



Conceptual depth of number and algebra materials in elementary school mathematics: a comparison of Indonesian and Chinese curricula

Satrianawati ^{a,1,*} , Wen Heng Fu ^{b,2}, Fitri Indriani ^{a,3}

^a Universitas Ahmad Dahlan, Yogyakarta, Indonesia

^b Harbin Normal University, Harbin, Heilongjiang, China

¹ satrianawati@pgsd.uad.ac.id; ² wenhengfu@126.com; ³ fitri.indriani@pgsd.uad.ac.id

* corresponding author

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ABSTRACT

This study presents a comparative content analysis examining the conceptual depth of Number and Algebra instruction in the primary school curricula of Indonesia and China for Grades 1 and 2. The primary objective is to analyze variations in how foundational concepts such as number introduction, basic operations, symbol awareness, patterns, and quantitative relationships are introduced to support pre-algebraic thinking. The findings reveal that the Chinese mathematics curriculum integrates pre-algebraic concepts earlier, more intensively, and at a higher level of abstraction than the Indonesian curriculum. China's curriculum places strong emphasis on quantitative relationships and symbolic reasoning, providing a structured bridge from basic arithmetic to formal algebra. In contrast, the Indonesian curriculum focuses primarily on mastering simple numerical operations within prescribed limits. These findings highlight the need to strengthen the pre-algebraic framework within the Indonesian curriculum specifically by enhancing place-value comprehension, relational reasoning, and symbol awareness to better prepare students for higher-level mathematical challenges. The study recommends adopting systematic curriculum practices to reinforce students' mathematical foundations from an early age.



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1. Introduction

The development of a solid mathematical foundation in the early stages of basic education greatly determines the quality of students' numeracy literacy nationally [1]. Grades 1 and 2 of elementary school are a crucial period where students begin to move from concrete thinking to understanding fundamental mathematical concepts such as numbers, basic operations, and quantitative relationships [2]. However, international evaluations such as PISA consistently show that Indonesian students still have difficulties in the aspects of mathematical reasoning, problem-solving that requires flexibility of thinking, and symbol awareness that should have been developed early through pre-algebraic concepts [3], [4]. This study shows that the Chinese mathematics curriculum has succeeded in explicitly instilling a pre-algebraic foundation from the 1st and 2nd grade levels of elementary school with the introduction of variable symbols, patterns, and quantitative relationships that are structured and gradual. This approach not only equips students with basic arithmetic skills but also forms an early awareness of abstract concepts that serve as a bridge to formal algebra [5]. On the other hand, the Indonesian curriculum is still more focused on the mastery of numbers and operations within certain limits without a deep integration of the awareness of symbols and patterns. The gap explains the many

challenges faced by Indonesian students in dealing with advanced mathematics learning and the need for curriculum reform that emphasizes the intensive and systematic cultivation of quantitative awareness of symbols and relationships [6], [7]. By referring to the best practices of the Chinese curriculum, Indonesia can develop a more effective mathematics learning model, increase students' readiness for more abstract mathematics topics, and ultimately improve the achievement of national mathematics competencies as well as global competitiveness.

Theoretical foundation, the integration of pre-algebraic thinking in early primary education relies on the Early Algebra Framework, which asserts that arithmetic and algebraic reasoning should be developed concurrently rather than sequentially. However, despite the acknowledged potential of the Chinese curriculum, a critical research gap remains: there is a lack of comparative empirical studies analyzing how specific pedagogical structures of pre-algebra from China can be contextually adapted into the Indonesian curriculum without disregarding local socio-cultural and cognitive readiness contexts. Furthermore, existing literature often treats foreign curriculum success normatively without evaluating its practical applicability in diverse educational environments. To bridge this gap, this study formulates the following research questions: (1) What are the structural and pedagogical differences in introducing pre-algebraic concepts between the lower-grade elementary mathematics curricula of Indonesia and China?; (2) How can the structured elements of the Chinese pre-algebraic approach be contextually adapted to enhance the Indonesian early mathematics curriculum?. Consequently, the objective of this research is to critically compare the pre-algebraic foundations of both curricula and formulate an evidence-based adaptation framework to strengthen Indonesian students' mathematical reasoning and global numeracy competencies.

