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IDENTIFYING MISCONCEPTIONS AND OVERCONFIDENCE IN FIFTH-GRADE NUMERACY: A FOUNDATION FOR DEVELOPING SMART POP-UP BOOKS BASED ON A DEEP LEARNING PEDAGOGY

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ABSTRACT

Although numeracy is a foundational skill in primary education, young learners often grapple with conceptual hurdles that are further complicated by overconfidence. This research seeks to uncover the interplay between numeracy misconceptions and overconfidence among fifth-grade students. These diagnostic insights serve as the empirical groundwork for designing a Smart Pop-up Book, driven by a deep learning pedagogical framework (*Mindful, Meaningful*, and *Joyful*). Through a quantitative descriptive approach, data were gathered from 60 students using a three-tier diagnostic test. The findings highlighted a striking metacognitive gap: 66.7% of students who provided incorrect answers demonstrated high levels of unwarranted confidence. Furthermore, genuine misconceptions accounted for the most prevalent cognitive error (32%), particularly concerning place value and sequential arithmetic operations. Rather than merely reporting errors, these findings directly inform the developmental blueprint of the learning media. By embedding deep learning principles, the proposed Smart Pop-up Book actively responds to the students' specific needs. It promotes *Mindful* reflection to recalibrate student confidence, integrates *Meaningful* contexts through 3D visualizations of local wisdom, and fosters *Joyful* engagement via digital gamification. Ultimately, this study underscores that a thorough, data-driven diagnosis of students' cognitive and metacognitive struggles is an essential prerequisite for developing empathetic and adaptive educational tools.

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INTRODUCTION

Numeracy is a fundamental competence in primary education, essential for developing the logical, analytical, and problem-solving reasoning required for informed decision-making in real-world contexts (Kemdikbudristek, 2022;

Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
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UNESCO, 2014). Numeracy extends beyond basic arithmetic skills; it encompasses the capacity to comprehend quantitative information, interpret data across various formats—such as tables, graphs, and diagrams—and apply mathematical concepts in real-world scenarios to facilitate informed decision-making (OECD, 2023). Within the 21st-century education framework, mastering numeracy transcends basic arithmetic; it demands the capacity to interpret quantitative data across various formats and apply mathematical concepts to complex contextual problems.

Unfortunately, global assessments such as the Programme for International Student Assessment (PISA, 2023) indicate that the mathematical proficiency of Indonesian students remains significantly below the OECD average. Only 18% of Indonesian students attained the minimum proficiency level (Level 2), compared to the OECD average of 69% (OECD, 2023). This decline highlights persistent challenges in grasping mathematical concepts that require multistep reasoning.

This macro-level deficiency is acutely reflected at the local level. Based on the 2024 and 2025 Education Profile (*Rapor Pendidikan*) for the Gandusari Subdistrict, Trenggalek Regency, numeracy proficiency underwent a 20% decrease within a single year. Currently, only 20% of students demonstrate the reasoning capacity to solve complex problems based on their mathematical knowledge. Furthermore, 60% of students can only apply basic concepts within limited contexts, while the remaining 20% possess only rudimentary computational skills (Kemdikbudristek, 2022). This local data confirms that student numeracy remains substandard and necessitates systematic pedagogical intervention.

Preliminary observations and interviews with fifth-grade teachers across three school clusters in Gandusari identified several contributing factors: (1) teacher-centric instructional methods; (2) limited use of innovative, digital-based learning media; (3) reliance on conventional whiteboards and textbooks; (4) infrequent exposure to extensive narrative tasks typical of the Minimum Competency Assessment (AKM); and (5) a lack of open-ended tasks necessary to stimulate critical thinking.

At the primary school level, these numeracy challenges often transcend procedural errors and evolve into entrenched conceptual misconceptions, cognitive structures that deviate from scientific accuracy yet are strongly believed to be true by the student (Ekowati et al., 2019; Rahayuningsih et al., 2025).

