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ANALYSIS OF INTEGER CONCEPT UNDERSTANDING BY PROSPECTIVE ELEMENTARY SCHOOL TEACHERS: IMPLICATIONS FOR ELEMENTARY MATHEMATICS TEACHING

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ABSTRACT

Mathematics is an essential subject in elementary education, with integers playing a key role as the foundation for more complex mathematical concepts. However, many students struggle to understand integers, particularly negative numbers and their operations. This study aims to analyze how prospective elementary school teachers represent the concept of integers and develop effective teaching strategies. A qualitative descriptive approach was employed, involving 12 prospective teachers divided into three groups based on their understanding of integers. The primary instrument used was the modified Content Representation (CoRe) to evaluate how these prospective teachers represent and teach integers. The results indicate that most prospective teachers have a good grasp of basic integer concepts and frequently use number lines as a visual aid. However, some teachers still face difficulties in explaining negative numbers and their operations. The use of technology, such as interactive applications and educational videos, was recognized as an effective strategy for improving students' understanding. This study concludes that developing pedagogical skills in prospective teachers, particularly in teaching integers, is crucial to enhancing the quality of mathematics instruction at the elementary level.

Keywords: *Integers; Content Representation; Pedagogical Content Knowledge; Prospective Teachers; Mathematics Teaching*

1. INTRODUCTION

Mathematics is a core subject in elementary education, and integers constitute a foundational concept for subsequent learning in number, algebra, and problem solving (Sidik & Wakih, 2020). Despite their centrality, persistent difficulties in understanding integers are widely documented at the student level, including

systematic misconceptions in operations with negative numbers and challenges linking symbolic rules to meaningful representations (Dewi & Haryanto, 2019; Mahmuda et al., 2021; Yanala, Uno, & Kaluku, 2021). Recent international work similarly underscores that many learners still struggle with connecting integer operations to conceptual models, and that classroom interventions often remain procedure-oriented rather than representation-rich (Süzen, Tutak, İlhan, & Nayiroğlu, 2024). This body of research, however, is predominantly student-centred mapping learners' errors and outcomes—while paying comparatively less attention to how prospective elementary teachers (pre-service teachers) understand, represent, and plan to teach integers.

Addressing this gap is critical because the quality of early mathematics instruction depends not only on teachers' content knowledge but also on their Pedagogical Content Knowledge (PCK) the integration of what to teach (content) and how to teach it (pedagogy) that enables the use of models, examples, and representations responsive to learners' difficulties (Shulman, 1986, 1987; Widodo, 2017). Contemporary international studies affirm that PCK develops during teacher education and practicum, yet they also reveal uneven growth across topics and persistent limitations in using multiple representations effectively (Li, 2024; Tossavainen, 2024; Dwirahayu, 2024). For instance, analyses of pre-service mathematics teachers' practicum experiences show that while teaching practice can catalyse PCK, many novices still underutilize manipulative-based and visual models when explaining core number ideas (Li, 2024; Tossavainen, 2024). Related research further indicates that beginning teachers' awareness of mathematical misconceptions remains variable, suggesting a need to explicitly cultivate diagnostic reasoning about learners' integer errors within teacher education curricula (Moosapoor, 2023).

Taken together, prior scholarship establishes (a) extensive student-focused evidence on integer misconceptions and low outcomes, and (b) emerging but still limited evidence on pre-service teachers' PCK especially their capacity to represent integer concepts through contexts, models (e.g., number line, counters, temperature/elevation), and multiple representations aligned to typical learner errors. Consequently, there is a clear research gap at the intersection of integers and pre-service teacher preparation: we know far less about how prospective elementary teachers conceptualize and represent integers and how these representations translate into planned instructional strategies. Addressing this gap is timely and novel, particularly in light of recent international findings (2023–2024) that call for strengthening topic-specific PCK and representation use in initial teacher education (Li, 2024; Tossavainen, 2024; Dwirahayu, 2024), and for bridging documented student misconceptions with teachers' pedagogical decision-making (Süzen et al., 2024; Moosapoor, 2023).