2. Research Method

This study adopts a qualitative approach utilizing a Comparative Content Analysis method to systematically evaluate the structure, scope, and depth of number and algebra learning materials in Grade 1 and Grade 2 elementary school curricula in Indonesia and China. The primary data sources consist of official curriculum policy documents: the Learning Outcomes (*Capaian Pembelajaran*/CP Phase A) of the Indonesian *Kurikulum Merdeka* and the Primary School Mathematics Curriculum Standards of China (Phase 1, Grades 1–2), focusing specifically on Numbers and Operations as well as Quantitative Relationships. Data collection and extraction are guided by a structured Curriculum Content Analysis Matrix (MACK). The MACK is designed based on the Early Algebra Framework to extract key indicators, including number limits, the introduction of relational and variable symbols, and the cognitive depth of pre-algebraic pattern concepts. Data analysis follows a three-stage comparative technique: (1) Description: Categorizing and mapping the curriculum content of both countries based on the MACK indicators; (2) Systematic Comparison: Juxtaposing corresponding topics to identify structural differences, progression order, and levels of abstraction (aligned with Bloom's/SOLO taxonomy); (3) Synthesis: Integrating comparative findings to formulate contextual curricular recommendations for the Indonesian context. To ensure qualitative rigor and credibility, investigator triangulation and document cross-checking were applied throughout the coding and matrix analysis process can be seen in Table 1.

Table 1. Early Algebra Framework

Early Algebra Dimensions	Analysis Indicator	Evaluation Criteria	Indonesia Curriculum (Phase A)	China Curriculum (Phase 1, Grade 1-2)
Generalized Arithmetic & Number Properties	Number Limits & Operational Properties	Number range limits (e.g., 1–20, 1–100) Explicit or implicit introduction of commutative/associative properties Use of the "=" sign as relational equality vs. operational instruction		
Equality, Relational & Variable Symbols	Understanding of Relational & Variable Symbols	Introduction of variable symbols/blank boxes (e.g., $3 + X = 7$)		

Early Algebra Dimensions	Analysis Indicator	Evaluation Criteria	Indonesia Curriculum (Phase A)	China Curriculum (Phase 1, Grade 1-2)
Functional Thinking & Patterns	Pattern Identification & Quantitative Relationships	Exploration of repeating patterns and growing patterns Ability to determine rules of quantitative relationships Cognitive taxonomy level (Understanding / Application / Reasoning & Problem Solving)		
Cognitive Depth & Abstraction	Level of Cognitive Depth			

3. Results and Discussion

3.1. Analysis of Number and Algebra Data on the Mathematics Curriculum of Chinese Elementary Schools (2022)

Mathematics curriculum content in the field of learning: Numbers and Algebra. Numbers and algebra take the core knowledge and basic ideas of mathematics as the main outline, with content that follows the student's cognitive laws gradually and has a different focus at each stage of learning [8]. The realm of "Integration and Practice" focuses on developing students' ability to comprehensively apply knowledge to solve practical problems [9], [10]. This domain will be based on the characteristics of students at each stage, with cross-disciplinary thematic learning as the main focus, supported by project-based and theme-based learning. By creating real, challenging problem scenarios, students will be guided to integrate mathematical knowledge and methods as well as other disciplines, thereby improving their problem-solving abilities [11]. The content of this learning domain increases spirally based on the requirements of the learning stage objectives, with specific and detailed settings [12]. Numbers and Algebra are important areas in students' compulsory mathematics learning, and at the Elementary School stage, it covers two themes: "Numbers and Operations" and "Quantitative Relationships". The content between stages is interrelated, from superficial to profound, progressive, and spirally increased, forming a relatively systematic structure of knowledge [13].