This issue is exacerbated when accompanied by *overconfidence*, a metacognitive discrepancy where students display high certainty in their incorrect answers. Diagnostic research suggests that overconfident students find conceptual restructuring significantly more challenging because they are completely unaware of their cognitive illusions (Yang, 2019, 2020).

To accurately capture this phenomenon, a diagnostic instrument must move beyond binary scoring to examine reasoning processes and confidence levels simultaneously. A three-tier diagnostic test effectively maps conceptual understanding across three layers: the answer (tier 1), the underlying reason (tier 2), and the confidence level (tier 3) (Peşman & Eryilmaz, 2010), thereby distinguishing between genuine understanding, deep-rooted misconceptions, and mere guesswork.

While diagnostic tools can map cognitive errors, these findings must logically dictate the design of corrective learning media. The "Smart Pop-up Book," characterized by interactive, three-dimensional visuals, aligns perfectly with the concrete operational stage of primary students (Harris Taylor & Larson Bluemel, 2003; Piaget, 1964; Whitney et al., 2011; Wulandari, 2022).

However, a critical research gap remains: most previous studies on pop-up books have focused exclusively on reading literacy, leaving mathematics and numeracy underexplored. Furthermore, existing mathematical pop-up media tend to be static and are rarely designed based on prior metacognitive diagnoses. Little to no literature discusses how the specific profiling of student overconfidence and misconceptions can directly inform the structural design of a learning medium.

To bridge this gap, this study integrates diagnostic findings with a Deep Learning pedagogy. Deep learning explicitly demands a shift from rote memorization toward a mindful (reflective), meaningful (conceptually connected), and joyful learning experience (Kemendikdasmen, 2025; Puskurjar, 2025). The novelty of this research lies in its empirical progression: it does not merely diagnose cognitive errors but utilizes the specific profiles of misconceptions and overconfidence as the foundational blueprint for developing an adaptive, Deep Learning-based Smart Pop-up Book.

Based on this background, the study aims to: (1) identify the profiles of whole-number numeracy misconceptions among fifth-grade students; (2) analyze their levels of overconfidence; and (3) formulate evidence-based recommendations

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Volume 15 No. 4 Desember 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

for developing a Deep Learning-driven Smart Pop-up Book that specifically targets these cognitive and metacognitive barriers.

METHOD

This study employs a quantitative descriptive approach aimed at identifying misconceptions and overconfidence levels among fifth-grade elementary school students in solving numeracy tasks. A descriptive approach was selected as this research focuses on the systematic mapping of students' conceptual states through diagnostic assessments without providing experimental treatments. According to (Creswell, 2012), quantitative descriptive research is utilized to objectively describe educational phenomena through the numerical measurement of observed variables.

The research was conducted in January 2026 at two elementary schools in East Java Province: SDN 1 Ngrayung in Trenggalek Regency and SD Brawijaya Smart School in Malang City. Both schools were purposively selected to represent different institutional characteristics (state and private) within the Gandusari Subdistrict, which exhibits similar numeracy proficiency issues according to the 2024–2025 Education Profile (*Rapor Pendidikan*).

The research subjects comprised 60 fifth-grade students (aged 10–11 years), consisting of 32 male students (53.3%) and 28 female students (46.7%). Subject selection utilized purposive sampling based on the following criteria: (1) students had completed basic numeracy material (whole numbers, place value, arithmetic operations, and simple problem solving) as per the Phase C learning objectives of the Merdeka Curriculum; (2) students were willing to participate with parental consent; and (3) students were present during data collection. The selection of fifth-graders was also informed by Piaget's (1964) theory of concrete operational cognitive development, noting that students at this stage begin to understand logical relationships between concepts but still require concrete visual aids to construct numerical abstractions.

