

EXAMINING THE RELATIONSHIP AMONG BELIEFS, PEDAGOGICAL-MATHEMATICAL KNOWLEDGE, AND EARLY NUMERACY INSTRUCTION IN PRE-SERVICE TEACHERS: AN EXPLORATORY SEQUENTIAL MIXED-METHODS STUDY

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Abstract

Early numeracy provides a foundation for later mathematical learning, yet early instruction often falls short of developmental expectations. This exploratory sequential mixed-methods study examined how pre-service early childhood teachers' belief orientations and pedagogical-mathematical knowledge jointly relate to instructional practice in early numeracy. In Phase I, six pre-service teachers were purposively selected and studied through interviews, lesson-plan analysis, and teaching observation. Cross-case thematic analysis identified three dominant belief orientations, namely instrumentalist, Platonist, and problem-solving, together with hybrid profiles that revealed uneven links between symbolic and contextual approaches. In Phase II, 182 pre-service teachers from three public universities in East Java completed an expert-reviewed and empirically screened 90-item questionnaire measuring belief orientation, pedagogical-mathematical knowledge, and self-reported instructional practice. The integrated regression model explained 73.4% of the variance in instructional practice ($R^2 = 0.734$, $p < .001$). Both belief orientation ($\beta = 0.328$, $p < .001$) and pedagogical-mathematical knowledge ($\beta = 0.568$, $p < .001$) significantly predicted practice, with pedagogical-mathematical knowledge emerging as the stronger predictor. The integrated findings suggest that beliefs shape pedagogical direction, whereas pedagogical-mathematical knowledge determines how effectively that direction can be enacted. The study contributes to the literature by showing that the belief-practice relationship in early numeracy is best understood as an enactment issue: beliefs orient teaching, but knowledge enables meaningful classroom implementation. The findings imply that teacher education should move beyond efforts to reshape beliefs alone and invest more systematically in topic-specific pedagogical knowledge of number concepts, representations, misconceptions, and scaffolding.

Keywords: Early Numeracy, Instructional Practice, Mixed-Methods Research, Pedagogical-Mathematical Knowledge, Teacher Beliefs



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INTRODUCTION

Early numeracy provides a crucial foundation for later mathematical learning. In early childhood settings, learning about number involves far more than recognizing numerals or reciting counting sequences. Young children must gradually coordinate quantity, order, one-to-one correspondence, and cardinality in ways that connect concrete experience with symbolic representation (Gelman & Gallistel, 1978; Sella et al., 2021). Effective teaching in the early years should therefore help children move from hands-on activity toward increasingly abstract mathematical understanding (Baroody & Coslick, 1998). Despite broad agreement on this developmental perspective, classroom practice often falls short of it. Early mathematics instruction still tends to emphasize symbol recognition, worksheet routines, and whole-group transmission rather than exploration, manipulation, and reasoning (Hamukonda & Luneta, 2023; Elmalı et al., 2025). This gap suggests that instructional decisions are shaped not only by knowledge of child development, but also by the beliefs teachers hold about mathematics and about how young children learn it (Pajares, 1992). Ernest (1989) identifies three broad orientations toward mathematics teaching, namely instrumentalist, Platonist, and problem-solving, and these orientations matter because they shape instructional priorities, classroom interaction, and the kinds of tasks teachers consider worthwhile (Beswick, 2012).

Beliefs alone, however, cannot fully explain instructional practice. Teachers may endorse student-centered ideas yet still struggle to translate those commitments into coherent teaching. This points to the importance of pedagogical knowledge, especially the kind of knowledge that enables teachers to transform mathematical content into forms that are accessible to young learners. Ball et al. (2008) argue that effective mathematics teaching requires not only mathematical understanding, but also the ability to represent ideas, anticipate misconceptions, and design instruction that supports conceptual growth. In early numeracy, such knowledge is especially important because number concepts are developed through carefully sequenced experiences rather than through symbol exposure alone (Li et al., 2024; Satan et al., 2024).