"Numbers and Operations" includes the recognition of integers, decimals, and fractions, as well as four basic operations. Numbers are an abstraction of quantity. The focus of number operations is on understanding the reason for calculation (算理/suàn lǐ) and mastery of algorithms; numbers and operations are closely related. Students experience the process of forming numbers from quantities, understand and master the concept of numbers; Experience the process of exploring reasons and calculation algorithms, understand the reason for calculation, and master algorithms. They begin to appreciate that numbers are a quantity abstraction, understand the essential consistency of the concept of numbers, and form number sense and symbol awareness; Internalize number operations and the relationships between operations, understand the essential consistency of number operations, and form numeracy skills and reasoning awareness. "Quantitative Relations" is primarily the use of symbols (including numbers) or expressions containing symbols to express relationships or patterns between quantities. Students experience the process of applying quantitative relationships to solve problems in real scenarios, internalize the meaning of addition models and multiplication models, improve the ability to find and propose problems, analyze and solve problems, and form model awareness and initial application awareness. This analysis is divided into 4 stages, namely.

1) Content Requirements: Number and Operation

- In a real scenario, living and understanding the meaning of numbers within the limit of 10,000, understanding the meaning of place values, and knowing that suanpan (abacus) can be used to represent multi-digit numbers.
- Understand the meaning of the symbol $<$, $=$, $>$ and be able to compare the size of numbers within the limit of 10,000; Through the comparison of number sizes, we live the relationship equal to and not equal to.
- In a concrete scenario, understand the meaning of the four basic operations and appreciate the relationships between operations.
- Explore the reasons and algorithms of addition and subtraction, and can do addition and subtraction of integers.

- Explore the reasons and algorithms of multiplication and division, and can perform simple integer multiplication and division.
- In the process of solving life scenario problems, internalizing the meaning of numbers and operations, forming the awareness of initial symbols, number sensitivity, calculating ability, and awareness of initial reasoning.

2) *Content Requirements: Quantitative Relationship*

- In a simple life scenario, applying numbers and number operations to solve problems, can explain the practical meaning of the result, forming the awareness of the initial application.
- Exploring the use of numbers or symbols to express patterns of change in simple scenarios [14].

3) *Academic Requirements: Numbers and Operations*

Cai Jinfa, Jiang Chunlian & Nie Bikai explained that there are academic requirements that must be met in studying number operations [15]. The main requirement is to use numbers to represent the number of objects or sequences of events, to be able to recognize, read, and write numbers within the limit of 10,000; to be able to name the values represented by numbers at different place values; to be able to use symbols to express the relationship of number sizes, to form the sensitivity of numbers and the awareness of the initial symbols. The second requirement is to explain the meaning of the four basic operations, knowing that subtraction is the inverse operation of addition, multiplication is a repetitive (simple) addition operation, and division is the inverse operation of multiplication; can quickly calculate the addition and subtraction of numbers within the limit of 20 and multiplication and division in a table; can quickly calculate the addition and subtraction of simple numbers within the limit of 100; can calculate the addition and subtraction of simple numbers within the limit of 100; can calculate the addition and reduction of two- and three-digit numbers. Forming early numeracy skills [16], [17].

4) *Academic Requirements: Quantitative Relationships*

The academic requirements that must be met are the ability to use numbers and number operations in familiar life scenarios, to reasonably express simple quantitative relationships, and to solve simple problems. In the process of problem solving, living the principles of problem solving, explaining the practical meaning of the calculation results, living the relationship between mathematics and the real world, forming early model awareness, geometric intuition, and application awareness.

3.2. Analysis of Number and Algebra Data in the Mathematics Curriculum for Grades 1 and 2 in Indonesian Elementary Schools (2022)

1) *Content Requirements: Number and Operation*

In the Independent Curriculum, the content requirements are expressed through Learning Outcomes (CP) on the Number element and the Algebraic element in Phase A (generally Grades 1 and 2) [18].

2) *Number Element (Number Focus & Operation)*

At the end of Phase A, learners: (1) Shows understanding and has number sense in numbers up to 100 (in other documents it is mentioned up to 999); (2) Can read, write, determine place values, compare, sort, and compose (arrange) and decompose (decompose) the numbers; (3) It can perform addition and subtraction operations using concrete objects that are up to 20 (in other documents it is mentioned up to 999, by counting and grouping place values); (4) Showing the understanding of fractions as part of the whole through the context of dividing an object or a collection of objects equally. The fractions introduced are half ($\frac{1}{2}$) and quarter ($\frac{1}{4}$).

