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Epistemological obstacles in pre-service elementary teachers' social arithmetic problem solving: evidence from contextual knowledge reconstruction

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Abstract

Background: Pre-service elementary teachers often struggle to transfer familiar social arithmetic concepts across novel contextual problems, indicating deep epistemological obstacles rather than superficial computational errors.
Aims: This study investigates the epistemological obstacles experienced by prospective teachers in solving contextual social arithmetic tasks involving percentage, discount, gross, net, and tare concepts.
Methods: A qualitative study informed by hermeneutic phenomenology was conducted with 50 pre-service elementary teachers selected purposively from a Basic Mathematics course. Data were obtained from five open-ended diagnostic tasks and follow-up semi-structured interviews with participants representing recurring response patterns. Written and interview data were analyzed iteratively by identifying significant problem-solving responses, examining participants' explanations of those responses, comparing interpretations across cases, and developing recurring obstacle patterns. Triangulation between written responses and interviews, peer debriefing, and an analytic audit trail were used to enhance trustworthiness.
Result: The findings revealed an overarching difficulty in reconstructing mathematical meaning when familiar social arithmetic concepts were embedded in changing contextual conditions. Three interconnected patterns were identified: contextual misinterpretation of percentage-based information, fragmented coordination of related quantities and units, and inappropriate transfer of familiar procedures to conditional situations. These patterns were evident when participants interpreted discounts as undifferentiated percentage operations, treated gross weight as equivalent to net weight despite tare information, or applied item-specific discounts to an entire transaction. The recurrence of these interpretations and their consistency with participants' verbal explanations indicated context-dependent epistemological constraints in several cases, while also revealing the need to distinguish such constraints from more fundamental conceptual misconceptions.
Conclusion: Social arithmetic instruction in teacher education must transition from procedural computations to tasks emphasizing contextual constraints, multi-quantity coordination, and explicit justification of mathematical procedures.

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INTRODUCTION

Mathematical problem solving is a fundamental competence for pre-service elementary teachers because teaching mathematics requires not only the ability to obtain correct answers but also the capacity to interpret mathematical relationships, explain reasoning, and connect mathematical concepts with meaningful situations. This competence becomes particularly important when prospective teachers encounter contextual problems in which mathematical information must be interpreted rather than directly translated into numerical operations (Rusmin et al., 2024; Amrina

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et al., 2024). Recent research also indicates that mathematical problem solving involves the coordination of conceptual knowledge, reasoning, and contextual interpretation rather than procedural competence alone (Rafiepour et al., 2025). Within teacher education, this capacity is essential because pre-service teachers will eventually be responsible for helping elementary students construct meaningful mathematical understanding (Nopriana et al., 2021, 2023b). Nevertheless, difficulties in mathematical problem solving remain evident among prospective teachers. Previous studies have identified reliance on procedural strategies, weak conceptual connections, and difficulty applying mathematical knowledge in unfamiliar situations (Novita et al., 2022; Nopriana et al., 2023b; Hadi & Ardianzah, 2025). Similar concerns have recently been reported in Nurrahmah et al. (2026), found that pre-service mathematics teachers experienced difficulties in understanding concepts and communicating mathematical meanings contextually, while Puspitasari and Fitriatien (2026) identified procedural formula application, dependence on familiar problem patterns, and limited interpretation of problem statements as important manifestations of learning difficulties.

One theoretical perspective for understanding this problem is the concept of learning obstacles, particularly epistemological obstacles. Brousseau (2002) conceptualizes epistemological obstacles as limitations arising from knowledge that may function effectively under certain conditions but becomes inadequate when learners encounter situations requiring that knowledge to be reconstructed or extended. Learning obstacles may involve ontogenic, didactical, and epistemological dimensions (Brousseau, 2002; Suryadi, 2019; Nopriana et al., 2023a). However, the present study focuses specifically on epistemological obstacles because its primary concern is how previously constructed mathematical knowledge functions or ceases to function when the context, referent, unit, or conditions of a problem change.

Recent studies reinforce the importance of this distinction. Sandra et al. (2026) found that epistemological obstacles can be manifested through fragmented conceptual understanding, misconceptions about mathematical relationships, reliance on trial-and-error strategies, and difficulties interpreting mathematical concepts meaningfully. Puspitasari and Fitriatien (2026) similarly identified dependence on familiar problem patterns and procedural formula application without sufficient conceptual reasoning. These findings indicate that an incorrect answer should not automatically be classified as an epistemological obstacle. The critical question is whether the error reflects missing computational knowledge or whether previously constructed knowledge becomes ineffective when applied beyond the conditions in which it was originally understood.

Previous studies have provided substantial evidence concerning procedural dependence, mathematical misconceptions, percentage understanding, contextual word-problem difficulties, and learning obstacles (Verschaffel et al., 2020; Machaba & Madzingira, 2025; Rafiepour et al., 2025; Marleny et al., 2026; Puspitasari & Fitriatien, 2026; Sandra et al., 2026). Nevertheless, three gaps remain. First, limited attention has been given specifically to epistemological obstacles in pre-service elementary teachers' social arithmetic problem solving. Second, existing studies have more frequently identified errors or learning obstacles than examined whether previously constructed knowledge becomes constrained when contextual conditions, units, or mathematical referents change. Third, written solutions are rarely integrated with participants' verbal explanations to distinguish context-dependent epistemological obstacles from conceptual misconceptions or isolated computational errors. Accordingly, the present study moves beyond error classification by examining how pre-service elementary teachers interpret and reconstruct social arithmetic knowledge across changing problem conditions. Written solutions are considered together with participants' verbal explanations to investigate not only what went wrong, but also why particular mathematical interpretations and procedures were activated. This approach provides a stronger empirical basis for identifying epistemological obstacles and contributes to understanding how

apparently familiar knowledge about percentages, discounts, gross–net–tare relationships, quantities, and units may lose its effectiveness when contextual conditions change.

This study aims to identify and interpret recurring epistemological obstacle patterns in pre-service elementary teachers' social arithmetic problem solving. Specifically, it examines how previously constructed knowledge concerning percentages, discounts, quantities and units, and gross–net–tare relationships becomes constrained when learners encounter unfamiliar or multi-condition contextual situations. By distinguishing context-dependent limitations in mathematical knowledge from isolated computational errors and conceptual misconceptions, this study seeks to provide an empirically grounded characterization of epistemological obstacles and to inform the development of social arithmetic instruction that promotes more flexible, interconnected, and context-sensitive mathematical understanding in elementary teacher education.