Belief orientation and pedagogical knowledge should therefore be viewed as complementary rather than competing influences on instructional practice. Beliefs shape what teachers notice, value, and intend to do, whereas pedagogical knowledge shapes how effectively those intentions can be enacted in practice. Recent research continues to show that beliefs, pedagogical content knowledge, and instructional motivation are related but not reducible to one another (Fukaya et al., 2024; Dağlı & Buldur, 2025). Evidence from early mathematics classrooms likewise suggests that topic-specific pedagogical knowledge predicts instructional quality more directly than broad reform-oriented commitments alone (Hill et al., 2008; Orcan-Kacan et al., 2023).

This issue is particularly important for pre-service teachers. At this stage, professional beliefs are still forming, while pedagogical knowledge is being developed through coursework and practicum experience. Recent reviews have emphasized that mathematics teacher knowledge becomes most meaningful when it is treated as topic-specific and enactment-oriented rather than as a generic teaching competence (Grigaliūnienė et al., 2025; Joaquim et al., 2025). Yet relatively few studies have examined how belief orientation and pedagogical-mathematical knowledge operate together in early numeracy, especially among pre-service early childhood teachers and in non-Western contexts. In Indonesia, this issue is especially salient because expectations for early symbol mastery may coexist with curricular ideals that promote child-centered learning. By integrating belief orientation and pedagogical-mathematical knowledge within one model, the present study offers a more comprehensive perspective for teacher education and curriculum development in Indonesia and in comparable educational contexts.

This study addresses that gap by examining the relative and combined contribution of belief orientation and pedagogical-mathematical knowledge to instructional practice in early numeracy. Using an exploratory sequential mixed-methods design, the study first identified belief orientations and pedagogical patterns qualitatively and then tested their predictive strength quantitatively. The study addressed three research questions: (1) What belief orientations characterize pre-service early childhood teachers in teaching number concepts? (2) What is the structure and depth of their pedagogical knowledge related to early numeracy? and (3) To what extent do belief orientation and pedagogical-mathematical knowledge predict instructional practice?

RESEARCH METHODS

Research Design

An exploratory sequential mixed-methods design (Creswell & Plano Clark, 2018) was used to examine teacher candidates' beliefs in depth through qualitative inquiry and then test the quantitative relevance of the resulting patterns. This design is well suited to complex constructs such as beliefs and pedagogical knowledge because it combines rich case-based analysis with broader statistical generalization about the factors associated with early numeracy teaching. In the qualitative phase, the study explored pre-service teachers' conceptions of early numeracy instruction and examined how those beliefs were reflected in lesson planning and teaching practice. In the quantitative phase, the study tested the predictive contribution of belief orientation and pedagogical-mathematical knowledge to instructional practice in a larger sample. Integration occurred during interpretation, when qualitative patterns were used to explain and deepen the quantitative findings.

This design was appropriate because the study did not begin with fixed explanatory categories. Instead, it first generated belief typologies and pedagogical patterns that later informed the interpretation of the quantitative constructs. The overall study sequence is presented in Figure 1.

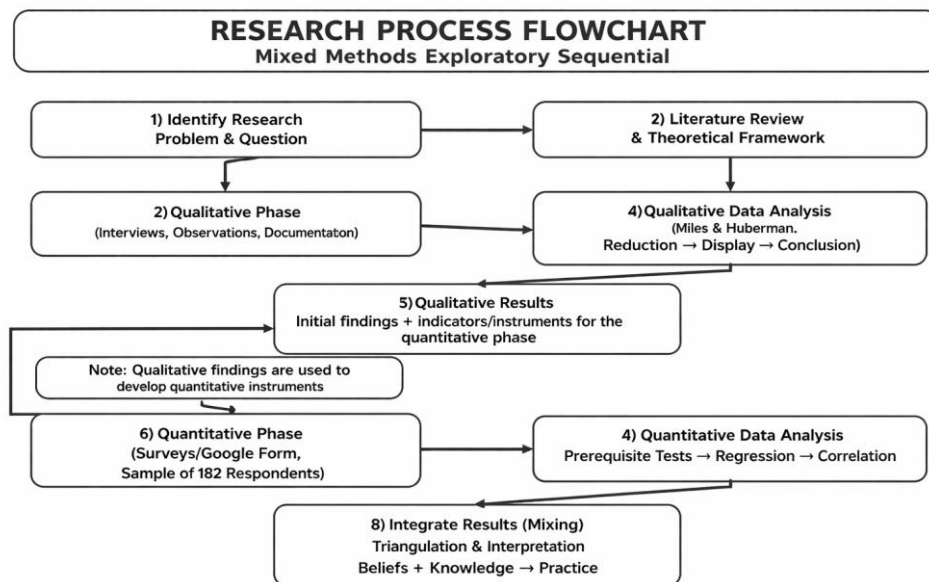


Figure 1. Research process flowchart.

