abstracting a pattern for a total of 10 trials. Children received accuracy feedback on the solve trials. In the instructional explanation condition, children were given explanations as to why two patterns were alike (e.g., because the part that repeats is the same). In the self-explanation condition, children were prompted to explain why two patterns are the same (e.g., "How is your pattern the same kind of pattern as mine?"). Finally, in the

instructional and self-explanation condition, children alternated between receiving instructional explanations and being prompted to self-explain.

Data Source

Assessment. Preschoolers' repeating pattern knowledge was assessed using tasks varying in four levels of increasing difficulty (See Figure 1; adapted from Rittle-Johnson et al., 2013). As shown in Figure 1, Level 1 items required children to duplicate a model pattern by making an exact replica, Level 2 items required children to extend an existing pattern by at least one full unit, Level 3 items required children to abstract patterns by recreating a model pattern using a different set of materials, and Level 4 items required children to identify the pattern unit. The pretest pattern assessment consisted of one duplicate item, two extend items, and two abstract items. The posttest pattern assessment included all five items from the pretest along with an additional abstract item and two pattern unit items (i.e., unit-identification and unit-tower) for a total of eight items.

Results

Table 1 presents mean accuracy scores by condition at pretest, intervention and posttest. At pretest, children generally could duplicate and extend patterns, and some children could abstract patterns. At posttest, children showed improvement on the abstract pattern items. This improvement was expected, as abstract patterning tasks were the focus of our intervention. In fact, children's abstract patterning accuracy increased just from Day 1 of the intervention to Day 2. Another focus of our intervention was on the pattern unit, or the part that repeats, and some children were able to complete the most difficult unit identification tasks at posttest.

Instructional explanations did not improve learning compared to self-explanation alone or a combination of the two. Children learned just as much if they generated explanations on their own than if they received instructional explanations or alternated between self- and instructional explanation. Controlling for pretest score, age, and performance on three executive function tasks, no differences by condition (instructional explanation $M = 4.75$, $SE = 0.23$; self-explanation $M = 4.56$, $SE = 0.23$; instructional and self-explanation $M = 5.13$, $SE = 0.23$) were found for posttest scores, $F(2, 113) = 1.57$, $p = 0.21$, $\eta^2 = 0.03$. Thus, the source of the explanation did not significantly impact learning. However, the source of the explanation may be important for more difficult, unfamiliar patterning tasks. While not significant, compared to the self-explanation group ($M = 0.46$, $SE = 0.10$) there was a trend in favor of instructional explanations, either alone ($M = 0.66$, $SE = 0.10$) or in combination with self-explanation ($M = 0.67$, $SE = 0.10$), for performance on the most difficult unit identification tasks at posttest, $p = 0.11$. Additionally, instructional explanations improved the quality of children's self-explanations (Fyfe et al., 2014). Children who alternated between instructional and self-explanations were more likely to adopt abstract language from the modeled explanation in their own explanations (e.g., "it goes same-same-different"), using corresponding labels on both patterns. Children who provided these types of explanations showed improvement in posttest scores.

Significance

Instructional and self-explanations both benefited children's abstract pattern knowledge similarly. Additionally, combining instructional and self-explanations proved to be equally advantageous as either explanation alone. While this study focuses on the impact of the source of

explanations for young children learning about repeating patterns, the source of explanation did not significantly impact learning.

Our results reveal important insight into young children's pattern knowledge. This study highlights 4-year-olds' ability to abstract patterns without extensive instruction. In a previous study, we found that children's performance on abstract pattern tasks significantly improved over the course of the preschool year despite most teachers reporting that they did not provide instruction or practice abstract patterning in the classroom (Rittle-Johnson et al., 2013). Together, these findings are encouraging considering the importance of understanding repeating patterns for early algebra (Papic et al., 2011).

This study suggests that even four-year-olds can generate self-explanations that promote learning. While the quality of self-explanations seems to play a role in learning and specifically transfer (Brown & Kane, 1988), and young children often struggle to give appropriate explanations (e.g., Honomichl & Chen, 2006; Rittle-Johnson et al., 2008), our findings suggest that 4-year-olds are in fact capable of generating sufficient explanations. However, providing instructional explanations impacts the quality of children's self-explanations (Fyfe et al., 2014). Instructional explanations increased children's use of abstract labels, which allows learners to use shared labels for two different patterns. Shared labels have been shown to elicit comparison and improve learning (Namy & Genter, 2002). Future research should utilize this capability and focus on ways to encourage children to use language provided by instructional explanations in their own explanations.

