FROM REPEATING TO GROWING: A SYSTEMATIC REVIEW OF EARLY PATTERNING RESEARCH AND MATHEMATICAL OUTCOMES

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This systematic review synthesizes 92 empirical studies published between 2000 and 2025 to examine the trajectory of research on patterning in mathematics education. Trend analysis reveals a shift from foundational descriptions toward cognitive mechanisms and mathematical outcomes, yet a critical disconnect persists: preschool research is saturated with repeating patterns, while growing patterns are significantly underrepresented until primary school. We synthesize findings on mathematics achievement to argue that mixed intervention results likely stem from failing to distinguish the specific cognitive roles of repeating versus growing patterns. We propose integrating growing patterns into early childhood curricula to bridge this "algebraic gap."

INTRODUCTION

Patterning is an important subject in mathematics education, and even some researchers have defined mathematics as the science of pattern (Steen, 1988). Consistent with this definition, studies showed that patterning knowledge contributes to future mathematics achievement (e.g., Rittle-Johnson et al., 2017). Identifying the structure of patterns, generalizing this structure using formal ($n + 2$) or informal form (each step increases by two), and flexibly adapting it into novel cases, especially useful for the development of algebraic reasoning (Blanton & Kaput, 2011).

Research presented at previous PME conferences has long argued for the centrality of structure in early mathematical development. Fox (2006) linked early patterning directly to algebraic development, while Mulligan and Mitchelmore (2009) conceptualized a child's "Awareness of Pattern and Structure" as a generalized tendency that predicts mathematical competence.

Despite this theoretical consensus, the operationalization of patterning in research varies significantly, primarily between repeating patterns (cyclic structures such as ABAB) and growing patterns (sequences that increase or decrease by a constant quantity). While recent reviews have examined patterning in the early years (e.g., Wijns et al., 2019), there remains a lack of systematic synthesis regarding how the field transitions from repeating to growing patterns as children move from preschool to primary education (ages 3–12).

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This paper addresses this gap by analyzing 92 studies to answer two questions:

1. How does the research focus shift between repeating and growing patterns across participant age groups?
2. To what extent does pattern type moderate the relationship between patterning knowledge and mathematics achievement?

METHOD

We conducted a systematic literature review following PRISMA 2020 guidelines (Page et al., 2021).

Data sources and search strategy

We searched Scopus, Web of Science, and Ebscohost for English-language peer-reviewed articles, books, and conference proceedings published between January 2000 and January 2025. We developed a search string of "(pattern*) in title AND (math* education OR early childhood education) AND (child* OR preschool* OR kindergarten* OR young OR kid OR primary)." Additionally, specific filters were applied, including education, educational research, and mathematics.