Figure 1 summarizes the exploratory sequential mixed-methods procedure used in this study. The design began with a qualitative exploration of teacher candidates' beliefs, lesson planning, and enacted instruction, and then moved to a quantitative phase that tested the predictive strength of the main constructs in a larger sample. This sequence allowed the study to move from nuanced case-based understanding to broader empirical validation.

Participants

In the qualitative phase, six pre-service early childhood teachers were purposively selected to represent low, medium, and high academic achievement based on grade point average. This strategy was intended to capture a broad range of pedagogical beliefs and practices across different levels of academic performance. The quantitative phase involved 182 sixth-semester pre-service teachers from three public universities in East Java. Participants were selected through cluster sampling. To be included, respondents had to have completed mathematics-related coursework and at least one teaching practicum. These criteria ensured that participants had sufficient exposure to early numeracy instruction to respond meaningfully to the instrument.

Instruments and data collection

Three instruments were used in the qualitative phase: a structured interview guide, a lesson-plan task, and a classroom observation sheet. The interview guide focused on beliefs about mathematics, views of young children's number learning, and instructional decision-making. Participants were also asked to prepare lesson plans and demonstrate how they would teach selected number concepts. Taken together, these sources made it possible to compare what participants believed, what they planned, and what they enacted. The quantitative phase used a five-point Likert-scale questionnaire designed to measure belief orientation, pedagogical-mathematical knowledge, and instructional practice. The initial blueprint contained 94 items distributed across the three constructs. After item screening, the final version contained 90 items: 28 for belief orientation, 24 for pedagogical-mathematical knowledge, and 38 for instructional practice. Negative items were reverse-coded prior to analysis so that higher scores consistently reflected stronger endorsement of the intended construct.

Table 1. Construct specification for the quantitative instrument.

| Construct | Indicators | Number of items | Example focus |
|---|--|-----------------|--|
| Belief (X1) | Nature of mathematics (instrumentalist vs. constructivist) | 10 | Mathematics as rules vs. reasoning |
| | Beliefs about children's number learning | 12 | Exploration vs. memorization |
| | Role of teacher in numeracy instruction | 10 | Facilitation vs. direct transmission |
| | Total belief items | 32 | |
| Pedagogical-mathematical knowledge (X2) | Conceptual understanding of number principles | 10 | Cardinality, one-to-one correspondence |
| | Representational progression (CPA framework) | 7 | Manipulatives and visual models |
| | Awareness of misconceptions and scaffolding | 7 | Identifying counting errors |
| | Total knowledge items | 24 | |
| Instructional practice (Y) | Lesson planning for conceptual understanding | 12 | Activity design and sequencing |
| | Classroom implementation strategies | 14 | Questioning and interaction |
| | Assessment of number understanding | 12 | Beyond worksheet evaluation |
| | Total practice items | 38 | |

Table 1 shows that the instrument was designed to distinguish clearly among epistemological orientation, pedagogical understanding, and classroom enactment before empirical screening was conducted.

Data Analysis

Qualitative data were analyzed thematically through cross-case comparison of interviews, lesson plans, and observation evidence. This triangulated approach was used to identify recurring belief orientations and to examine whether pedagogical reasoning was consistent with enacted practice.

Research Quality and Ethical Considerations

Trustworthiness in the qualitative phase was strengthened through data-source triangulation, comparison across academic profiles, and the use of multiple forms of qualitative evidence rather than a single interview source. Ethical safeguards were applied throughout the study. Participation was voluntary, informed consent was obtained, and participant anonymity and data confidentiality were maintained during data collection, analysis, and reporting.

Quantitative analysis was conducted using SPSS version 27. The analysis included item-validity screening, reliability testing using Cronbach's alpha, assumption checking, Pearson correlation, and multiple linear regression. The psychometric results are reported in the Results and Discussion section because they form part of the empirical basis for interpreting the model.