The primary instrument used in this study is a 10-item three-tier diagnostic numeracy test. The three-tier format was selected for its ability to identify conceptual understanding more accurately than conventional multiple-choice tests. Each item consists of three tiers:

1. Tier 1 (Content): A multiple-choice question with four options (A, B, C, D) to measure numeracy concept mastery. Scored 1 for correct and 0 for incorrect responses.
2. Tier 2 (Reasoning): A multiple-choice question providing four preset reasons to evaluate students' critical thinking and reasoning abilities. Scored 1 for correct and 0 for incorrect responses.
3. Tier 3 (Confidence): A three-point Likert scale (1 = Not Confident, 2 = Confident, 3 = Very Confident) to measure the student's level of certainty regarding their selected answers.

This simplified three-point scale was deliberately chosen over the more complex, widely used Certainty of Response Index (CRI) (Hasan et al., 1999) to suit the cognitive development of 10- to 11-year-old students. A standard 6-point CRI often causes cognitive overload in primary school students during self-assessment. While the 3-point scale lacks the fine-grained granularity of the CRI, it provides a highly operational and age-appropriate distinction between doubt, standard confidence, and overconfidence (Peşman & Eryilmaz, 2010).

The numeracy content tested adheres to basic elementary school numeracy indicators aligned with the Minimum Competency Assessment (AKM) levels 2 and 3, focusing on number sense, arithmetic operations, data interpretation, and contextual problem-solving (Kemdikbud, 2020). The numeracy indicators used in this study are presented in Table 1.

Table 1. Numeracy Indicators in the Diagnostic Instrument

No	Numeracy Indicator	Competency Description	Item Number
1	Understanding place value	Determining the position of digits within a number according to place value (hundreds, thousands, ten-thousands, etc.)	1, 2
2	Applying basic arithmetic operations	Solving addition, subtraction, multiplication, and division of whole numbers	3, 4, 5
3	Interpreting numerical data	Reading numerical information in the form of tables or images and comparing values	6, 7

Sosioedukasi
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Volume 15 No. 4 Desember 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

No	Numeracy Indicator	Competency Description	Item Number
4	Solving contextual problems	Connecting number concepts with daily situations (word problems)	8, 9
5	Drawing numerical conclusions	Making decisions based on relationships between numbers and number patterns	10

Source: Adapted from Kemdikbud (2020)

The content validity of the instrument was evaluated by two mathematics education experts from the Universitas Negeri Malang. The assessment results yielded an average Content Validity Index (CVI) of 0.89, categorized as highly valid. The instrument's reliability was tested using Cronbach's Alpha with a non-participant sample of 20 students, resulting in $\alpha = 0.82$ for Tier 1, $\alpha = 0.79$ for Tier 2, and $\alpha = 0.85$ for Tier 3.

Data were collected using a Google Form-based digital assessment in a closely supervised classroom setting. Students completed the items independently within 60 minutes after receiving clear instructions on the three-tier responding method.

Data analysis was conducted in several stages using Microsoft Excel to allow for manual verification of each data point. To ensure precision, data analysis was conducted systematically in three operational stages. Stage 1: Scoring and Proficiency Categorization. Students' final numeracy scores were calculated based on the cumulative correct responses from Tier 1 and Tier 2. The scores were then grouped into three proficiency levels (High, Moderate, Low). Stage 2: Cross-Tabulation of Conceptual Profiles (Three-Tier Analysis). A matrix analysis was performed for each student's response per item. By cross-referencing the accuracy of Tier 1, the alignment of Tier 2, and the confidence level in Tier 3, each response was operationalized into a specific conceptual category (e.g., Misconception, Overconfidence, Lucky Guess) as outlined in Table 2 (Peşman & Eryilmaz, 2010). Stage 3. Prevalence Calculation. The percentage of each conceptual category was calculated using the standard formula $P = \frac{f}{N} \times 100\%$ where P is the percentage, f is the frequency of a specific conceptual category, and N is the total number of students (60). This stage specifically isolated the frequency of misconceptions and overconfidence to serve as the baseline data for media development.