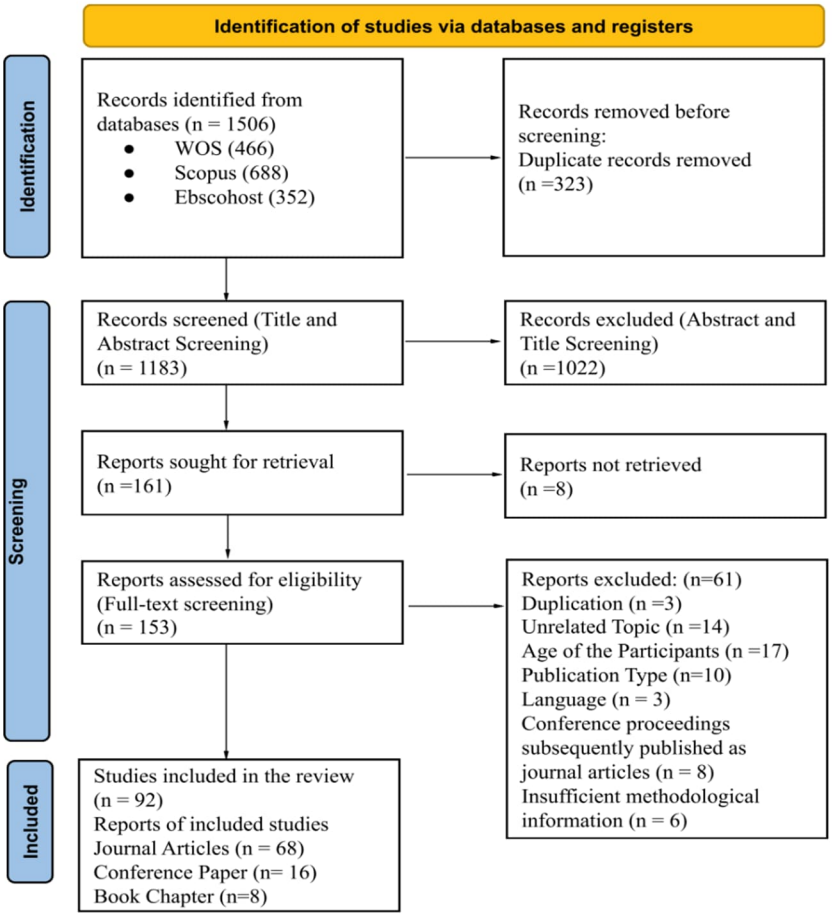
Study selection

Initial search yielded 1,506 results (WOS: 466, Scopus: 688, Ebscohost: 352). After 323 duplications were resolved, 1183 articles remained for two-stage exclusion: title and abstract screening. Two researchers independently evaluated the studies based on predetermined eligibility criteria. After the screening, we have 161 studies for full-text screening. A total of 69 articles were removed: 8 could not be retrieved, and 61 were removed following full-text screening due to the reasons provided in Figure 1. Therefore, 92 studies were included in the current study.

Data analysis

Data were analyzed using deductive qualitative content analysis, following Mayring's (2014) structured content analysis approach. To address the first research question, studies were coded according to descriptive categories, including publication period, geographical distribution, research methods, participants' age, study design (quantitative, qualitative, and mixed), and study type (correlational, causal, test development, and others). To address the second research question, studies were coded with respect to topics (math achievement, assessment, cognitive aspects, learning trajectories, strategy use, patterning, spontaneous focus on pattern, and others), their methodological orientation (quantitative, qualitative, or mixed methods), and pattern types. For analytical clarity, pattern types were categorized as repeating, growing, or others. Studies addressing both repeating and growing patterns were included in both categories.

Figure 1: PRISMA diagram.



RESULTS

The trajectory of patterning research (2000–2025)

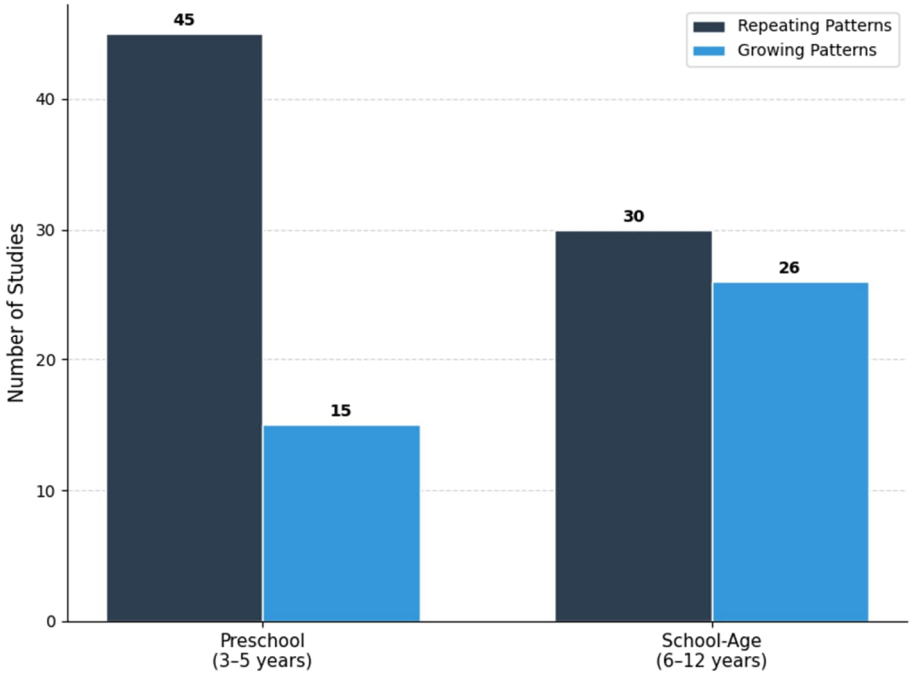
The analysis reveals a robust and accelerating interest in early patterning. Publication volume has tripled over the last decade, rising from 10 studies in 2006–2010 to 32 studies in 2020–2025. Geographically, the United States ($n = 26$) and Australia ($n = 15$) dominate the field, followed by European contributions from Germany and Belgium.