The present study responds to this need by analysing how prospective elementary teachers represent integer concepts and articulate teaching strategies for introducing and consolidating these ideas. By foregrounding representational competence (e.g., selecting and coordinating number-line, context, and manipulative models) as a core dimension of PCK, this research contributes (i) topic-specific evidence on pre-service teachers' understanding of integers, and (ii) design implications for teacher education that directly target common student difficulties with negative numbers and integer operations. In doing so, the study advances the international conversation on strengthening PCK in initial teacher education and offers actionable insights for improving early mathematics instruction on a concept that underpins later mathematical learning.

2. RESEARCH METHOD

This study uses a qualitative descriptive approach, which aims to describe phenomena according to existing conditions without manipulating independent variables (MacMillan and Schumacher 2001). This study focuses on second-semester elementary school teacher candidates taking mathematics learning courses at Ganesha University of Education, with 12 research subjects divided into three groups based on the results of the integer *content knowledge ability test.*

The population of this study was selected using the *stratified random sampling method* . In this technique, the population is divided into strata based on certain characteristics, such as the level of knowledge of integers. From each stratum, a random sample was taken, resulting in a total of 12 students as respondents, consisting of 4 students from the high ability group, 4 students from the medium ability group, and 4 students from the low ability group (Amoah et al. 2020).

The main instrument used in this study was *the Content Representation* **(CoRe)** , which was developed by Loughran et al. (2012)and modified to measure representation of integer content. CoRe allowed researchers to analyze how prospective teachers represented integer concepts and the strategies they used in their teaching.

Data collection was conducted through interviews and document analysis . The interviews aimed to explore the representations and teaching strategies implemented by student teachers. The data analysis process included transcription, coding, grouping, and drawing conclusions from the interviews and related documents.

3. RESULT AND ANALYSIS

RESULT

Respondents (prospective teachers) consistently identified the definition of integers (negative–0–positive), basic operations (addition–subtraction–

multiplication–division), and the number line as the main components. The majority mentioned the properties of operations (commutative, associative, distributive) and sign rules, although some were still unclear about the characteristics of integers (misdefinitions and misconceptions). The dominant representations included: number lines, temperature/altitude contexts, and debt-credit analogies.

The selection of basic topics was driven by their function as prerequisites for more advanced topics (introductory algebra) and their everyday relevance (money/temperature/time). Prospective teachers emphasized a gradual sequence: concept → operation → contextual application.

Respondents generally postponed highly abstract concepts (logarithms, formal algebra, advanced geometry, proofs) to higher grade levels. Some also preferred to delay complex operations with negative integers until the prerequisite concepts were firmly established.

The most frequently cited challenges were: (i) the meaning of the negative sign (why (−)×(−)=+), (ii) placement and ordering on the number line, (iii) transferring from procedural rules to conceptual reasoning, and (iv) heterogeneity in students' learning styles and prior knowledge.

Proposed strategies included: the use of concrete contexts and manipulatives, varied media (visuals, games/ice-breakers), step-by-step practice with feedback, cooperative/peer-tutoring learning, and diverse formative assessments (quizzes, oral questioning, process observation). Frequently used technology included: slides/presentations, instructional videos, interactive quizzes (Quizizz/Kahoot), collaborative boards (Jamboard), and where available mathematics applications (GeoGebra/Khan Academy). Adaptation to facility limitations was mentioned as a key consideration..

ANALYSIS

Critical Synthesis and Theoretical Connections

The findings affirm that representational competence (the ability to select and coordinate number lines, contexts, and manipulatives) is a key component of Pedagogical Content Knowledge (PCK) (Shulman). The gradual sequencing pattern aligns with Vygotskian constructivism (scaffolding within the ZPD) and cognitive load reduction principles. The difficulties with negative signs and ordering support the cognitive development literature (highlighting the challenge of transitioning from "all positive" experiences to invisible negative entities).

However, the analysis also reveals two gaps:

- **Procedural dominance over reasoning**: respondents often begin with "sign rules" rather than building meaning through models (counters/tiles, directional relationships on the number line, rise-and-fall contexts).

- **Insufficiently diagnostic assessment variation:** quizzes and oral questioning are used but not yet systematically map error patterns (for example: assuming −3 is greater than −1 because |−3| > |−1|).

These findings are consistent with patterns reported in several contexts:

- Finland and Scandinavia: prospective teachers are strong in curriculum-based planning and representation bridging but still require explicit training to coordinate multiple models within a single lesson.
- United States and Canada: the focus on number talks and productive struggle promotes conceptual reasoning, yet prospective teachers still need task designs that link the number line to real contexts (temperature/elevation) so that sign rules are not taught merely as mnemonics.
- Turkey and East Asia: the use of manipulatives (cards/tiles) has increased, but the translation from manipulatives to symbolic representation is not always made explicit; common errors in mixed operations with negatives still appear in non-routine tasks.