Table 2. Student Response Classification Criteria

Answer (Tier 1)	Reason (Tier 2)	Confidence (Tier 3)	Category	Interpretation
Correct	Correct	Confident/Very Confident	Sound Understanding	The student understands the concept correctly and provides logical reasoning.
Incorrect	Incorrect	Confident	Misconception	The student possesses a deep-rooted incorrect understanding and is unaware of the error.
Incorrect	Incorrect	Not Confident	Lack of Knowledge	The student does not understand the concept and is aware of their lack of understanding.
Incorrect	Incorrect	Very Confident	Overconfidence	The student has very high confidence in an incorrect answer.
Correct	Incorrect	Confident/Very Confident	Lucky Guess	The student answered correctly but does not understand the reasoning (guessing).
Incorrect	Correct	Confident	Careless Error	The student made a computational error despite having correct reasoning.

Source: Modified from (Peşman & Eryilmaz, 2010)

To facilitate the interpretation of numeracy proficiency levels, scores were grouped into three categories based on the score ranges suggested by (Ekowati et al., 2019) as shown in Table 3.

Table 3. Numeracy Proficiency Level Categories

Category	Score Range
High	≥80

Sosioedukasi
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Volume 15 No. 4 Desember 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

Moderate	60 – 79
Low	<60

Source: Ekowati et al. (2019)

The categorization in Table 3 utilizes a criterion-referenced evaluation framework established by Ekowati et al. (2019). This specific range was adopted because it provides a clear, operational threshold commonly used in the Indonesian primary education assessment system to differentiate between students who have mastered the material (High), those who are developing competence (Moderate), and those who require immediate pedagogical intervention (Low).

Within the context of Research and Development (R&D), this diagnostic analysis serves as a rigorous conceptual needs assessment. According to the (Lee & Owens, 2004) developmental model, a needs assessment is the crucial initial stage that dictates the relevance of an instructional product. Consequently, the isolated data regarding students' specific misconceptions and overconfidence levels act as the empirical foundation for designing the adaptive, deep-learning characteristics of the Smart Pop-up Book.

RESULT AND DISCUSSION

Categorization of Student Numeracy Proficiency Levels

Based on the criteria established in Table 3, student numeracy scores were classified into three categories: high, moderate, and low. The distribution is presented in Table 4.

Table 4. Distribution of Students by Numeracy Proficiency Category

Category	Score range	Number of students	Percentage
High	≥80	12	20%
Moderate	60 – 79	38	63.3%
Low	<60	10	16.7%
Total		60	100%

Source: Researcher's Processed Data, 2026

The data shows that 63.3% of students fall into the moderate category, 20% in the high category, and 16.7% in the low category. These findings indicate that the majority of students possess suboptimal numeracy skills and require further conceptual reinforcement. Only one-fifth of the participants reached the high category, while nearly one-third (including those in the low category) require serious pedagogical intervention.

Descriptive Statistics of Numeracy Scores

The descriptive statistics derived from the three-tier diagnostic test are summarized in Table 5.

Table 5. Descriptive Statistics of Student Numeracy Scores

Statistical Measure	Value
Number of Students (N)	60
Maximum Score	100
Minimum Score	40
Mean	67.33
Median	67.50
Mode	70
Standar Deviation	14.25

Source: Researcher's Processed Data, 2026

The average numeracy score of 67.33 (on a 0–100 scale) falls within the moderate category. Only two students (3.3%) achieved a perfect score, while 16.7% scored below 50. A standard deviation of 14.25 indicates a wide dispersion of abilities among students. These results suggest that most students have not mastered numeracy concepts deeply, particularly those involving multistep reasoning and place value. This condition aligns with PISA 2022 reports stating that only 18% of

Sosioedukasi
JURNAL ILMIAH ILMU PENDIDIKAN DAN SOSIAL
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Volume 15 No. 4 Desember 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

Indonesian students achieve minimum proficiency in mathematics (OECD, 2023) and mirrors the 20% decline in numeracy reported in the Trenggalek Education Profile (Kemdikbudristek, 2022).