The "pattern type gap" in early childhood

A critical finding of this review is the imbalance in pattern types studied across age groups. As shown in our coding of pattern types by age (see Figure 2):

- **Preschool (3-5 years):** Research is heavily skewed toward repeating patterns ($n = 45$) compared to growing patterns ($n = 15$).
- **School-Age (6-12 years):** The focus becomes balanced, with repeating ($n = 30$) and growing patterns ($n = 26$) receiving nearly equal attention.

Figure 2: Distribution of pattern types by age group.



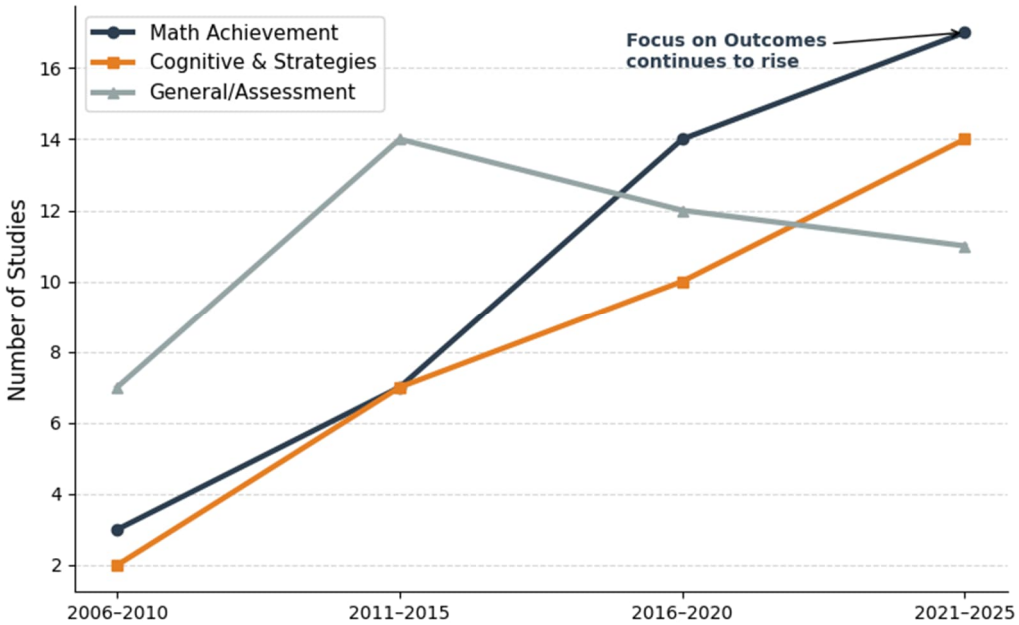
This discrepancy suggests a "blind spot" in the literature: while growing patterns are acknowledged as the bridge to functional thinking, they are largely absent from preschool research, which focuses almost exclusively on the less mathematically complex repeating structures.

Shifting research priorities: From definition to impact

To provide a clearer picture of the field's evolution, the original subject codes were aggregated into three distinct meta-categories for trend analysis (see Figure 3). First, Mathematics Achievement represents studies explicitly investigating the link between patterning and mathematical outcomes. Second, Cognitive & Strategies aggregates research on the underlying mechanisms of patterning, including "strategy use," "cognitive aspects," and "spontaneous focus on pattern" (SFOP). Finally, General/Assessment combines foundational research topics—such as assessment validation, learning trajectories, and general patterning descriptions—which focus on defining the construct rather than its application or mechanisms.