RESULTS AND DISCUSSION

Qualitative Results

The qualitative phase identified three main belief orientations in teaching number concepts: Platonist, problem-solving, and instrumentalist. In addition to these dominant patterns, some participants showed hybrid tendencies that combined symbolic and contextual approaches. To ensure that these typologies were grounded in both stated beliefs and enacted practice, interview data, lesson plans, and classroom observations were triangulated.

Table 2. Triangulation of beliefs, knowledge, and practice across qualitative participants.

| Subject | Aspect | Indicator | Data (interview, lesson plan, observation) | Dominant orientation |
|---------|-----------|-----------------------------|---|----------------------|
| S1 | Beliefs | Problem-solving approach | Prefers concrete objects and play; uses real objects (balls) to teach quantity. | Problem-solving |
| S1 | Knowledge | Number concepts | Emphasizes one-to-one correspondence and cardinality through real objects. | Problem-solving |
| S1 | Practice | Activity-based teaching | Children count and compare with physical objects. | Problem-solving |
| S2 | Beliefs | Platonist approach | Prioritizes number symbols first; relies on symbol worksheets. | Platonist |
| S2 | Knowledge | Symbols and sequence | Introduces symbols before objects and stresses correct sequence. | Platonist |
| S2 | Practice | Worksheet-based symbol work | Children write numbers 1-10 and match symbols. | Platonist |
| S3 | Beliefs | Hybrid profile | Introduces symbols first, then links them to counted objects. | Hybrid |
| S3 | Knowledge | Linking symbols and objects | Uses objects to reinforce already introduced symbols. | Hybrid |
| S3 | Practice | Combined routine | Alternates between numeral work and counting fruits or toys. | Hybrid |
| S4 | Beliefs | Instrumentalist approach | Prioritizes number order and symbol recognition through repetition. | Instrumentalist |

| Subject | Aspect | Indicator | Data (interview, lesson plan, observation) | Dominant orientation |
|---------|-----------|-----------------------------------|---|----------------------|
| S4 | Knowledge | Structured repetition | Teaches number sequence mainly through repeated drill. | Instrumentalist |
| S4 | Practice | Repeated exercises | Children repeatedly write numbers and rehearse order. | Instrumentalist |
| S5 | Beliefs | Problem-solving tendency | Uses manipulatives and contextual tasks to support number meaning. | Problem-solving |
| S5 | Knowledge | Critical thinking and application | Connects counting to simple problem situations. | Problem-solving |
| S5 | Practice | Manipulative-based teaching | Children solve counting tasks using real objects. | Problem-solving |
| S6 | Beliefs | Instrumentalist approach | Believes children should memorize number symbols and sequences first. | Instrumentalist |
| S6 | Knowledge | Correct writing and sequence | Focuses on tracing and correct numeral formation. | Instrumentalist |
| S6 | Practice | Writing for recognition | Writing numbers is treated as the main introduction to number. | Instrumentalist |

Table 2 reveals clear contrasts across participants. Those with problem-solving orientations tended to use concrete objects, play-based tasks, and contextualized counting experiences. Participants with Platonist and instrumentalist orientations placed greater emphasis on symbols, sequence, repetition, and worksheet routines. Hybrid profiles suggested partial movement between symbolic and contextual approaches, but not yet a fully integrated instructional model.

Quantitative Results

The quantitative phase examined the measurement quality of the instrument and the statistical relationships among the three main constructs. The first step was to assess validity and reliability.

Table 3. Item screening and internal consistency of the quantitative scales.

| Scale | Initial items | Retained items | Validity rule | Cronbach's alpha |
|---|---------------|---|---|------------------|
| Beliefs (X1) | 32 | 28 (4 items removed: K2, K3, K9, and K29) | Corrected item-total correlation > .296 | $\alpha = .842$ |
| Pedagogical-mathematical knowledge (X2) | 24 | 24 | Corrected item-total correlation > .296 | $\alpha = .904$ |
| Instructional practice (Y) | 38 | 38 | Corrected item-total correlation > .296 | $\alpha = .983$ |

Table 3 indicates that four belief items were removed after item screening based on the item-total correlation criterion. The retained scales showed strong internal consistency, with Cronbach's alpha coefficients of .842 for beliefs, .904 for pedagogical-mathematical knowledge, and .983 for instructional practice. Taken together, Table 3 suggests that the final 90-item instrument was sufficiently reliable for the subsequent inferential analyses, although future studies may strengthen construct validation through factor-analytic procedures with larger samples. Before estimating the regression model, the standard assumptions of multiple regression were examined. The results are summarized in Table 4.