Critically, the findings of this study add evidence that the main strengths of prospective teachers lie in sequencing and selecting basic visual tools, while the areas needing reinforcement are: (i) reasoning about why, not just how; (ii) diagnostic assessment based on error analysis; and (iii) technology integration that goes beyond quizzes toward dynamic representations (e.g., animations of shifts on the number line or vectors).

Practical Implications for Teacher Education

To ensure that the research results are directly integrated into teacher education programs (PGSD/PPG), the following implementation plan is proposed, based on CoRe and PCK:

a) 4–6 Session Module Design: "Integers for Teaching"

Session 1 – Big Ideas & Misconceptions Mapping

Product: Misconception map (negative sign, ordering, mixed operations) and anticipation guide.

Activity: Analysis of student work and error patterns (10-minute light diagnostic).

Session 2 – Representations that Explain (Not Just Show)

Focus: Coordination of number line ↔ context (temperature/debt-credit/elevation) ↔ manipulatives (two-color counters).

Rubric: "Can your representation explain why (−)×(−)=+ without citing a mere 'sign rule'?"

Session 3 – Task Design & Cognitive Demand

Output: Tiered tasks: from bridging tasks (concrete → visual → symbolic) to non-routine problems.
Principle: multiple entry points & low floor–high ceiling design.

Session 4 – Formative Assessment & Feedback
Instruments: Exit slip using two-tier items (answer + reasoning), 5-minute diagnostic interview protocol.
Practice: Feedback moves (probe – revoice – press for reasoning).

Session 5 – Tech for Dynamic Meaning
Tools: GeoGebra/Desmos for number line shift animations and "step-and-direction" simulations.
Criterion: technology must enrich conceptual meaning (not just function as a quiz tool).

Session 6 – Microteaching & CoRe Artifact
Final Product: CoRe for the integer subtopic (big ideas, assessment, representation, anticipated misconceptions), plus a 10–12 minute microteaching video.

b) Recommended Concrete Teaching Aids

- Two-color counters (physical or virtual), integer chips, temperature/altitude cards.
- CoRe template and representation assessment rubric (accuracy, clarity, inter-model connectivity, conceptual reasoning).
- Tiered diagnostic item bank (e.g., testing negative number ordering, mixed operations, and justifications).

c) Program Success Evaluation

- PCK Gain: Pre–post measurement using student work analysis scenarios and content representation inventory.
- Lesson Quality: Microteaching rubric (coherence of flow, explicitness of "why," use of multiple representations).
- Classroom Transfer: Follow-up during teaching practicum (short observations focused on representation and formative assessment).

Limitations and Directions

Data are sourced from the answers of prospective teachers in one study program context; observations of real classroom practice are limited. Further studies need to assess the accuracy of representations in teaching performance (not just plans), as well as test the effectiveness of the above modules on the

achievement of PCK and understanding of elementary students on the topic of integers.

4. CONCLUSION

The results of this study indicate that prospective elementary school teachers have a fairly good understanding of the basic concepts of integers and the importance of implementing effective teaching strategies. The majority of respondents emphasized gradual teaching, starting with an introduction to the concepts of positive numbers, zero, and negative numbers, as well as basic integer operations. Number lines were also frequently identified as a useful visual aid in clarifying students' understanding. However, several misunderstandings regarding integer concepts remain that need to be addressed, particularly regarding operations with negative numbers and the use of signs in mathematical operations.

The use of technology in integer learning is recognized as having significant potential to increase student engagement and understanding. Interactive applications like Quizizz and Kahoot, as well as visual media like PowerPoint and YouTube videos, are frequently used by prospective teachers to enrich their teaching methods. However, it is important to adapt the technology to the resources available at the school and to consider the diverse needs and learning styles of students.

This research underscores the importance of further developing prospective teachers' pedagogical content knowledge (PCK) regarding integer concepts. Improved training and guidance are needed to enable prospective teachers to address teaching difficulties, particularly in explaining negative numbers more effectively. This research also provides a basis for developing better learning models to improve elementary school students' mathematical understanding, particularly in integer concepts.

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