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CURRICULUM COGNITIVE LOAD DYNAMICS IN GRADE VIII MATHEMATICS TEXTBOOKS: A CROSS-ANALYSIS OF HOTS, NUMERICAL CONTEXT, AND TASK FUNCTIONALITY

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ABSTRACT

Modern educational reforms demand textbook tasks to optimize cognitive loads while cultivating 21st-century competencies, specifically Higher Order Thinking Skills (HOTS) and contextual numeracy literacy. This study examines the curricular integration of mathematical tasks within a newly adapted Grade VIII textbook, evaluating the instructional architecture across three functional task categories: exploratory Problems, structural Exercises, and summative Competency Tests. Utilizing a quantitative-qualitative content analysis methodology, a comprehensive dataset of 99 tasks spanning four core curricular units (Three-Dimensional Geometry, Statistics, Probability, and Congruence & Similarity) was coded using the Revised Bloom's Taxonomy and PISA-aligned numeracy frameworks. The results reveal a highly dense cognitive architecture, with C4 (Analyzing) serving as the primary curricular anchor (48.5%). Numeracy mapping shows severe structural skewness, with Scientific contexts dominating at 61.6% while Occupational contexts remain critically marginalized (5.1%). Crucially, a significant cross-tabulation anomaly was discovered: exploratory "Problems" carry the heaviest cognitive load, with 45.2% coded as C5 (Evaluating) and 6.5% as C6 (Creating), vastly outperforming the final "Competency Tests" which compress demand toward mid-tier standardization (57.5% C4). This reveals a non-linear curricular design matching inquiry-driven instructional dynamics rather than traditional linear testing. Implications for textbook publishers and pedagogical sequencing under contemporary inquiry-based curricula are discussed.

Keywords: Curriculum Dynamics, Cognitive Load, Mathematics Textbooks, HOTS, Numerical Context, Task Typology.

1 INTRODUCTION

In the wake of global educational standardizations, the structure of mathematics curriculum frameworks has undergone a paradigm shift from rote execution of procedural operations toward the fluid application of Higher Order Thinking Skills (HOTS) and robust mathematical literacy. Globally, contemporary educational mandates increasingly prioritize the cultivation of mathematical competence rooted in realistic problem-solving and critical reasoning over traditional rote learning. This systemic shift is particularly evident in transitional education systems within developing nations, which have launched large-scale curricular overhauls—such as Indonesia's recent transition to a competency-based curriculum—to foster 21st-century literacies (Sujadi et al., 2021). Instructional materials, particularly textbooks, serve as the primary vehicle for enacting these curricular ideals in daily classroom environments (Suryawan & Sa'dijah, 2020). Consequently, analyzing the structural composition of text-bound mathematical tasks is vital to understand the true cognitive load experienced by students.

A prevalent challenge in textbook development is maintaining a balanced distribution of cognitive demands and real-world contexts that prevent insular learning (Wijaya et al., 2015). Consequently, textbook tasks must align with international baseline metrics like PISA, which favor multi-layered situational analysis over plain algorithmic calculations. This international benchmarking heavily influences national evaluation schemes in emerging economies, where localized minimum competency assessments are being restructured to mirror global literacy frameworks (Prabawati & Herman, 2022). Furthermore, a modern math curriculum dictates that mathematical modeling should be contextualized within rich scenarios—ranging from intimate personal spaces to broader social and scientific dimensions (Purnomo et al., 2023). Despite these systemic requirements, empirical work frequently highlights that textbooks are often structurally misaligned with macro-curricular policies, defaulting instead to isolated, low-level procedural mechanical drills (Retnawati et al., 2018).

To conceptualize task-based cognitive load, this study integrates Sweller's (2010) Cognitive Load Theory with Stein et al.'s (2000) Task Framework on cognitive demand. While cognitive load theory addresses how instructional design impacts working memory capacity, the task framework categorizes mathematical tasks into low-level procedural drills versus high-level dynamic reasoning. Recent mathematics curriculum research emphasizes that textbooks act as the primary "potentially implemented curriculum" (Fan et al., 2013; Pepin et al., 2017). However, existing literature predominantly treats task difficulty as a static, linear progression from basic exercises to review tests (Maher & Siswono, 2022). A critical gap remains in understanding how cognitive demands fluctuate across functional task typologies within inquiry-based curriculum frameworks, particularly in how real-world numeracy contexts are integrated to scaffold high-tier mathematical processing.