Table 4. Assumption checks for the multiple regression model.

| Assumption | Test | Decision rule | Result | Interpretation |
|--------------------|--|---------------|------------------------------------|--------------------------------|
| Residual normality | Kolmogorov-Smirnov test (unstandardized residuals) | $p > .05$ | $p < .001$ | Normality not supported |
| Linearity | Linearity test | $p > .05$ | $p = .816; .791; .835$ | Linearity supported |
| Homoscedasticity | Glejser test | $p > .05$ | X1: $p = .967$; X2: $p = .179$ | No heteroscedasticity detected |

Table 4 shows that the assumptions of linearity and homoscedasticity were satisfied, whereas the normality of residuals was not fully supported by the Kolmogorov-Smirnov test. Given the relatively large sample size ($N = 182$), the regression model was retained for analysis; however, the non-normal residuals should be considered when interpreting the results. Future studies may therefore consider robust or bootstrapped estimation procedures to assess the stability of the findings. The bivariate and multivariate relationships among beliefs, pedagogical-mathematical knowledge, and instructional practice are presented in Tables 5 and 6.

Table 5. Bivariate correlations and multiple correlation with instructional practice.

| Association | r | p |
|---|------------|----------|
| Belief orientation (X1) and instructional practice (Y) | .791 | $< .001$ |
| Pedagogical-mathematical knowledge (X2) and instructional practice (Y) | .835 | $< .001$ |
| Belief orientation and pedagogical-mathematical knowledge jointly with instructional practice (Y) | $R = .857$ | $< .001$ |

Table 5 shows that both belief orientation and pedagogical-mathematical knowledge were positively and significantly associated with instructional practice. The association between pedagogical-mathematical knowledge and instructional practice ($r = .835, p < .001$) was stronger than the association between belief orientation and instructional practice ($r = .791, p < .001$). The multiple correlation further indicates that, when considered together, the two predictors were strongly related to instructional practice ($R = .857, p < .001$).

Table 6. Multiple regression predicting instructional practice.

| Predictor | B | SE B | β | t | p |
|---|--------|-------|---------|-------|----------|
| Constant | -1.697 | - | - | - | - |
| Belief orientation (X1) | 0.557 | 0.113 | .328 | 4.926 | $< .001$ |
| Pedagogical-mathematical knowledge (X2) | 0.967 | 0.114 | .568 | 8.522 | $< .001$ |

Table 6 shows that the regression equation for predicting instructional practice was $Y = -1.697 + 0.557X1 + 0.967X2$. The overall model accounted for 73.4% of the variance in instructional practice

($R^2 = .734$, $p < .001$). Both belief orientation ($\beta = .328$, $p < .001$) and pedagogical-mathematical knowledge ($\beta = .568$, $p < .001$) made significant positive contributions to the model, with pedagogical-mathematical knowledge emerging as the stronger predictor.

Integrated Mixed-Methods Results

To integrate both phases, a joint display was developed to align the qualitative belief typologies with the quantitative model. Table 7 summarizes how the qualitative patterns informed the instrument and how the quantitative findings clarified the relative contribution of each construct.

Table 7. Joint display linking qualitative typologies and quantitative findings.

| Qualitative typology or indicator | Contribution to the quantitative strand | Quantitative evidence | Integrated meta-inference |
|---|---|---|--|
| Platonist tendency emphasizing symbols and worksheets | Informed questionnaire items capturing symbolic orientation and teacher-centered instructional tendencies | Belief orientation was a significant predictor, although its standardized effect was smaller than that of pedagogical-mathematical knowledge ($\beta = .328$, $p < .001$). | Beliefs appear to shape instructional direction, but they do not by themselves ensure high-quality enactment. |
| Problem-solving enactment using concrete materials and contextual tasks | Informed practice indicators related to CPA-oriented support, contextual counting, and scaffolding | Pedagogical-mathematical knowledge emerged as the stronger predictor of instructional practice ($\beta = .568$, $p < .001$). | Pedagogical-mathematical knowledge appears to support more faithful enactment of child-centered numeracy instruction. |
| Instrumentalist procedural rehearsal such as tracing and copying | Informed practice indicators that distinguished procedural routines from conceptual scaffolding | The regression model accounted for a substantial proportion of the variance in instructional practice ($R^2 = .734$). | Variation in instructional practice appears to be associated more strongly with enactment capacity than with belief orientation alone. |