LITERATURE REVIEW

This distinction is particularly relevant to social arithmetic, where mathematical procedures are inseparable from the meanings and referents of quantities. Concepts such as percentage, discount, gross weight, net weight, tare, and unit price require learners to coordinate numerical relationships with contextual information. Percentage provides a clear example. Marleny et al. (2026) reported persistent difficulties in percentage understanding, particularly when the percent symbol is interpreted as a standalone numerical value rather than as the relational meaning of "per hundred." Their findings also emphasize that instruction detached from meaningful contexts may restrict learners' ability to connect percentages with related mathematical concepts. Similarly, Machaba and Madzingira (2025) found that difficulties in ratio and proportion were associated with inadequate foundational conceptual understanding and inappropriate strategies, including additive reasoning and erroneous procedural applications. These findings are relevant because percentage reasoning fundamentally involves proportional relationships.

Research on mathematical word problems further demonstrates that contextual interpretation is not secondary to mathematical computation. Rafiepour et al. (2025) found that pre-service teachers may successfully process mathematical elements while failing to incorporate real-world conditions appropriately into their solutions. Mathematical understanding therefore requires coordination between mathematical representations, conceptual relationships, and contextual information rather than mechanical manipulation of numerical data (Duval, 2006; Verschaffel et al., 2020). Recent studies on learning obstacles similarly show that students may depend on familiar procedures even when problem conditions require conceptual reinterpretation (Sandra et al., 2026; Puspitasari & Fitriatien, 2026). However, these studies leave an important issue unresolved. Existing research has predominantly documented what errors or learning obstacles occur, whereas considerably less attention has been given to how learners themselves interpret the mathematical and contextual information that generates those errors. This distinction is essential for identifying epistemological obstacles because an incorrect written response alone cannot determine whether the difficulty results from a computational slip, incomplete conceptual knowledge, or the inappropriate transfer of previously constructed knowledge. Consequently, evidence about learners' reasoning is required to explain why a particular procedure was selected and how the meaning of the problem was constructed.

A hermeneutic phenomenological perspective is particularly appropriate for addressing this issue because the research question concerns the meaning underlying participants' mathematical responses, rather than merely the frequency or categories of their errors. Unlike descriptive qualitative error analysis, which can identify and classify observable difficulties, hermeneutic

phenomenology enables written responses to be interpreted in relation to participants' verbal accounts of how they understood the problem and justified their reasoning (van Manen, 1990; Nopriana et al., 2025). In the present study, this perspective therefore provides the interpretative bridge needed to determine whether an incorrect response reflects an isolated error or a limitation in how previously constructed mathematical knowledge is understood and applied across contexts. The detailed analytical procedures for implementing this approach are presented in the Method section.

METHOD

Research Design

This study employed a qualitative research design using a hermeneutic phenomenological approach to investigate the epistemological obstacles experienced by pre-service elementary teachers when solving contextual social arithmetic problems. Hermeneutic phenomenology was considered appropriate because the purpose of the study was not merely to classify students' errors or describe their problem-solving performance, but to interpret how they understood mathematical information, activated prior knowledge, and assigned meaning to concepts when problem conditions changed. Compared with descriptive qualitative or conventional error-analysis approaches, hermeneutic phenomenology enables the analysis to move from identifying *what* students did incorrectly toward interpreting *how* their prior understanding shaped the ways in which they interpreted and solved the problems (van Manen, 1990).

In this study, hermeneutic phenomenology was operationalized through an iterative interpretation of students' written solutions and verbal explanations. The analysis began by identifying significant responses in the written solutions, particularly responses indicating difficulties in interpreting contextual information, coordinating related mathematical concepts, or applying previously learned concepts to different situations. These written responses were subsequently examined alongside interview data in which participants explained how they understood the information provided, why they selected particular mathematical operations, and how they connected the concepts involved. Interpretation proceeded iteratively between individual parts of the data—such as particular calculations, statements, and explanations—and the overall pattern of each participant's reasoning. Written and interview data were then compared across participants to identify recurring patterns of meaning and context-dependent limitations in mathematical knowledge.

The concept of learning obstacles from Didactical Design Research (DDR) was used as an analytical framework rather than as a separate research design. Specifically, the prospective analysis component of DDR informed the identification and characterization of epistemological obstacles (Suryadi, 2019a, 2019b; Nopriana et al., 2025). Within this framework, an error was not automatically classified as an epistemological obstacle. A response was interpreted as indicating a potential epistemological obstacle when the participant demonstrated relevant prior mathematical knowledge but encountered difficulty applying or reconstructing that knowledge when the context, referent, unit, or conditions of the problem changed. Isolated computational errors without evidence of context-dependent conceptual limitation were therefore not treated as epistemological obstacles. Accordingly, the two perspectives served complementary but distinct functions. DDR provided the conceptual lens for identifying *where and under what conditions* mathematical knowledge became limited, whereas hermeneutic phenomenology provided the interpretative process for examining *how participants understood and gave meaning to those conditions*.

Participant

The participants were 50 undergraduate students enrolled in the Elementary Teacher Education Program at a private university in Cirebon, West Java, Indonesia. Purposive sampling was used because participants were required to have prior exposure to the mathematical concepts investigated in the study while simultaneously encountering these concepts in contextual problem-solving situations. The inclusion criteria were students who (1) were actively enrolled in the Basic Mathematics course, (2) had previously learned fundamental percentage and social arithmetic concepts, including discount, gross, net, and tare, and (3) completed all five diagnostic social arithmetic problems. The 50 participants represented the intact group of students who met these criteria and participated in the diagnostic stage, allowing recurring response patterns to be examined across the group rather than relying on isolated individual errors.

For the follow-up interviews, 5 participants were purposively selected based on their written responses. Selection was based on maximum variation in the identified response patterns, particularly participants whose solutions represented recurring difficulties related to contextual interpretation, percentage and discount concepts, coordination of gross–net–tare relationships, and the application of mathematical procedures under changing problem conditions. Participants whose responses represented similar patterns were compared to determine whether the observed difficulties reflected recurring interpretations rather than isolated computational mistakes. The interviews were used to clarify participants' reasoning and to examine the meanings underlying their written responses.

Instrument

The primary data sources consisted of students' written responses to five open-ended social arithmetic problems and semi-structured interviews. The diagnostic problems addressed contextual situations involving percentages, discounts, gross weight, net weight, tare, and related conditions requiring students to coordinate mathematical concepts with real-world information. The open-ended format was used to make students' problem-solving processes visible rather than capturing only their final answers. The semi-structured interview protocol was developed to elaborate on significant patterns identified in the written responses. Interview questions prompted participants to explain how they interpreted the information in each problem, why they selected particular operations, what mathematical concepts they considered relevant, and whether their reasoning changed when contextual conditions were reconsidered. Thus, the interviews did not constitute a separate source of findings but served to clarify and deepen the interpretation of the written evidence.