Distribution of Student Confidence Levels

Student confidence levels, recorded in Tier 3, are presented in Table 6.

Table 6. Distribution of Student Confidence Levels (N=60)

Confidence Level	Number of Students	Percentage
Very Confident	33	55%
Confident	10	16.7%
Not Confident	17	28.3%

Source: Researcher's Processed Data, 2026

A total of 71.7% of students expressed confidence or high confidence in their answers. This high subjective competence suggests that students perceive themselves as capable; however, high confidence does not always correlate with accuracy. This phenomenon warrants further analysis of the "calibration" between confidence and actual performance, consistent with (Fahsyah Nurzaman et al., 2021) who noted that primary students often exhibit high confidence despite suboptimal academic performance.

Cross-tabulation of Confidence and Accuracy (Overconfidence)

To evaluate calibration accuracy, a cross-tabulation was performed between Tier 3 (Confidence) and Tier 1 (Answer Accuracy) for the first item. The results are shown in Table 7.

Table 7. Cross-tabulation of Confidence and Accuracy

Answer Accuracy	Confidence Level	Number of Students	Percentage within Group
Correct (n=54)	Very Confident	29	53.7%
Correct (n=54)	Confident	9	16.7%
Correct (n=54)	Not Confident	16	29.6%
Incorrect (n=6)	Very Confident	4	66.7%
Incorrect (n=6)	Confident	1	16.7%
Incorrect (n=6)	Not Confident	1	16.7%

Source: Researcher's Processed Data, 2026

The primary finding from Table 7 is that among students who answered incorrectly, 66.7% were "Very Confident" in their wrong choice, indicating significant overconfidence. Conversely, 29.6% of students who answered correctly were "Not Confident," a state known as under confidencee. These findings support the research of Koriat & Ackerman (2022), suggesting that elementary students often lack effective calibration skills. Overconfidence acts as a barrier to learning because students who are certain of their misconceptions are less likely to revise their knowledge.

Conceptual Classification Based on the Three-Tier Test

Analyzing patterns across all three tiers for the 10 items yielded the conceptual classifications presented in Table 8.

Table 8. Distribution of Student Conceptual Categories

Category	Percentage	Interpretation
Sound Understanding	28%	Correct answer, correct reason, and confident.
Misconception	32%	Incorrect answer, incorrect reason, but confident.
Lack of Knowledge	18%	Incorrect answer, incorrect reason, and not confident.
Overconfidence	15%	Incorrect answer, incorrect reason, but very confident.
Lucky Guess	5%	Correct answer but incorrect reason, with high confidence.
Careless Error	2%	Incorrect answer but correct reasoning, with confidence.

Sosioedukasi
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Volume 15 No. 4 Desember 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

Source: Researcher's Processed Data, 2026

Misconception was the most dominant category (32%). Combined with the Overconfidence category (15%), nearly half of the students (47%) exhibited high confidence in erroneous understandings. This suggests a lack of metacognitive awareness. Only 28% of students demonstrated a "Sound Understanding."

Misconception Patterns per Numeracy Indicator

An analysis of misconceptions per indicator (from Table 1) is presented in Table 9.

Table 9. Misconception Percentage per Numeracy Indicator

Numeracy Indicator	Misconception %	Example of Error
Understanding place value	42%	Viewing '4' in 645,372 as "tens" (40) rather than "ten-thousands" (40,000).
Basic arithmetic operations	35%	Incorrect order of operations in sequential subtraction.
Solving contextual problems	35%	Misinterpreting word problems; focusing on numbers without context.
Interpreting numerical data	28%	Difficulty comparing values within tables or graphs.
Drawing numerical conclusions	25%	Errors in identifying number patterns or relationships.