3) *Content Requirements: Quantitative Relationship*

Content requirements that are equivalent to building quantitative relationship skills in Numbers and Algebra materials in Indonesian Elementary Schools (SD) based on the Learning Outcomes (CP) of the 2022 Independent Curriculum [19]. The content requirements that support the understanding of quantitative relationships focus on the understanding of equivalence, number structures, and patterns as pre-algebraic foundations [20]. As can be seen in Table 2.

Table 2. Content Requirements Relevant to Quantitative Relationships

Element	Content Requirements Relevant to Quantitative Relationships
Number Structure and Equivalence	The focus on number composition and decomposition moves students beyond rote counting, teaching them that numerical quantities can be flexibly represented in multiple forms ($10 = 7 + 3$). This develops early awareness of structural equivalence.
Patterning as Functional Thinking	The inclusion of visual and numerical pattern recognition under the Algebra element builds foundational relational reasoning. It encourages learners to identify underlying mathematical structures before formal algebraic notation is introduced.
Relational Meaning of Equality	Under the Operation element, the curriculum shifts the conceptualization of the equals sign ($=$) from an operational trigger (a signal to compute) to a relational indicator of balance between two sides.

However, unlike the Chinese curriculum which transitions early into explicit variable symbols and higher levels of mathematical abstraction the Indonesian curriculum confines these quantitative relationships to concrete manipulations and simple operational limits in Phase A.

3.3. Academic Requirements: Numbers and Operations

The academic requirements in the 2022 Independent Curriculum (*Kurikulum Merdeka*) establish the expected mastery level for students at the end of Phase A (Grades 1 and 2) [21]. While the curriculum outlines competencies such as number sense (up to 999), place value representation, comparison/sorting, addition/subtraction, and introductory fractions ($1/2$ and $1/4$), a critical analysis reveals specific characteristics regarding depth, abstraction, and concept sequencing: (1) Level of Abstraction and Operational Limits: The Indonesian curriculum maintains a concrete-to-semi-abstract continuum, capping numerical scope at 999 for Phase A. The development of basic operations relies heavily on concrete counting strategies and physical grouping. While effective for grounding early arithmetic, this keeps the abstraction level comparatively low, prioritizing procedural execution over symbolic representation; (2) Concept Development Sequence: The progression follows a linear arithmetic model: moving from counting to reading/writing, comparing, and finally calculating with addition and subtraction. Number composition and decomposition are introduced primarily as strategies for computation rather than as formal structural properties of equality; (3) Implicit Pre-Algebraic Connections: Early algebraic thinking is only implicitly embedded within the "Numbers and Operations" strand. Concepts like inverse relationships (e.g., subtraction as the reverse of addition) or generalized relational properties are not explicitly formalized in Phase A; (4) Comparative Evaluation (Strengths & Limitations): The curriculum provides an accessible, developmentally appropriate framework that solidifies foundational number sense and practical counting strategies using real-world contexts. By focusing heavily on procedural arithmetic within restricted number limits and delaying the explicit introduction of operational structures and symbolic relations, the Indonesian curriculum limits early exposure to high-level abstract reasoning. In comparison to the Chinese curriculum which integrates higher numerical bounds (up to 10,000), abacus based structural place value, and explicit relational models in Grades 1 and 2 the Indonesian framework creates a gentler but less abstract foundation, requiring a steeper conceptual transition in later grades [22].