Because interpretation in hermeneutic phenomenology involves researcher judgment, several procedures were employed to reduce the influence of researcher preconceptions. Interpretations were grounded in participants' written responses and verbal explanations rather than inferred solely from incorrect answers. Written and interview evidence was compared before an error was characterized as an epistemological obstacle. The researcher also maintained analytic notes documenting the development and revision of interpretations, while peer debriefing was used to examine whether the proposed obstacle patterns were supported by the available evidence. Interpretations that could not be supported by converging written and interview evidence were treated cautiously and were not used as the basis for major thematic conclusions.

Procedure

Data collection was conducted during one academic semester and consisted of three interconnected phases. In the first phase, all 50 participants completed five open-ended diagnostic social arithmetic problems. Their responses were examined to identify recurring solution patterns and potential epistemological obstacles, particularly difficulties that emerged when familiar

mathematical concepts were applied under different contextual conditions. In the second phase, participants representing the identified response patterns were selected for semi-structured interviews. During the interviews, participants were asked to revisit their written solutions and explain how they interpreted relevant quantities, units, percentages, discounts, and contextual conditions. Follow-up questions were used to clarify the reasoning underlying particular operations and to determine whether an incorrect response reflected an isolated computational error or a more persistent limitation in applying previously constructed knowledge. In the third phase, written responses and interview transcripts were analyzed iteratively. Initial interpretations derived from the diagnostic responses were reconsidered in light of participants' verbal explanations. Similar and contrasting cases were compared across participants, and recurring interpretations were progressively organized into broader epistemological obstacle patterns. This movement between written evidence, participants' explanations, and cross-case patterns constituted the hermeneutic interpretative process used to characterize the epistemological obstacles reported in this study.

Analysis Plan

Epistemological obstacles were identified using the prospective analytical perspective of DDR, while hermeneutic phenomenological analysis was used to interpret the meanings underlying participants' written and verbal responses. Written responses and interview transcripts were examined iteratively, compared within and across cases, and organized into recurring obstacle patterns. Data were collected through written tests and follow-up interviews. The data analysis in this study employed phenomenological data analysis techniques, specifically following the steps outlined by Creswell (Cresswell, 2013), as illustrated in Figure 1.

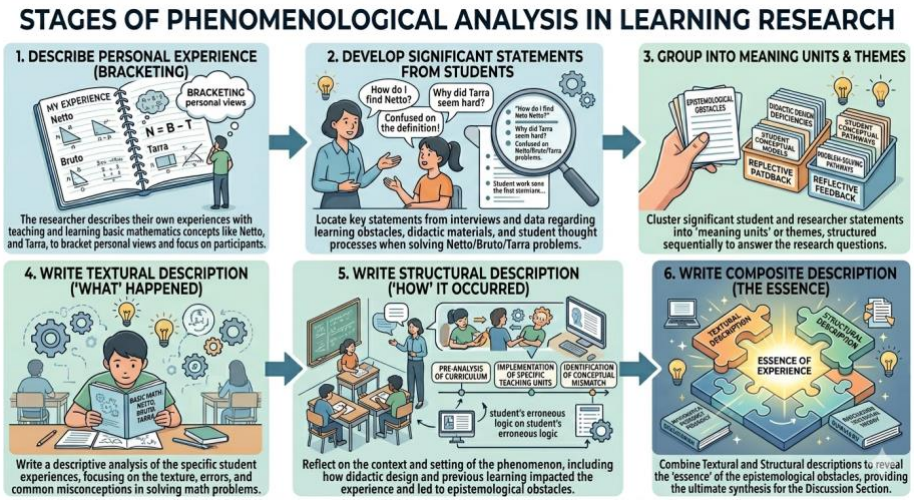

Figure 1. Phenomenological Data Analysis Techniques

To ensure trustworthiness, the study applied credibility, dependability, and confirmability criteria through data triangulation (test and interview), peer debriefing, and careful documentation of the analytic process.

RESULTS AND DISCUSSION

Results

Analysis of the written responses and follow-up interviews revealed three interconnected patterns of difficulty in pre-service elementary teachers' social arithmetic problem solving: (1) contextual misinterpretation of percentage-based information, (2) fragmented coordination of quantities, units, and related concepts, and (3) inappropriate transfer of familiar procedures across

contextual conditions. These patterns are presented below through the integration of written evidence, interview evidence, and interpretative analysis.

Contextual misinterpretation of percentage-based information

Problem 1.

A building contractor purchases 45 sacks of cement at a price of Rp7,000 per kg. Each sack weighs 40 kg with a tare of 1.5%. The contractor receives a 10% discount for paying in cash. Calculate the total amount he has to pay.

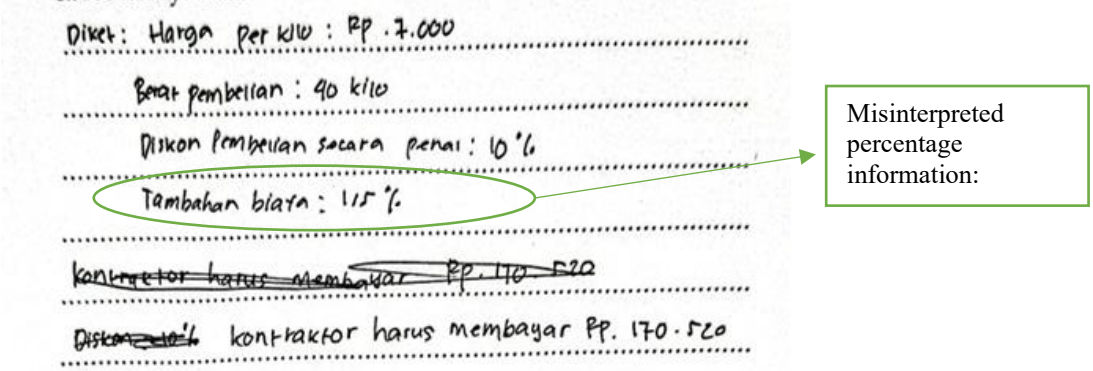

Figure 2. Student 1's written response indicating contextual misinterpretation of percentage information

Based on the analysis of Student 1's responses, the student experienced difficulty in understanding the context of the problem. The student wrote that there was an "additional cost of 15%," whereas the problem only mentioned a 10% discount. This indicates a misinterpretation of the problem situation, particularly in distinguishing between a price reduction (discount) and an added cost. Such an error reflects an epistemological obstacle, where previously constructed knowledge interferes with the correct interpretation of a new context [12]. In this case, the student appears to activate an inappropriate schema, treating percentage situations uniformly without recognizing the semantic differences between increase and decrease in real-world contexts. During the follow-up interview, the researcher asked Student 1 to explain how the percentage information had been interpreted.