Despite global mandates pushing for Higher Order Thinking Skills (HOTS) and contextual literacy, textbook design frequently suffers from "curricular misalignment"—where instructional tasks fail to operationalize macro-level reform goals. Grade VIII represents a pivotal transitional phase in secondary mathematics, where abstract algebraic and spatial reasoning are introduced alongside complex quantitative literacy. The recent implementation of Indonesia's Kurikulum Merdeka serves as an ideal critical case study representing transitional educational systems in the Global South. It provides a unique analytical lens to evaluate how modern competency-based policy translates into micro-level instructional materials.

To address this gap, this study answers three central Research Questions (RQs):

- RQ1: How are cognitive demands (HOTS) and numerical literacy contexts distributed across the Grade VIII mathematics textbook?
- RQ2: How do cognitive complexity and literacy contexts vary across specific mathematical content domains?
- RQ3: How does cognitive load vary across functional task typologies (introductory Problems, Exercises, and Competency Tests), and does it follow a linear or non-linear pedagogical sequence?

2 METHODOLOGY

2.1 Data Corpus and Sampling Strategy

This study employed a quantitative-qualitative content analysis design (Krippendorff, 2018). The sample comprised all N = 99 structured task items embedded within the latest standardized Grade VIII Mathematics Textbook (Ministry of Education, Culture, Research, and Technology, 2022). Tasks were selected across four core mathematical content domains: (1) Three-Dimensional Geometry (n = 32), (2) Statistics (n = 20), (3) Probability (n = 20), and (4) Congruence & Similarity (n = 27).

2.2 Analytical Frameworks and Coding Protocol

Each task unit (defined as an independent sub-question requiring a distinct mathematical response) was coded across three discrete analytical dimensions:

- **Cognitive Demand (HOTS Alignment):** Evaluated using the Revised Bloom's Taxonomy (Anderson & Krathwohl, 2001), classified into C2 (Understanding), C3 (Applying), C4 (Analyzing), C5 (Evaluating), and C6 (Creating).
- **Numerical Context:** Categorized using PISA 2022 framework criteria into four real-world settings: Personal, Scientific (purely intra-mathematical or natural science), Occupational (workplace-related), and Social (community issues).
- **Functional Task Typology:** Classified based on structural positioning in the learning cycle: *Problems* (introductory exploratory tasks), *Exercises* (sub-chapter reinforcement), and *Competency Tests* (end-of-chapter summative reviews).

2.3 Coding Reliability and Data Analytics

Coding was performed independently by two experts in mathematics education using a double-blind protocol. To establish inter-rater reliability, a randomly selected subset of 25% (n = 25) of the tasks was evaluated prior to full dataset coding. Cohen's Kappa (κ) was computed, yielding $\kappa = 0.86$ for Cognitive Levels and $\kappa = 0.89$ for Numerical Contexts, indicating high inter-rater agreement. Discrepancies were resolved through consensus moderation. Data were processed using Python's Pandas package to execute cross-tabulations and chi-square independence tests across functional typologies.

3 RESULTS AND DISCUSSION

3.1 Macro-Curricular Mapping of Cognitive Demand and Numerical Literacy Contexts

The initial macro-analysis of the 99 items isolates the total baseline delivery of both cognitive indicators and contextual scenarios across the whole textbook, as documented in Table 1.

Table 1: Curricular Profile of Cognitive Levels (HOTS) and Numerical Contexts (N = 99)

Analytical Dimension	Curricular Indicator Category	Frequency (f)	Percentage (%)
Cognitive Level (HOTS Alignment)	C2 (Understanding)	1	1.0%
	C3 (Applying)	26	26.3%
	C4 (Analyzing)	48	48.5%
	C5 (Evaluating)	22	22.2%
	C6 (Creating)	2	2.0%
Numerical Literacy Context	Personal	12	12.1%
	Scientific (Intra-mathematical / Science)	61	61.6%
	Occupational (Workplace/Professional)	5	5.1%
	Social (Community/Societal)	21	21.2%

The macro-metrics in Table 1 indicate that the textbook possesses an advanced academic profile, with high-tier analytical processing representing a combined 72.7% of the material (C4 through C6 indicators). Level C4 (Analyzing) establishes itself as the primary cognitive driver of the textbook, capturing 48.5% of total items. Conversely, genuine open-ended creative formulation at the C6 level is rare (2.0%). This reflects a curriculum that successfully avoids low-level rote repetition but exhibits limitations in providing open, student-led mathematical construction (Wardhani & Kusuma, 2021).