3.4. Academic Requirements: Quantitative Relationships

At the end of Phase A (Grades 1 and 2), the 2022 Independent Curriculum outlines key expectations regarding patterns, number composition/decomposition, and relational symbols ($>$, $<$, $=$). Evaluating these requirements through the lens of pre-algebraic development highlights several analytical insights: (1) Progression of Pattern Recognition to Functional Thinking: The curriculum introduces pattern identification, imitation, and continuation using concrete visual attributes (shapes, colors, sizes) and simple number sequences. While this establishes initial structural awareness, the depth remains largely descriptive. The framework does not yet explicitly extend pattern identification toward functional relationships (such as input-output rules or functional tables), keeping students' engagement with patterns at an intuitive level; (2) Conceptualization of Equivalence and Structural Relations: Demonstrating that a quantity can be composed and decomposed (e.g., $8 = 5 + 3$) introduces the foundational concept of numerical flexibility and equivalence. However, the Indonesian curriculum treats composition primarily as a strategy for addition/subtraction computation rather than as a

formal study of algebraic equality or variable expressions; (3) Scope and Function of Relational Symbols ($>$, $<$, $=$): Relational symbols are utilized primarily for direct comparisons of scalar numbers up to 999. The equals sign ($=$) begins to be introduced with a relational interpretation (balance between quantities) rather than purely as an operational result trigger. Nevertheless, the complexity remains constrained to simple numeric comparison rather than algebraic equivalence involving unknown terms or expressions (e.g., $a + 3 = 8$); (4) Comparative Reflections (Indonesian vs. Chinese Curriculum): The Indonesian curriculum successfully incorporates gentle, non-threatening entry points into relational thinking using familiar concrete contexts and basic visual patterns. The curriculum exhibits a lower level of abstraction and a limited progression toward symbolic representation. Whereas the Chinese curriculum explicitly integrates variable symbols, generalized quantitative relationships, and mathematical modeling as core tools from Grades 1 and 2, the Indonesian framework keeps quantitative relationships bounded within basic arithmetic comparisons and concrete pattern continuation. This limits early opportunities for students to build formal pre-algebraic reasoning.

3.5. Discussion

The comparative content analysis reveals structural divergence between the primary mathematics curricula of Indonesia (Phase A) and China (Phase 1, Grades 1–2) across two critical domains: Numbers and Operations and Quantitative Relationships. Rather than merely reflecting differing scope or pacing, these disparities represent fundamentally distinct curricular philosophies regarding early mathematical cognition and symbolization.

1) Structural Divergence in Curricular Design and Abstraction

The data demonstrate that the Chinese mathematics curriculum operationalizes a spiral model with early structural abstraction. In Grades 1 and 2, it establishes explicit links between arithmetic operations and generalizable quantitative properties. For instance, while both curricula cover basic addition and subtraction, the Chinese curriculum extends numerical boundaries to 10,000, incorporates multi-digit place value tools (such as the *suanpan*), and introduces relational symbols ($<$, $=$, $>$) alongside algebraic models of multiplication and division early on. This enables students to transition from perceptual counting to conceptual operation, supporting what Radford terms algebraic symbolization the ability to identify and express generality through mathematical notation. The Chinese curriculum emphasizes the explicit introduction of pre-algebraic concepts from the early stages of learning [23], [24]. This is reflected in the cultivation of awareness of symbols and patterns, including the understanding of quantitative relations and the use of variable symbols in simple scenarios [25]. This emphasis allows students to build a strong foundation to move from arithmetic to algebra, which is an essential ability for readiness for more abstract math material at the next level [26].

In contrast, the Indonesian *Kurikulum Merdeka* maintains a concrete to representational focus, capping Phase A numerical limits at 999 and emphasizing procedural computation and contextual grouping. Thus, there is an urgent need to enrich the Indonesian curriculum with materials that instill awareness of symbols and understanding of quantitative relationships as part of early mathematics teaching, as it has been applied systematically and in stages in the Chinese curriculum. While this design aligns with Bruner's enactive-iconic continuum by ensuring developmental accessibility, it defers formal engagement with symbolic relationships and structural patterns. Number decomposition (e.g., $10 = 7 + 3$) is positioned primarily as a flexible strategy for mental computation rather than as a relational expression of structural equality. Consequently, the Indonesian framework prioritizes early fluency and number sense over abstract pre-algebraic modeling.