Researcher: *"What does the 10% information in the problem mean?"*
Student 1: *"It means there is a percentage that must be calculated from the price."*
Researcher: *"Should that percentage increase or reduce the amount that the contractor has to pay?"*
Student 1: *"I initially added it because when I saw a percentage in a price problem, I thought it had to be added to the total."*
Researcher: *"What does the word discount mean in this situation?"*
Student 1: *"It should actually reduce the price. I did not pay attention to the meaning of the word discount when I calculated it."*

The written and verbal evidence indicates that the difficulty was located in the interpretation of the percentage within its contextual meaning rather than in performing percentage calculations alone. Student 1 recognized percentage as a relevant mathematical concept, but initially treated percentage information as a uniform operation without distinguishing whether it represented an increase or decrease. The interview further showed that the student reconsidered the operation after attending to the semantic meaning of *discount*. This context-dependent limitation suggests a potential epistemological obstacle in transferring percentage knowledge from familiar numerical procedures to a situation in which the percentage must first be interpreted according to its contextual function. This interpretation is particularly relevant because percentage understanding requires learners to recognize percentage as a relational concept rather than merely respond

procedurally to the percent symbol. Recent evidence has similarly identified difficulties in constructing the relational meaning of percentages when learners encounter contextual situations (Marleny et al., 2026).

Fragmented coordination of quantities, units, and related concepts

A second recurring pattern concerned students' difficulty in coordinating several related quantities within the same contextual problem, particularly gross weight, tare, net weight, number of sacks, and price per kilogram.

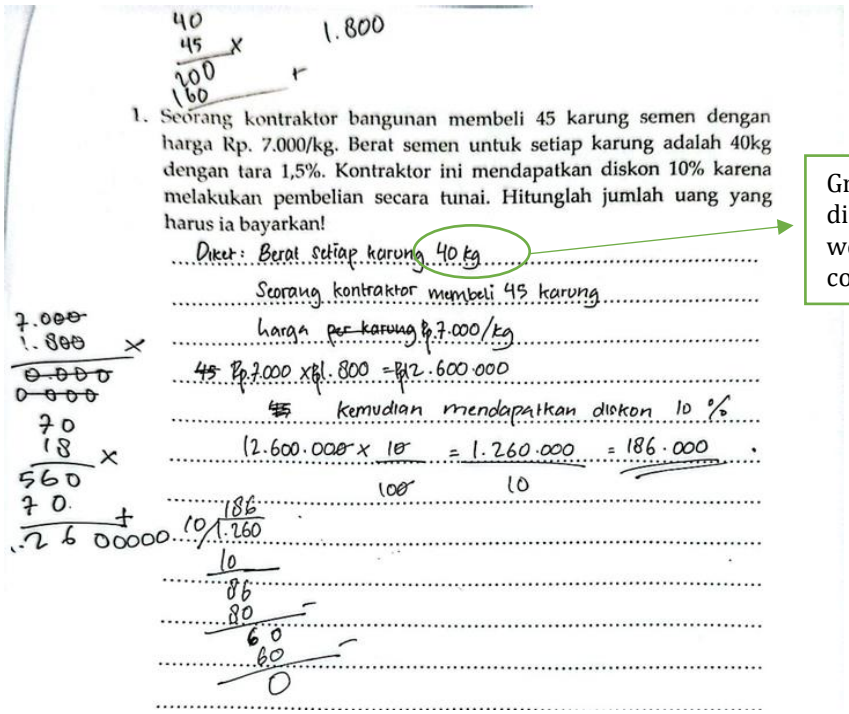

Figure 3. Student 2's written response indicating failure to coordinate gross weight, tare, and net weight

Student 2's response indicates that although the problem states a tare of 1.5%, the student directly assumed that the net weight of the cement is 40 kg per sack. Consequently, gross weight was treated as equivalent to net weight. The response demonstrates that the student did not integrate the tare condition into the relationship among gross, tare, and net quantities. The written response was explored further during the interview.

Researcher: *"Why did you use 40 kg as the amount of cement in each sack?"*
Student 2: *"Because the problem says that one sack weighs 40 kg, so I used 40 kg directly."*
Researcher: *"What does the 1.5% tare represent?"*
Student 2: *"It is the weight of the sack, but at first I did not think it had to be removed from the 40 kg."*
Researcher: *"If tare is the weight of the packaging, is the amount of cement still 40 kg?"*
Student 2: *"No. The tare should first be subtracted, so the cement itself weighs less than 40 kg."*

The interview clarifies that Student 2 was familiar with the meaning of tare but did not spontaneously coordinate it with gross and net weight when solving the contextual problem. Thus, the difficulty was not simply the absence of knowledge about tare. Rather, previously learned knowledge remained disconnected from the new configuration of quantities presented in the problem. This provides stronger evidence of a context-dependent limitation in conceptual coordination than could be inferred from the written response alone. From an epistemological perspective, this reflects a limitation in the student's conceptual structure, where previously learned knowledge is applied inappropriately to a new context (Brousseau, 2002).

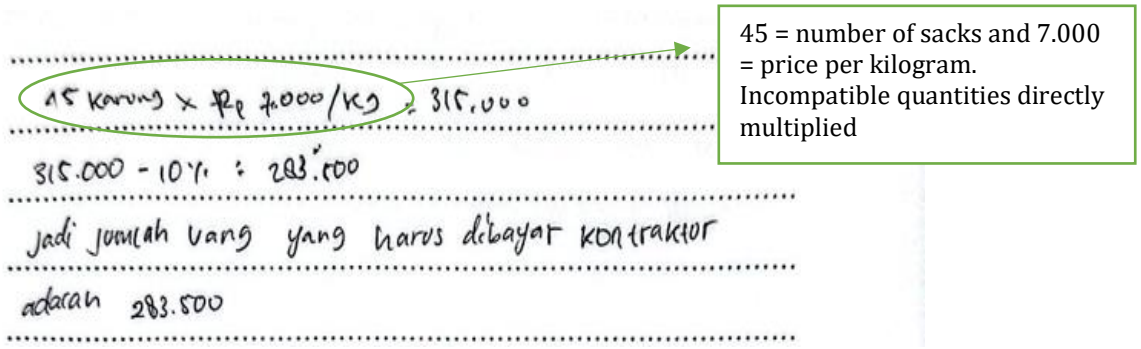

Figure 4. Student 3's written response indicating failure to coordinate quantity and unit price

Student 3 multiplied 45 sacks directly by Rp7,000, although the stated price was Rp7,000 per kilogram. The solution omitted the intermediate relationship between the number of sacks and the weight per sack. As a result, the calculation combined quantities with incompatible units. The researcher asked Student 3 to explain the meaning of the two numbers used in the multiplication.