In terms of numerical literacy, the analysis reveals a significant structural imbalance (skewness). Purely academic, technical, or intra-mathematical contexts (Scientific) govern 61.6% of the problem environments. In sharp contrast, workplace-related contexts (Occupational) are severely underrepresented at only 5.1%. This represents a notable curricular gap; while the textbook prepares students well for abstract mathematical reasoning, it offers limited

opportunities to see the practical utility of mathematics in vocational and professional careers—a core tenet of modern literacy-oriented educational reforms (Zulkardi & Kohar, 2019). This baseline distribution of both cognitive tasks and contextual environments across the textbook is visually conceptualized in Figure 1.

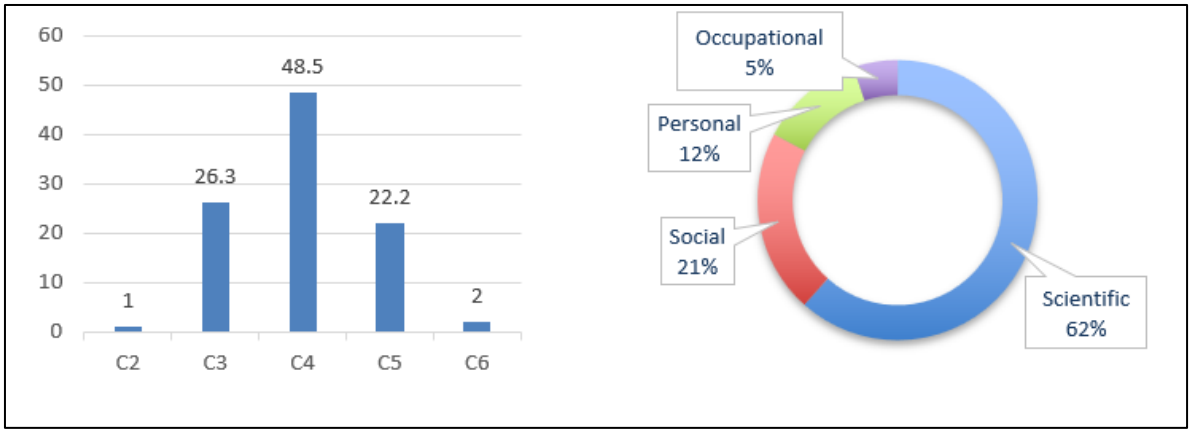

Figure 1: Macro Distribution of Cognitive Demands (HOTS) and Numerical Literacy Contexts.

3.2 Intra-Curricular Variations Across Core Mathematical Units

The distribution of cognitive load and contextual backgrounds varies significantly across individual subject modules. Table 2 details the cross-tabulation across the four discrete chapters.

Table 2: Cross-Tabulation of Cognitive Levels and Literacy Contexts by Curricular Chapter

Curricular Content Units	C2	C3	C4	C5	C6	Pers.	Sci.	Occ.	Soc.
Three-Dimensional Geometry	1	3	24	4	0	2	28	1	1
Statistics	0	7	8	3	2	3	6	2	9
Probability	0	10	10	0	0	6	6	2	6
Congruence & Similarity	0	6	6	15	0	1	21	0	5

The data in Table 2 reveal how different mathematical topics are assigned specific pedagogical roles within the curriculum. The Three-Dimensional Geometry unit focuses heavily on standard spatial-procedural analysis, anchoring its 24 C4-level tasks within 28 abstract Scientific settings. Conversely, the Statistics module serves as the primary real-world application hub, containing the highest concentration of community-based problems (9 Social tasks) and hosting both of the textbook's advanced C6 (Creating) problems through data representation tasks (Pratama & Harun, 2021).

3.3 Task Functionality Analysis: Deconstructing the Cognitive Load Anomaly

The most compelling finding relates to how cognitive demand is distributed across the instructional sequence of tasks, as classified by their functional positioning within the learning cycle (Table 3).

Table 3: Proportional Distribution of Cognitive Levels Across Task Typologies

Functional Task Typology	C2 (%)	C3 (%)	C4 (%)	C5 (%)	C6 (%)	Total Items
Problem (Exploratory Challenges)	3.2%	9.7%	35.5%	45.2%	6.5%	31 units
Exercise (Sub-Chapter Reinforcement)	0.0%	32.1%	50.0%	17.9%	0.0%	28 units
Competency Test (Summative Review)	0.0%	35.0%	57.5%	7.5%	0.0%	40 units

A Chi-Square test of independence confirmed that the distribution of cognitive levels significantly differed across functional task typologies ($\chi^2(8, N = 99) = 24.61, p = .002$), demonstrating that the heavy concentration of higher-order demands within exploratory Problems is statistically significant rather than a random artifact of task selection.