Source: Researcher's Processed Data, 2026

The highest misconception occurred in "Understanding place value" (42%). This exceptionally high prevalence reveals a critical flaw in how foundational mathematics is internalized by young learners. This vulnerability primarily stems from students relying on rote, procedural memorization—such as reading digits from right to left—without grasping the structural meaning of the base-10 positional system. For instance, rather than perceiving the digit '4' in 645,372 as representing a magnitude of 40,000, students often isolate the digit, treating it merely as a standalone entity.

This cognitive fragmentation is highly detrimental, particularly when students attempt arithmetic operations such as multidigit addition. Previous studies on elementary students' mathematical errors emphasize that the lack of place value comprehension directly triggers systematic calculation mistakes (Matitaputty, 2016; Selvianiresa et al., 2017). Because students do not fundamentally understand why a digit in the tens place carries a greater magnitude than one in the ones place, their operational skills become structurally flawed. When performing vertical addition, students with place value misconceptions frequently misalign digits or fail to comprehend the concept of regrouping, as they view the process merely as calculating isolated single digits rather than manipulating actual quantities (Khoiriyah et al., 2026; Mulyasari et al., 2023; Nurhaswinda et al., 2026; Yona, 2014). For example, they might treat columns as isolated single-digit operations rather than understanding that a 'ten' is a new collection of ten 'ones'.

This cognitive fragmentation is highly detrimental, particularly when students attempt arithmetic operations such as multidigit addition. Because students do not fundamentally understand why a digit in the tens place carries a greater magnitude than one in the ones place, their operational skills become structurally flawed. When performing vertical addition, students with place value misconceptions frequently misalign digits or fail to comprehend the concept of regrouping, as they view the process merely as calculating isolated single digits rather than manipulating actual quantities.

This structural misunderstanding becomes significantly more problematic when compounded by overconfidence. When students apply a flawed procedural rule—such as ignoring a zero in the middle of a number or misaligning addition columns—they often do so systematically and with high certainty because they believe they are correctly applying a memorized formula. This creates a dangerous metacognitive barrier: students experience a cognitive illusion of competence and remain entirely unaware of their conceptual errors, making them highly resistant to change. Because their mechanical calculation produces a definitive result, they see no reason to dismantle and reconstruct their cognitive schemas (Harianti et al., 2022; Yuliani et al., 2026)

Therefore, merely informing students that their answers are incorrect is pedagogically insufficient. To effectively address this, learning media must actively disrupt this unwarranted confidence through a *mindful* approach that triggers cognitive conflict. This must be combined with concrete visual manipulations—such as the 3D components planned for the

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Volume 15 No. 4 Desember 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

Smart Pop-up Book—that allow students to physically see and reflect upon the actual magnitude of hundreds, tens, and ones, effectively bridging the gap between abstract symbols and concrete numerical realities.

Implications for the Development of Deep Learning-Based Smart Pop-up Books

The diagnostic findings directly inform the design of the "Smart Pop-up Book." Table 10 links these findings to recommended features and Deep Learning principles.

Table 10. Implications of Findings for Pop-up Book Design

Diagnostic Finding	Implication	Smart Pop-up Book Feature	Deep Learning Principle
Overconfidence (47% total)	Students are unaware of errors; need reflective feedback	"Confidence Check" feature; reflective prompts: "Are you sure?"	Mindful
Place value misconception (42%)	Concepts are too abstract; need concrete representation	3D Pop-ups; "Lift the Flap" revealing values (e.g., 4 → 40,000).	Meaningful
Under confidence/ procedural errors	Need step-by-step simulation	QR code-linked step-by-step animated simulations.	Meaningful
Lucky guessing	Need to bridge reasoning and answers	Two-step verification: reason must be selected before the answer.	Meaningful
Moderate proficiency (Mean 67.33)	Need higher engagement and visual reinforcement	3D local wisdom contexts (Prigi Beach, Trenggalek local culinary).	Joyful

Source: Researcher's Processed Data, 2026

Mindful Principle (Metacognitive Awareness)

High overconfidence suggests that students lack metacognitive awareness. The "Smart Pop-up Book" integrates mindful learning by requiring students to evaluate their own thinking. For instance, before revealing the correct answer in the digital gamification layer, the system asks students to rate their confidence. If they are "Very Confident" but incorrect, the system provides a gentle prompt: "You were very sure, but there is a misunderstanding in the place value. Let's look at the ten-thousands flap again."