More generally, this study illustrates the benefits of considering both exploration and instruction to support learning. We found exploration, explicit instruction, and a combination of the two to be equally effective. Even though recent arguments have favored direct instruction (Csibra & Gergely, 2009; Kirschner et al., 2006; Tomasello et al., 2005), these results suggest that exploring and generating explanations can be just as effective, even when explanations seem superficial. The potential benefits of exploration and self-explanation may be due to actively engaging the learner in manipulating, linking, and evaluating information rather than the discovery of the information and links per se. However, more research is needed to disentangle the nuances of encouraging patterning skills in young children using exploration methods, especially self-explanation.

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Figure 1. Sample items for each pattern level, including a sample correct response.

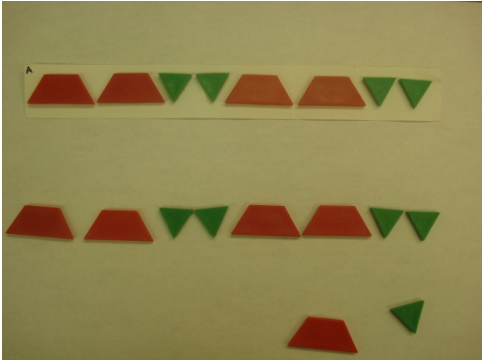
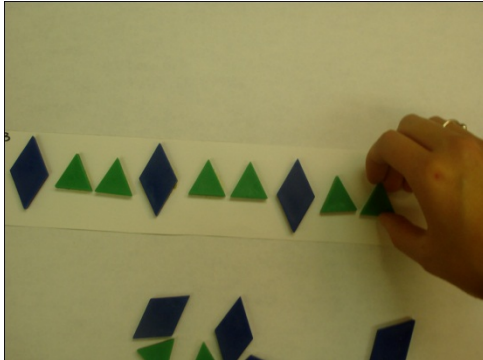
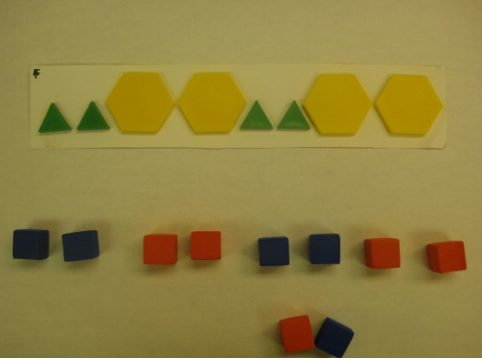
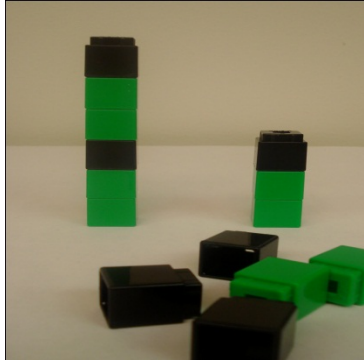
<p style="text-align: center;">Duplicate Pattern AABB</p>  <p>“I made a pattern with these blocks. Please make the same kind of pattern here.” (Trapezoids were red; triangles were green.)</p>	<p style="text-align: center;">Extend Pattern ABB</p>  <p>“I made a pattern with these blocks. Finish my pattern here the way I would.” (Diamonds were blue; triangles were green)</p>
<p style="text-align: center;">Abstract Color AABB</p>  <p>“I made a pattern with these blocks. Please make the same kind of pattern here, using these cubes.” (Triangles were green; hexagons were yellow; blocks were blue and red)</p>	<p style="text-align: center;">Unit Tower AAB</p>  <p>“What is the smallest tower you could make and still keep the same pattern as this?” after a demonstration with an AB tower. (cubes were green and black)</p>

Table 1. Pretest, intervention, and posttest repeating pattern assessment means by condition

	Instructional Explanation	Self- Explanation	Instructional and Self-Explanation	Total
Pretest				
Level 1 Duplicate	0.90	0.90	0.93	0.91
Level 2 Extend	0.60	0.69	0.57	0.62
Level 3 Abstract	0.40	0.39	0.35	0.38
Total Score	0.58	0.61	0.55	0.58
Intervention				
Level 3 Day 1	0.62	0.48	0.55	0.55
Level 3 Day 2	0.66	0.62	0.63	0.64
Total	0.63	0.54	0.58	0.58
Posttest				
Level 1 Duplicate	0.85	0.85	1.00	0.90
Level 2 Extend	0.61	0.69	0.60	0.63
Level 3 Abstract	0.69	0.67	0.65	0.67
Level 4 Unit ID	0.36	0.23	0.30	0.30
Total Score	0.60	0.59	0.59	0.69