As illustrated in Figure 3, the focus of patterning research has undergone a significant structural shift over the last two decades. While foundational research—including general patterning characteristics, assessment development, and learning trajectories—peaked around 2011–2015 and has since plateaued or even declined, studies examining the impact on mathematics achievement have shown a steep and continuous rise.

Figure 3: Evolution of research topics grouped by focus area (2006–2025).



This divergence signals that the field has largely established *how* to assess patterning and is now primarily concerned with *what* patterning predicts. Concurrently, the rise in research on Cognitive & Strategies since 2006 indicates a growing interest in the underlying mechanisms—such as Spontaneous Focus on Pattern (SFOP) and functional thinking strategies—that mediate the relationship between patterning and mathematics. This triangulation suggests the field is moving away from describing patterning in isolation and toward understanding it as a dynamic cognitive process that drives mathematical development.

Patterning and mathematics achievement: A nuanced relationship

Mathematics achievement was the most frequently researched topic, accounting for 34.2% of the included studies. When analyzing these studies, a clear distinction emerges based on study design and pattern type.

Studies utilizing correlational and longitudinal designs consistently report moderate to strong associations between patterning skills and mathematics achievement. For instance, Zippert et al. (2020) found moderate associations in preschoolers, and De Keyser et al. (2020) reported strong correlations with numerical skills.

The results from causal intervention studies are mixed. While some interventions demonstrate that patterning instruction significantly boosts mathematics performance compared to direct instruction (e.g., Kidd et al., 2013), others report non-significant transfer effects (e.g., McKnight et al., 2021; Strauss et al., 2020).

Our synthesis suggests these "mixed" results may be explained by the specific pattern type utilized. Studies that differentiate between pattern types indicate they support different mathematical competencies:

- **Repeating patterns** appear to predict procedural understanding and early numeracy but may have saturation limits. Borriello et al. (2023) found that repeating pattern knowledge predicted procedural but not conceptual understanding when controlling for growing patterns.
- **Growing patterns** are more strongly linked to proportional reasoning and abstract conceptualization. Vanluydt et al. (2021) found that growing and repeating patterns were associated with distinct types of proportional reasoning tasks.

DISCUSSION

This systematic review moves beyond a simple description of trends to highlight a structural issue in the field of patterning research. While the volume of research has increased, the heavy saturation of repeating pattern studies in the preschool years may be limiting our understanding of the developmental roots of algebraic reasoning.

We argue that the conflicting findings regarding the transfer of patterning skills to general mathematics achievement are likely an artifact of the "Pattern Type Gap." Many interventions focus heavily on repeating patterns. However, if repeating patterns primarily support procedural numeracy while growing patterns support functional/conceptual thinking, then interventions that fail to transition students from repeating to growing patterns may fail to trigger the deeper algebraic reasoning required for broad mathematical achievement.

The field has successfully established that children can identify repeating patterns. The challenge—and the necessary future direction—is to explore the "zone of proximal development" between repeating and growing patterns. The limited number of studies on "spontaneous focus on pattern" suggests a move toward examining *how* children attend to structure, but this needs to be applied specifically to how children perceive the *changing* nature of growing patterns.

Implications for research and practice

Future research should prioritize the preschool-to-primary transition (ages 4–7) with a specific focus on introducing growing patterns earlier. We need to move beyond asking "Does patterning help math?" to asking "Which specific patterning structures support which specific mathematical concepts?" Additionally, the lack of research on learning trajectories and strategy use highlights the need for qualitative work to map the cognitive shift from recognizing a "unit of repeat" to recognizing a "unit of change."

Limitations

This review is limited to English-language publications identified in three major databases as of January 2025. While comprehensive, it may omit gray literature or non-English studies that contribute to local understandings of patterning curriculum.

CONCLUSION

The "Science of Pattern" is a fundamental definition of mathematics, yet our educational research has disproportionately focused on the simplest iteration of that science—repeating patterns. To fully realize the potential of patterning as a route to algebra, the field must embrace the complexity of growing patterns in the early years.

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