Traditional instructional models typically assume that cognitive difficulty escalates linearly, peaking at the final assessment stage (*Competency Test*). However, the empirical data in Table 3 reveals a striking curricular anomaly. The highest cognitive demands are concentrated at the beginning of the learning sequence within the introductory *Problem* blocks, which feature intense high-tier demands: 45.2% at C5 (Evaluating) and 6.5% at C6 (Creating) (Sweller, 2010).

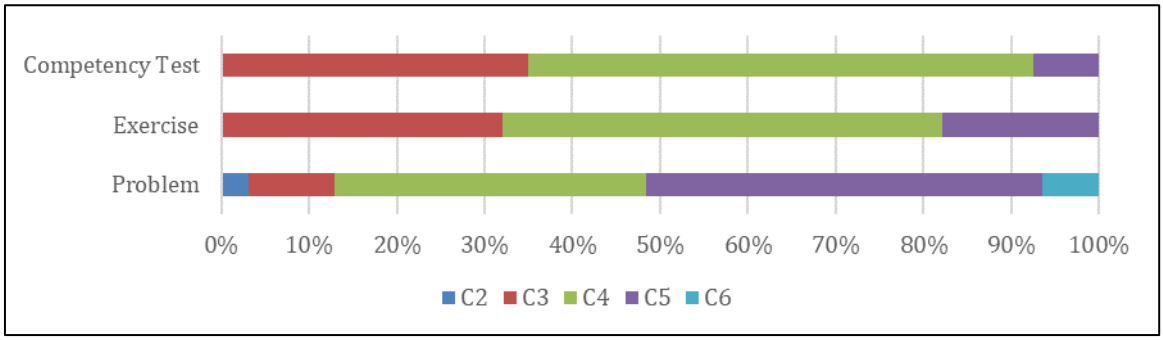

Figure 2: Task Functionality Analysis

This non-linear cognitive distribution is clearly illustrated in Figure 2, which highlights the structural anomaly where exploratory *Problems* paradoxically demand higher-tier evaluation (C5) and creation (C6) skills compared to the standardized summative review. This structural pattern reflects an intentional paradigm shift toward inquiry-driven, guided-discovery instructional frameworks, which underpins modern global educational standards and is exemplified by Indonesia's contemporary curriculum design. Within this model, introductory *Problems* function as catalysts for cognitive conflict. They are deliberately designed with high cognitive loads to disrupt naive mental models, spark peer discourse, and encourage deep exploration under teacher guidance (Nirmala & Rosmawati, 2023).

4 CONCLUSION

This content analysis of 99 mathematical tasks across a Grade VIII textbook highlights two primary conclusions. First, the material demonstrates alignment with modern 21st-century educational frameworks, featuring a combined HOTS representation of 72.7%. Second, the instructional design utilizes a non-linear approach to cognitive load management within introductory Problems, while using end-of-chapter *Competency Tests* as standardized instruments focused on steady analytical execution (C4).

Recommendations

Based on these findings, two primary recommendations are proposed. First, textbook publishers and curriculum designers must address the severe contextual skewness by intentionally integrating more 'Occupational' and 'Personal' scenarios, ensuring mathematics is not perceived as a purely abstract, scientific endeavor. Second, pedagogical sequencing should leverage the discovered cognitive anomaly; teachers must be professionally trained to scaffold the high cognitive loads (C5–C6) embedded within introductory *Problems* rather than defaulting to traditional linear mechanics, thereby maximizing the potential of inquiry-driven curricula.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Disclosure of conflict of interest

The authors have no competing interests to declare that are relevant to the content of this article.

Availability of data and material

The datasets analyzed during the current study (textbook task coding sheet) are available from the corresponding author on reasonable request.

Authors' contributions

Ade Nandang Mustafa was responsible for conceptualization, methodology, software (data analytics using Python), formal analysis (primary textbook coding and cross-tabulation), investigation, data curation, and writing the original

draft. Dinar Nirmalasari contributed to formal analysis (deepening and theoretical refinement), supervision, validation, and writing (review & editing).

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