Researcher: *"What does the number 45 represent?"*
Student 3: *"The number of cement sacks."*
Researcher: *"And what does Rp7,000 represent?"*
Student 3: *"The price of the cement."*
Researcher: *"Is Rp7,000 the price of one sack or one kilogram?"*
Student 3: *"One kilogram. I multiplied it directly by 45 because I focused on the number of sacks."*
Researcher: *"What information should be used before multiplying by Rp7,000?"*
Student 3: *"The total kilograms of cement should be found first."*

Student 3 could identify the meaning of each quantity when explicitly questioned but failed to coordinate them while constructing the solution. This distinction is important. The difficulty did not arise because the student was completely unaware of the unit price; rather, the relevant knowledge was not activated appropriately when several quantities and units had to be coordinated simultaneously. Together, Students 2 and 3 illustrate a broader pattern of fragmented coordination, in which individual concepts were partially available but were not integrated into a coherent quantitative structure for solving the contextual problem. This pattern is consistent with recent findings on learning obstacles showing that fragmented conceptual understanding and dependence on familiar procedures can constrain learners when mathematical relationships must be reorganized within a problem situation (Sandra et al., 2026).

Inappropriate transfer of familiar procedures across contextual conditions

The second problem required students not only to perform percentage calculations but also to interpret restrictions concerning the scope and eligibility of two different price reductions.

Problem 2

> **Zahid is going shopping at a store called "Tidur Nyenyak" to buy a blanket and bed sheets. He finds a blanket he likes priced at Rp350,000. He already has a voucher worth Rp85,000, which can be used for a minimum purchase of Rp300,000. He then moves to another section to look for bed sheets and becomes interested in a gray set priced at Rp200,000 with a 20% discount. According to the store's policy, Zahid can only use one type of discount and cannot combine both. If you were Zahid, which type of discount would you choose?**

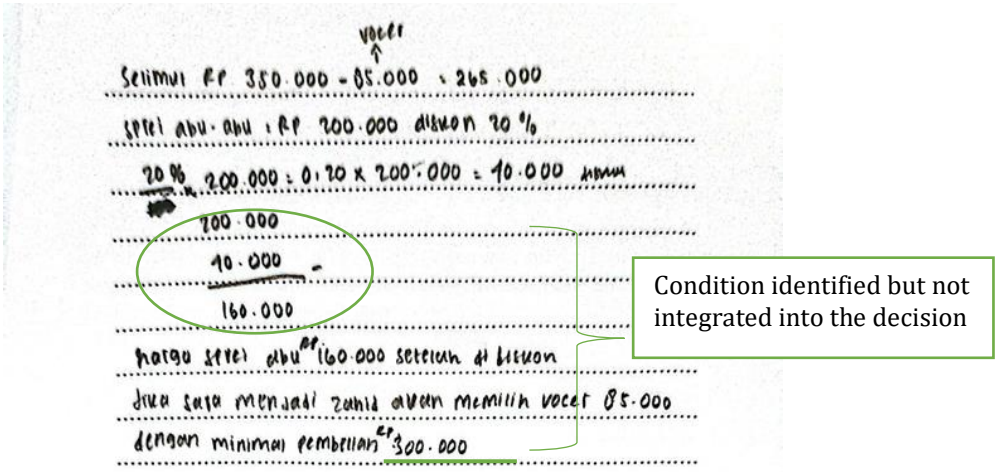

Figure 5. Student 1's written response indicating incomplete use of the voucher condition

Student 1 recorded the minimum purchase requirement of Rp300,000 but did not use this information when determining which price reduction should be selected. Thus, an important contextual condition was recognized at the reading stage but disconnected from the final decision-making process.

Researcher: *"You wrote that the voucher requires a minimum purchase of Rp300,000. Why did you not use that condition in your final comparison?"*
Student 1: *"I noticed the condition, but I thought I only needed to compare the voucher value with the 20% discount."*
Researcher: *"Why is the minimum purchase condition important?"*
Student 1: *"Because we have to check whether the purchase is eligible for the voucher before using it."*
Researcher: *"So can the voucher condition be ignored when deciding which option is better?"*
Student 1: *"No. It has to be checked first.*

The evidence suggests that Student 1 could identify the voucher condition linguistically but did not initially incorporate it into the mathematical decision structure. The difficulty therefore involved connecting conditional contextual information to the procedure used for comparison. The interview provides evidence that the condition became meaningful only after it was explicitly reconsidered, indicating a limitation in coordinating contextual constraints during problem solving.

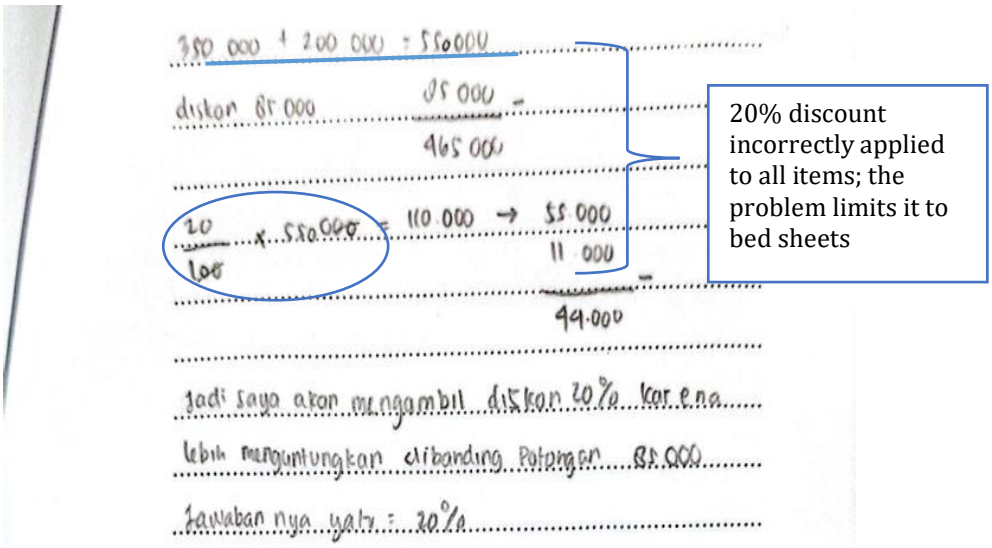

Figure 6. Student 2's written response indicating inappropriate application of an item-specific discount

Student 2 first added the prices of the blanket and bed sheets and correctly considered the Rp85,000 voucher. However, when evaluating the 20% discount option, the student calculated 20% from the total purchase rather than from the Rp200,000 price of the bed sheets. Thus, a familiar percentage procedure was extended beyond the referent specified in the problem.

