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Enhancing the Quality of Children's Explanations to Promote Patterning Knowledge

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Abstract

Explanations are an important source of knowledge change. In the current study, we examined the impact of self-explanations alone or in combination with instructional-explanations for four-year-old children learning to abstract repeating patterns (i.e., create the same kind of pattern using new materials). Children provided a variety of explanations, some more sophisticated than others. Children in the combination condition often adopted the modeled explanation and used the abstract language in their own self-explanations. Further, children who used this abstract language exhibited higher knowledge of patterns on a posttest than children who did not. Overall, findings indicate that the quality of explanations matters and that combining self- and instructional-explanations can help young children develop an understanding of patterns.

Keywords: Mathematics Education, Learning Processes/Strategies, Preschool

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Objectives

Explanations are a ubiquitous instructional strategy used in classroom teaching, tutoring, and peer learning, and they are an important source of knowledge change. The goal of the current study was to examine the quality of self-explanations and its relation to learning outcomes. We investigated explanations in the context of preschoolers learning about repeating patterns (i.e., linear patterns that have a unit that repeats) and specifically their ability to abstract the pattern (i.e., make the same kind of pattern using new materials). Patterning is a common activity for children (Ginsburg, Lin, Ness, & Seo, 2003) and is a central component of mathematics knowledge (e.g., National Council of Teachers of Mathematics, 2000).

Theoretical Framework

Self-explanations comprise an important learning activity in which the learner generates an explanation in an attempt to make sense of learning materials (Chi, 2000). Prompting even young children to self-explain can improve learning (e.g., Amsterlaw & Wellman, 2006; Pillow et al., 2002; Rittle-Johnson et al., 2008). For example, generating explanations improved four- and five-year olds' problem-solving performance and also facilitated transfer to a novel patterning task (Rittle-Johnson et al., 2008). Indeed, self-explanation was recently identified as one of five evidence-based learning techniques with at least moderate utility across a variety of learning conditions and age ranges (Dunlosky et al., 2013). Self-explanation is thought to benefit learning by helping learners generate new inferences and repair flawed or incomplete mental models (Chi, 2000). Further, self-explanation has been shown to facilitate the discovery of new problem-solving procedures (e.g., Rittle-Johnson, 2006).

Although the mere act of explaining can aid learning, researchers suggest that the content of the explanations often matters (Chi et al., 1994; Renkl, 1997). Indeed, a number of studies demonstrate that higher-quality explanations are associated with greater learning outcomes (e.g., Chi et al., 1989; Matthews & Rittle-Johnson, 2009). For example, elementary-school children who explained math problems in terms of the concept of equality had higher posttest scores than children who explained math problems in terms of a basic procedure (Matthews & Rittle-Johnson, 2009). Similarly, Brown and Kane (1988) found that four-year-olds solving analogy problems generally benefitted from prompts to self-explain. However, the few children who were unable to generate an appropriate explanation failed on the subsequent transfer problems. These results suggest that self-explanation alone can be beneficial, but primarily when the quality of explanation is high.

Unfortunately, young children often struggle to provide appropriate explanations (e.g., Honomichl & Chen, 2006; Rittle-Johnson et al., 2008). For example, Matthews and Rittle-Johnson (2009, Exp. 2) found that elementary-school children provided conceptual explanations to math problems on only one third of all trials, even *after* receiving instruction on the concept. Thus, one goal of current research is to investigate ways to improve the quality of children's self-explanations to maximize the benefits of self-explanation for learning.

One potential solution is to interleave instructional-explanations that contain relevant, correct information. Instructional explanations are an important source of knowledge change and children learn extensively from more knowledgeable social partners (e.g., Wittwer & Renkl, 2008). Further, they provide children with an opportunity to hear and subsequently model higher-quality explanations. However, research on the combination of self- and instructional-

explanations in young children is limited and somewhat mixed. For example, four-year-olds were asked to explain two patterns without input, then listen to a high-quality explanation modeled by the experimenter, and finally attempt to explain two more patterns (Rittle-Johnson, et al., in press). Sophisticated explanations were rare before the experimenter modeled an explanation, but they increased significantly afterward. Crowley and Siegler (1999) similarly found that instructional-explanations improved the quality of self-explanations, but the combination was not more effective than self-explanation alone. In contrast, recent research found that the combination improved children's learning of addition problems relative to self-explanation alone (Calin-Jageman & Ratner, 2005). In the current study, we examined the impact of self-explanations alone or in combination with instructional-explanations for four-year-old children learning to abstract repeating patterns. Our focus was on the quality of these explanations and its relation to relevant learning outcomes.