2) Re-evaluating the Connection to Student Achievement and Assessment (PISA)

While international benchmarks such as PISA repeatedly highlight challenges among Indonesian students in mathematical reasoning, problem solving, and symbolic interpretation [4], [27], directly linking curriculum content to standardized performance requires critical qualification. Learning outcomes are shaped by a complex interplay of systemic factors, including teacher pedagogical content knowledge (PCK), classroom implementation fidelity, socio-economic disparities, and assessment alignment. The learning process in the Chinese curriculum that emphasizes the integration of number concepts and quantitative relationships through thematic and project-based learning also contributes to students' ability to apply mathematics practically and creatively [28], [29]. A spiral approach that allows for gradual deepening of the material as well as the early recognition of patterns and symbols forms a solid

knowledge structure for students. Nevertheless, intended curriculum design sets the upper bound of pedagogical opportunity. When a curriculum delays exposure to relational symbols, variable notation, and pattern generalization, students have fewer opportunities to develop structural reasoning in early childhood. The high performance observed in Chinese educational regions reflects an alignment between high-abstraction intended curricula, targeted teacher professional development, and problem-solving pedagogy. Therefore, while curriculum enrichment is not a sole remedy, incorporating pre-algebraic structures in early grades removes a critical systemic bottleneck in students' long-term mathematical trajectories.

3) Pedagogical Implications for the Indonesian Curriculum

To bridge the transition from arithmetic to formal algebra without overwhelming early learners, the Indonesian curriculum can adopt key structural insights from the Chinese model: (1) Explicit Pre-Algebraic Integration: Transitioning pattern tasks from visual descriptions to functional relationships (e.g., identifying underlying input-output rules); (2) Relational Understanding of Equivalence: Re-framing the equals sign (=) as a relational balance symbol rather than an operational trigger for computation; (3) Structured Concrete-to-Abstract Tools: Incorporating structured tools like the abacus alongside physical manipulatives to strengthen multi-digit place value understanding.

4) Limitations of the Study

This research focuses exclusively on the intended curriculum as articulated in official policy documents (Indonesia's *Capaian Pembelajaran* and China's Primary School Mathematics Curriculum Standards). It does not evaluate the implemented curriculum within actual classrooms or the achieved curriculum measured through direct student testing. Variations in textbook design, teacher instructional strategies, and regional implementation were outside the scope of this document analysis. Future empirical research should combine content analysis with classroom observations and longitudinal student assessments to measure the direct effect of pre-algebraic instructional tasks on student learning gains.

4. Conclusion

This study conducted a comparative content analysis of the depth, abstraction level, and conceptual structure of number and algebra materials in Grades 1 and 2 curricula of Indonesia (*Kurikulum Merdeka*, Phase A) and China (2022 Curriculum Standards). The document analysis demonstrates that the Chinese curriculum integrates pre-algebraic concepts earlier, more systematically, and with higher abstraction by explicitly embedding relational symbols, generalized pattern modeling, multi-digit place value structures (using the abacus), and functional relationships. In contrast, the Indonesian curriculum emphasizes foundational arithmetic fluency, concrete grouping, and basic pattern continuation up to a lower numerical limit (999), deferring explicit symbolic abstraction. The main scientific contribution of this research lies in providing a detailed comparative matrix and structural analysis that maps how pre-algebraic foundations are configured in early primary education across two distinct national frameworks. By delineating the gap between procedural arithmetic focus and explicit symbolic reasoning, this study offers evidence-based insights for curriculum designers aiming to strengthen early mathematical cognition. Based on these document-derived findings, this study recommends strengthening the pre-algebraic dimension in the Indonesian elementary curriculum for Phase A. Specifically, curriculum frameworks should transition pattern tasks toward functional rules, introduce the equals sign (=) with an explicit relational balance focus, and incorporate structured concrete models to support place value understanding. Limitations: This study analyzed exclusively official, intended curriculum standards and outcomes documents. It did not empirically measure classroom implementation, teacher pedagogical execution, or actual student learning achievements. Future research should investigate how these curricular differences manifest in instructional delivery and empirically measure their impact on students' long-term pre-algebraic competence.

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