Researcher: "In your calculation, what amount did you use as the basis for the 20% discount?"
Student 2: "I used the total price of the blanket and bed sheets."
Researcher: "Why did you apply the discount to the total?"
Student 2: "Because I thought that once there is a 20% discount, it applies to everything that Zahid buys."
Researcher: "What does the sentence stating that the bed sheets are discounted by 20% mean?"
Student 2: "It means the 20% should only be calculated from the price of the bed sheets."
Researcher: "Would the procedure change if the discount applied to the whole transaction?"
Student 2: "Yes, then I could calculate it from the total purchase."

The dialogue demonstrates why the incorrect calculation cannot be interpreted solely from its numerical form. Student 2 possessed a procedure for calculating percentage discounts but initially generalized that procedure to the entire transaction without identifying the intended referent. Once the contextual scope was made explicit, the student recognized that the percentage should be applied only to the bed sheets. This pattern indicates an inappropriate transfer of a familiar procedure when the applicability of that procedure is constrained by contextual conditions. Similar characteristics have been reported in learning-obstacle research, where dependence on familiar problem patterns and procedural formula application may hinder conceptual reasoning when problem conditions change (Puspitasari & Fitriatien, 2026).

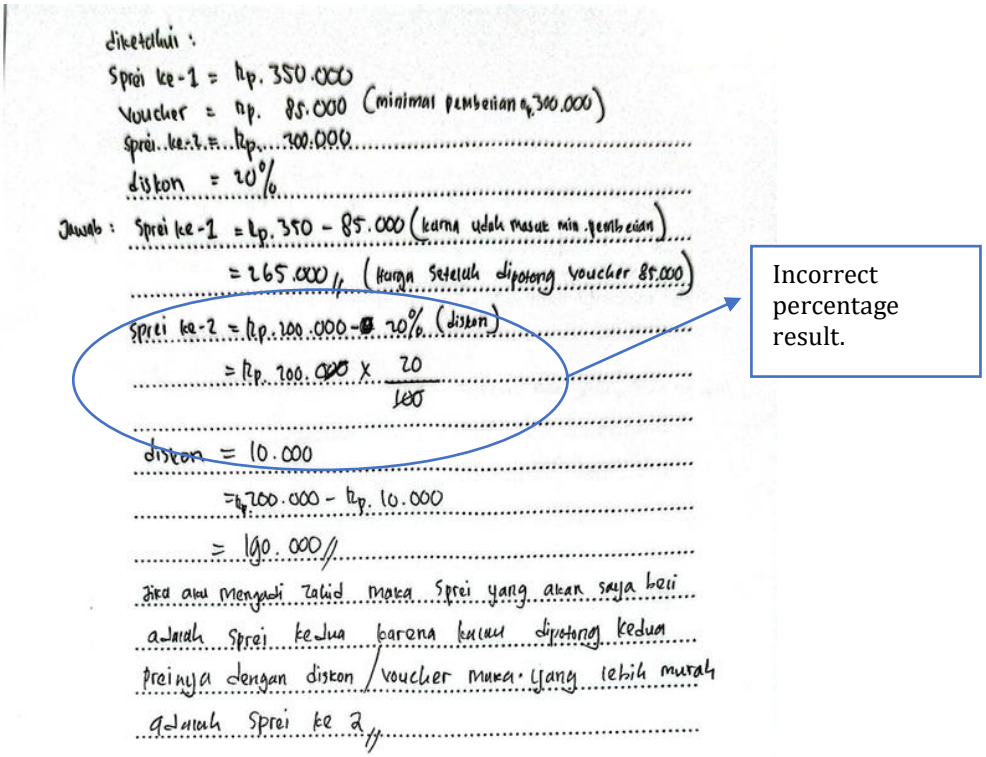

Figure 7. Student 3's written response showing an incorrect percentage calculation

Student 3 wrote (20% X Rp200,000 = Rp10,000). Based solely on the written response, this result demonstrates an incorrect percentage calculation. However, the numerical error alone is insufficient to classify the response as an epistemological obstacle because it could represent a temporary computational error, an incorrect percentage procedure, or a more persistent context-

dependent limitation. The follow-up interview was conducted to clarify how Student 3 interpreted the meaning of 20% in the calculation.

Researcher: *"How did you obtain Rp10,000 from 20% of Rp200,000?"*
Student 3: *"I divided Rp200,000 by 20, so the result was Rp10,000."*
Researcher: *"Why did you divide Rp200,000 by 20?"*
Student 3: *"Because the discount is 20%. I thought that to find 20% of Rp200,000, the price should be divided by 20."*
Researcher: *"What does 20% mean mathematically?"*
Student 3: *"I thought 20% meant that the amount had to be divided by 20."*
Researcher: *"So, when you wrote (20% X Rp200,000), the calculation you actually performed was (Rp200,000 : 20)?"*
Student 3: *"Yes."*

The interview evidence clarifies that Student 3's written result was not caused by an incidental arithmetic error. The student consistently interpreted 20% as an instruction to divide the original amount by 20, which explains the calculation (Rp200,000 \div 20 = Rp10,000). Thus, the written response and verbal explanation reveal a conceptual limitation in interpreting percentage as a proportional relationship. Rather than understanding 20% as (20/100) of a quantity, the student associated the numerical value 20 directly with division by 20. This finding resonates with Marleny et al. (2026), who reported difficulties in understanding percentage relationally, particularly when learners interpret percentage symbols without adequately connecting them to their "per hundred" meaning. It is also consistent with Machaba and Madzingira (2025), who demonstrated that misconceptions in ratio and proportion may be associated with inappropriate strategies and insufficient understanding of the underlying proportional relationships. Nevertheless, this case should be interpreted cautiously. Although the interview confirms that the response was not an incidental computational error, additional evidence across contrasting percentage situations would be required to establish whether the difficulty represents a context-dependent epistemological obstacle or a more fundamental conceptual misconception.