Meaningful Principle (Contextual and Concrete)

To address the 42% place value misconception, the book utilizes the meaningful principle through 3D visualizations. Using "lift the flap" mechanisms for numbers like 645,372, students can physically lift the digit '4' to see "40,000" underneath. Furthermore, the content is rooted in Trenggalek local wisdom, such as comparing visitor numbers at Prigi Beach or calculating discounts for Trenggalek local culinary, making abstract numbers relevant to their daily lives.

Joyful Principle (Positive Engagement)

To mitigate under confidence and math anxiety, the joyful principle is applied through gamification and visual "surprises." As pages are opened, 3D objects "jump" out, creating an enthusiastic learning atmosphere. Digital badges such as "Place Value Expert" or "Numeracy Detective" provide positive reinforcement, shifting the focus from "avoiding mistakes" to "exploring concepts."

Product Specifications

The proposed "Smart Pop-up Book" specifications are summarized in Table 11.

Table 11. Smart Pop-up Book Product Specifications

Category	Specification
Physical form	25×25 cm boardbook; 210gsm cardstock for durability.
Interactive elements	Pull-tabs, lift the flap, V-folds 3D paper engineering.
Digital integration	QR codes leading to interactive quizzes (Genially/Wordwall) with immediate feedback.

Sosioedukasi
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ISSN: 2086-6135 E-ISSN: 2541-612x
Volume 15 No. 4 Desember 2026 https://ejournal.unibabwi.ac.id/index.php/sosioedukasi/index

Context	Trenggalek Local Wisdom (Prigi Beach, Mount Wilis, Batik, local culinary).
Metacognitive features	Teacher guides and student reflection prompts included.

Source: Researcher's Processed Data, 2026

CONCLUSION

This study demonstrates that fifth-grade students' moderate numeracy proficiency is fundamentally undermined by entrenched conceptual misconceptions, most notably in place value and sequential arithmetic operations, compounded by pervasive overconfidence. Rather than merely lacking procedural knowledge, nearly half of the students exhibited high certainty in erroneous reasoning, creating a cognitive illusion of competence that resists conventional instruction. Addressing the final research objective, these diagnostic profiles provide an empirical blueprint for developing a Smart Pop-up Book grounded in Deep Learning pedagogy: integrating *Mindful* confidence-check prompts to trigger cognitive conflict, *Meaningful* three-dimensional manipulatives rooted in Trenggalek local wisdom to concretize abstract magnitudes, and *Joyful* digital gamification to sustain engagement.

Theoretically, these findings extend instructional design models by establishing metacognitive calibration as a critical prerequisite for conceptual-change media in primary mathematics. Practically, the study informs classroom pedagogy and educational media development by encouraging teachers to adopt routine three-tier diagnostic assessments for differentiated instruction, while guiding developers in translating specific error patterns into targeted, culturally contextualized learning tools.

Nevertheless, several limitations must be acknowledged. Because this research employed a descriptive design with a limited sample of 60 students across two schools, the findings are restricted to whole-number numeracy and do not yet empirically verify the effectiveness of the proposed product. Additionally, the simplified three-point confidence scale provides less granular metacognitive measurement than a six-point Certainty of Response Index (CRI). Future research should therefore prioritize prototyping and validating the Smart Pop-up Book through quasi-experimental designs, longitudinal retention assessments, and broader numeracy domains to evaluate its long-term impact on conceptual mastery and metacognitive accuracy.

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