Method and Data Sources

Participants. Participants were 83 children (36 female) attending one of ten preschools in Tennessee. Approximately 27% of the participants were ethnic minorities from low-income families and the mean age was 4.6 years (min = 4.0, max = 5.8).

Design and Procedure. Children participated individually in a quiet room at their preschools on two consecutive days. On the first day, children completed a brief pattern pretest and completed the first half of the tutoring intervention. On the second day, children completed the second half of the intervention and also took a posttest. Each session lasted approximately 30 minutes. Children in the current sample were randomly assigned to one of two conditions: self-explanation only (n = 41) or self- and instructional-explanations (n = 42).

Assessment. The pretest and posttest assessed children's pattern knowledge using four different types of tasks that varied in difficulty (Rittle-Johnson et al., 2013). The first and easiest task required children to *duplicate* a model pattern by making an exact replica with the same materials. The second task required children to *extend* an existing pattern by at least one pattern unit. The third task required children to *abstract* a pattern by recreating it using new materials. Finally, the fourth and most difficult task required children to identify the pattern *unit*. The pretest contained five items: one duplicate, two extend, and two abstract items. The posttest contained those five items plus an extra abstract item and two unit identification items. For each item, the pattern unit contained three (e.g., AAB) or four elements (e.g., AABB).

Intervention. During the intervention, children saw 10 examples of abstracting a pattern. On half of the trials, the child first attempted to abstract the pattern before being shown a correct example. In the self-explanation condition, children were promoted to explain why the two patterns were alike on all 10 trials ("how is your pattern the same kind of pattern as mine?"). In the self- and instructional-explanation condition, children alternated between providing self-explanations (on 5 of the 10 trials) and receiving instructional-explanations (on 5 trials). For the instructional-explanations, the experimenter explained why the two patterns were alike (e.g., "The part that repeats in my pattern is same-same-different. The part that repeats in your pattern is same-same-different. These patterns are like because the part that repeats is the same.").

Children's explanations during the intervention were coded for content into one of nine codes (see Table 1 for a description of each one). We were particularly interested in children's use of the linking same-different language, which was modeled by the experimenter. A second rater coded 30% of the explanations and interrater reliability was high (kappa = .96).

Results

Children provided a variety of explanations (see Table 2 for frequency data). Although children were asked to explain how the two patterns were alike, the majority of explanations were in reference to a single pattern. For example, a common explanation was to label the elements from one of the patterns in order. Unfortunately, a large proportion of explanations were still vague, highlighting the difficulty of obtaining appropriate explanations from young children. However, a substantial number of explanations were more sophisticated in nature and showed evidence of linking between the two patterns. For example, over one third of the children verbally linked the two patterns by matching up corresponding elements ("red in mine goes with green in yours, blue in mine goes with yellow in yours"). Similarly, a number of children linked the two patterns by using same/different language in reference to the unit of repeat in each pattern ("they both go same, same, different").

Several differences between conditions emerged in explanation quality. Children in the self- and instructional-explanation condition used same/different language more frequently, either in reference to a single pattern or in reference to linking the two patterns, $ps < .001$. Similarly, more children in that combination condition used those same/different explanations at least once, ps $< .001$. Thus, children in the self- and instructional-explanation condition adopted the high-quality explanation modeled by the experimenter. Children in the self-explanation only condition tended to verbally link the corresponding elements more frequently, $p = .08$, and more children in the self-explanation condition explained by labeling the elements in order, $p = .02$.