Discussion

The findings reveal three interconnected patterns of epistemological difficulty in pre-service elementary teachers' social arithmetic problem solving: contextual misinterpretation of percentage-based information, fragmented coordination of quantities, units, and related concepts, and inappropriate transfer of familiar procedures across contextual conditions. These patterns suggest that students' difficulties cannot be understood solely as computational errors. Instead, the integration of written responses and interview evidence shows that mathematical knowledge may become limited when students are required to reinterpret its meaning, coordinate several quantitative relationships, or determine whether a familiar procedure remains applicable under changing contextual conditions. This interpretation is consistent with Brousseau's (2002) conception of epistemological obstacles as limitations arising from knowledge that may function appropriately in certain situations but becomes inadequate when applied to different conditions.

Contextual Meaning as a Source of Epistemological Obstacle

The first pattern concerned students' difficulty in interpreting percentage information according to its contextual meaning. In Problem 1, Student 1 recognized percentage as relevant but interpreted a discount as an additional cost. The interview clarified that the student initially associated the presence of percentage information with an operation on the total amount without sufficiently considering whether the contextual term *discount* represented an increase or a decrease.

When the meaning of *discount* was explicitly reconsidered, the student recognized that it should reduce the price.

This finding supports the distinction between performing a mathematical procedure and understanding the meaning represented by that procedure. Duval (2006) argued that mathematical understanding depends on the ability to coordinate mathematical meanings and representations rather than merely manipulate symbolic forms. Similarly, Lithner (2008) showed that reliance on familiar or imitative procedures can restrict mathematical reasoning when learners encounter situations requiring adaptation. Earlier research involving prospective teachers also identified persistent difficulties with percentage reasoning and the interpretation of percentage relationships (Son & Lee, 2016). Recent evidence further strengthens this interpretation. Marleny et al. (2026) showed that difficulties in percentage understanding may occur when learners fail to construct percentage as a relational "per hundred" concept and instead treat its symbolic or numerical form superficially. Likewise, Machaba and Madzingira (2025) demonstrated that misconceptions in ratio and proportion may emerge through inappropriate strategies when learners lack sufficiently connected understanding of proportional relationships. These findings support the present interpretation that percentage errors should be examined not merely in terms of computational accuracy but also in terms of the mathematical meaning assigned to percentage within a particular context.

Recent research extends these earlier observations by demonstrating the central role of context in mathematical word-problem solving. Rafiepour et al. (2025), for example, found that pre-service teachers may recognize relevant mathematical information while failing to integrate real-world considerations appropriately into their solutions. Sanders et al. (2025) likewise emphasize that solving mathematical word problems requires coordination among mathematical, linguistic, and contextual features. Thus, the present study extends earlier findings on procedural and representational difficulties by showing that percentage knowledge may be available but become ineffective when students must determine the contextual function of that percentage. From an epistemological perspective, the issue is therefore not simply whether students know how to calculate percentages, but whether their knowledge remains functional when the semantic meaning of percentage changes across situations. This supports Brousseau's (2002) view that previously constructed knowledge may become an obstacle when its range of applicability is not appropriately reconstructed for a new situation.

Fragmented coordination of quantities, units, and related concepts

The second pattern emerged when students had to coordinate several related quantities simultaneously. In the cement problem, Student 2 treated 40 kg as the net amount of cement despite the presence of a 1.5% tare, whereas Student 3 multiplied the number of sacks directly by a price expressed per kilogram. Importantly, interview evidence indicated that the students could identify the meaning of *tare*, *kilogram*, and *price per kilogram* when explicitly questioned. Their difficulty emerged when these individual concepts had to be integrated into a coherent quantitative structure. This finding resonates with Duval's (2006) argument that successful mathematical activity requires coordination among different mathematical representations and meanings. It also extends Lithner's (2008) distinction between imitative and creative mathematical reasoning: reliance on immediately available numerical information may produce locally plausible procedures without establishing the relationships required by the problem. Verschaffel et al. (2020) similarly emphasize that successful word-problem solving requires learners to construct a meaningful representation of the situation rather than translate numbers directly into arithmetic operations.

This interpretation is also supported by Sandra et al. (2026), who identified fragmented conceptual understanding as an important characteristic of epistemological learning obstacles. Their findings suggest that learners may possess elements of relevant mathematical knowledge while

experiencing difficulty connecting those elements into a coherent conceptual structure. Similarly, Puspitasari and Fitriatien (2026) reported that dependence on familiar problem patterns and procedural formula application may limit learners' ability to reason conceptually when problem situations require different mathematical relationships. The present study extends these findings to social arithmetic by showing, through both written and verbal evidence, that pre-service elementary teachers could sometimes identify individual concepts such as tare, kilograms, and unit price when explicitly questioned but failed to coordinate them spontaneously during problem solving. Thus, the obstacle was not necessarily the absence of individual concepts but the fragmentation of those concepts when they had to function simultaneously within a contextual quantitative structure.

More recent studies provide additional support for this interpretation. Research with prospective primary teachers has demonstrated that contextual situations influence the mathematical structures and meanings mobilized when working with concepts such as fractions (Mallart et al., 2024). Research on proportional reasoning likewise emphasizes the importance of developing interconnected knowledge resources rather than isolated procedural knowledge (Weiland et al., 2021). Together, these studies suggest that possessing individual mathematical concepts does not guarantee that learners can coordinate them effectively within complex contextual situations. The contribution of the present study is to demonstrate this fragmentation specifically within social arithmetic. Gross weight, tare, net weight, number of sacks, kilograms, and price per kilogram are individually familiar concepts. Nevertheless, solving the problem requires these concepts to function as an interconnected quantitative system. The students' written and verbal responses suggest that relevant knowledge was partially available but remained locally organized. Consequently, the epistemological difficulty concerned not simply missing knowledge but limited flexibility in coordinating available knowledge when several quantities and units interacted simultaneously.

Inappropriate transfer of familiar procedures across contextual conditions

The third pattern involved transferring familiar procedures without sufficiently considering the conditions governing their applicability. In Problem 2, students were required to compare a fixed-value voucher with an item-specific percentage discount while considering minimum-purchase and non-combination conditions. Student 1 recognized the minimum-purchase requirement but did not initially integrate it into the final decision, whereas Student 2 applied the 20% discount to the entire transaction even though it applied only to the bed sheets. Interview evidence showed that Student 2 understood how to calculate a percentage discount but initially generalized the procedure to the total purchase.

This finding is consistent with earlier research indicating that students frequently experience difficulty transferring mathematical knowledge from familiar to unfamiliar situations (Lithner, 2008; Verschaffel et al., 2020). However, the present findings provide a more specific interpretation: students may notice contextual information without using that information to delimit the applicability of a mathematical operation. Thus, recognizing a condition and incorporating that condition into mathematical reasoning constitute distinct processes. Recent studies reinforce this interpretation. Rafiepour et al. (2025) reported that pre-service teachers may process the mathematical components of word problems while inadequately incorporating realistic contextual considerations. Sanders et al. (2025) similarly demonstrate that multi-step word problems become demanding because mathematical, linguistic, and contextual features must be coordinated. Furthermore, Lee (2025) found that purposeful teacher questioning can facilitate students' contextualization of mathematical word problems by directing attention toward relationships, procedural meaning, and the justification of solution strategies.

Student 3 provides a particularly important case for distinguishing epistemological obstacles from simple computational errors. The student calculated 20% of Rp200,000 as Rp10,000 and explained during the interview that obtaining 20% meant dividing Rp200,000 by 20. Because the verbal explanation reproduced the reasoning underlying the written calculation, the error cannot be interpreted as an accidental arithmetic slip. Instead, it reflects an incorrect mathematical meaning assigned to percentage, namely treating "20%" as "divide by 20" rather than 20/100 of a quantity. This finding is consistent with earlier literature showing that percentage understanding is closely related to proportional reasoning and requires more than procedural manipulation (Son & Lee, 2016; Verschaffel et al., 2020; Weiland et al., 2021).

Nevertheless, this case also demonstrates why epistemological obstacles should be distinguished carefully from conceptual misconceptions. If a student consistently interprets 20% incorrectly across both familiar and unfamiliar situations, the difficulty may primarily represent incomplete conceptual knowledge. Stronger evidence of an epistemological obstacle exists when relevant knowledge functions appropriately in one situation but becomes ineffective after the context, referent, unit, or problem conditions change. This distinction strengthens the interpretation of epistemological obstacles and prevents every systematic mathematical error from being classified under the same theoretical construct.

Taken together, the findings suggest that the central difficulty experienced by the participants was limited flexibility in reconstructing mathematical meaning across contextual conditions. The contribution of this study therefore extends beyond identifying individual errors in discount, tare, units, and percentage calculations. Earlier studies have established difficulties involving representation (Duval, 2006), reliance on familiar reasoning procedures (Lithner, 2008), percentage understanding (Son & Lee, 2016), realistic word-problem reasoning (Verschaffel et al., 2020), proportional reasoning (Weiland et al., 2021), and contextual interpretation among pre-service teachers (Rafiepour et al., 2025). The present study connects these strands by demonstrating, through combined written and interview evidence, where previously constructed mathematical knowledge loses its effectiveness when contextual conditions change. This provides a more empirically grounded characterization of epistemological obstacles in social arithmetic problem solving.

Implications

The findings have important implications for mathematics instruction in elementary teacher education. Social arithmetic should not be taught primarily through repeated practice of formulas for percentages, discounts, gross weight, net weight, and tare. Instruction should provide contrastive and variation-based contextual tasks that require pre-service teachers to identify what each quantity represents, coordinate units and related concepts, determine the referent of a percentage, and justify whether a mathematical procedure remains applicable when contextual conditions change. Such experiences may promote more flexible mathematical knowledge rather than reliance on familiar procedures (Lithner, 2008; Weiland et al., 2021). Teacher educators should also incorporate purposeful questioning during problem solving, such as *"20% of what?"*, *"What does this quantity represent?"*, and *"Would this procedure remain valid if the condition changed?"* Such prompts can make students' interpretations visible and encourage them to reconsider relationships between mathematical procedures and contextual information (Lee, 2025). This is particularly important for pre-service elementary teachers because their ability to interpret mathematical situations will subsequently influence how they explain concepts, anticipate students' difficulties, and design meaningful learning experiences.

Limitations and Suggestions for Future Research

This study reveals that pre-service elementary teachers' difficulties in solving contextual social arithmetic problems extend beyond isolated computational errors. The integration of written responses and interview evidence identified three interconnected patterns: contextual misinterpretation of percentage-based information, fragmented coordination of quantities, units, and related concepts, and inappropriate transfer of familiar procedures across contextual conditions. Students sometimes possessed relevant mathematical knowledge but were unable to appropriately reconstruct or coordinate that knowledge when the meaning, referent, unit, or conditions of the problem changed. These findings indicate that epistemological obstacles may emerge when previously constructed knowledge remains locally functional but lacks the flexibility required for application across varying contextual situations. However, difficulties that persist even in familiar situations, such as a fundamental misunderstanding of percentage, should be distinguished from epistemological obstacles and interpreted more cautiously as conceptual limitations.

The study therefore contributes to understanding epistemological obstacles by demonstrating that identifying incorrect answers alone is insufficient; interpretations should be supported by evidence of how students understand and apply their mathematical knowledge across contexts. For elementary teacher education, the findings highlight the importance of developing context-sensitive and interconnected mathematical understanding rather than emphasizing procedural proficiency alone. Social arithmetic instruction should provide opportunities for pre-service teachers to interpret the meaning and referent of quantities, coordinate multiple mathematical relationships, and justify the applicability of procedures under different conditions. Such experiences are essential for preparing prospective teachers not only to solve contextual mathematical problems but also to anticipate, interpret, and respond meaningfully to similar difficulties in their future students.

CONCLUSION

This study reveals that pre-service elementary teachers' difficulties in solving contextual social arithmetic problems extend beyond isolated computational errors. The integration of written responses and interview evidence identified three interconnected patterns: contextual misinterpretation of percentage-based information, fragmented coordination of quantities, units, and related concepts, and inappropriate transfer of familiar procedures across contextual conditions. Students sometimes possessed relevant mathematical knowledge but were unable to appropriately reconstruct or coordinate that knowledge when the meaning, referent, unit, or conditions of the problem changed. These findings indicate that epistemological obstacles may emerge when previously constructed knowledge remains locally functional but lacks the flexibility required for application across varying contextual situations. However, difficulties that persist even in familiar situations, such as a fundamental misunderstanding of percentage, should be distinguished from epistemological obstacles and interpreted more cautiously as conceptual limitations.

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Such experiences are essential for preparing prospective teachers not only to solve contextual mathematical problems but also to anticipate, interpret, and respond meaningfully to similar difficulties in their future students.

AUTHOR CONTRIBUTIONS STATEMENT

Tri Nopriana contributed to conceptualization, research design, methodology, data collection, formal analysis, interpretation of the findings, and writing the original draft. Dina Pratiwi Dwi Santi contributed to data collection, data validation, qualitative analysis, interpretation of participants' responses, and manuscript review and editing. Siska Firmasari contributed to methodological validation, data interpretation, supervision, and critical revision of the manuscript for intellectual and academic content. All authors read and approved the final version of the manuscript.

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