We explored whether the frequency of linking same/different language was correlated with learning outcomes. After controlling for pretest performance, use of linking same/different explanations was positively correlated with children's performance on the intervention solve items, $r(80) = .21$, $p = .05$, and their performance on the difficult unit identification posttest items, $r(80) = .23$, $p = .04$, though not with overall posttest scores. We also examined whether children who ever used the linking same/different explanation differed from children who never used it. Fourteen children (17% of sample) used the linking same/different explanation at least once. All of these children were in the self- and instructional-explanation condition. Children who used linking same/different language had higher total posttest scores ($M = 5.9$ out of 8) than children who did not use it ($M = 4.5$), $p = .03$. Importantly, these relationships are unique to use of the linking same/different explanation and do not hold for any of the other explanation types. Further, there was no effect of condition on posttest.

Scholarly Significance

In general, these results are consistent with previous research that suggests the content of explanations matters. Higher-quality explanations are often associated with greater learning outcomes (Chi et al., 1989; Matthews & Rittle-Johnson, 2009). Indeed, in the current study, frequency of using a high-quality explanation was positively correlated with relevant learning outcomes. Further, children who used the abstract same/different language in reference to the two patterns had higher scores on the posttest than children who did not. It was particularly interesting that adoption of this abstract language was related to performance on the most difficult posttest items, the unit identification items. Perhaps the abstract language in reference to both patterns highlighted the deep structure of the patterns (as opposed to their surface features) and facilitated attention to the unit of repeat. Drawing attention to structure is one of the central tenets of several theories of learning (e.g., Chi et al., 1981; Schwartz et al., 2011) and detecting underlying structure is often essential to transferring knowledge to novel, more difficult tasks.

These results also suggest that instructional-explanations can be a good resource for improving the quality of self-explanations. Indeed, the current findings are consistent with previous research showing that instructional-explanations can improve the quality of children's self-explanations (e.g., e.g., Crowley & Siegler, 1999; Rittle-Johnson et al., in press). However, the provision of instructional explanations in and of itself did not lead to greater posttest performance. Rather, only children who adopted the higher quality explanations demonstrated greater posttest knowledge. Unfortunately, a number of children still provided vague, non-pattern explanations on a large proportion of trials, even after exposure to a high-quality explanation, highlighting the fact that children often struggle to provide appropriate explanations in a variety of learning settings. Thus, finding ways to optimize the quality and benefits of explanations is a key endeavor for current and future researchers.

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Table 1

Description and Example of each Explanation Code

Explanation Code	**Description**	**Example**
Links Same/Different	Links the two patterns using same/different language	"Both patterns go same, same, different"
Links Elements	Links elements in both patterns using verbal labels	"Red in mine go with green in yours, blue go with yellow"
Links by Pointing	Links elements in both patterns using gestures only	Points to first three blocks in each pattern.
Same/Different	Uses same/different language in reference to elements in one pattern	"My pattern has one that's different and two the same"
Labels Items in Order	Labels the characteristics of at least three elements of one pattern	"Mine goes red, red, blue, red, red, blue"
Gestures to Pattern	Points to or sweeps over at least three elements of one pattern	Points to each element in one pattern.
Names Characteristics	Names characteristics of pattern elements without reference to position	"Yellow and blue"
Vague	Gives non-pattern response that does not fall into above categories	"Long" "Good"
No Response	Provides no response or provides explanation of uncertainty	Silence or "I don't know"

Table 2

Explanation Use by Condition

Explanation	**% Used Across Trials**		**% of Children Who Used**	
	SE	*SE+IE*	*SE*	*SE+IE*
Links Same/Different	0*	12	0*	33
Links Elements	20^	10	44	31
Links by Pointing	6	3	22	12
Same/Different	1*	21	7*	52
Labels Items in Order	25	23	71*	45
Gestures to Pattern	5	2	17	10
Names Characteristics	6	1	17	7
Vague	32	23	66	52
No Response	5	4	20	10

Note. *p < .05; ^p < .10; SE = self-explanation only condition; SE+IE = self- and instructional-explanation condition.