Table 7 shows a coherent integrated pattern across the two phases. Belief orientation appears to shape the general direction of instruction, whereas pedagogical-mathematical knowledge appears to influence how effectively that direction is enacted in classroom practice. In this sense, the joint display helps explain why teachers with broadly progressive beliefs may still rely on narrow or procedural routines when their understanding of number concepts, representations, and scaffolding remains limited.

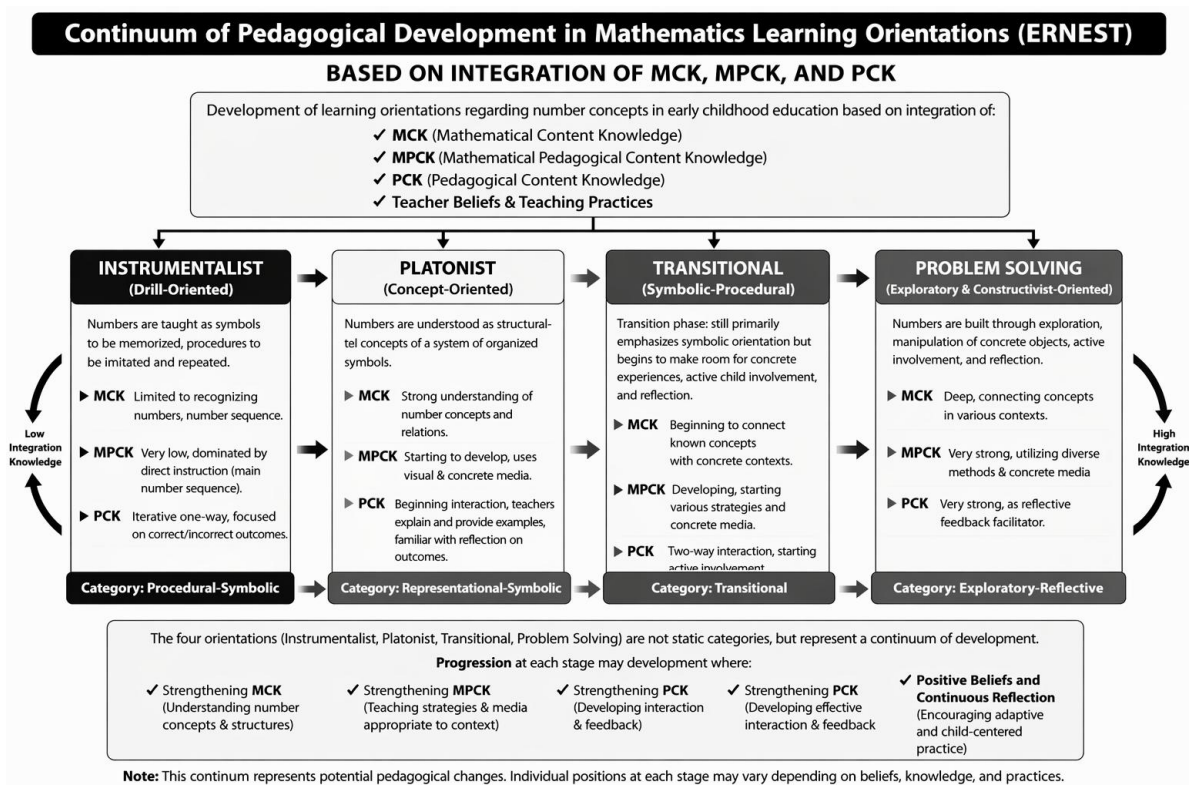


Figure 2. Continuum of Pedagogical Development in Mathematics Learning Orientations (ERNEST)

Figure 2 presents the continuum of pedagogical development in mathematics learning orientations identified in this study. The continuum extends Ernest's theory of mathematics-related beliefs, which distinguishes instrumentalist, Platonist, and problem-solving orientations. Building on that framework, the present study shows that pre-service teachers' pedagogical development is not organized into rigid categories. Instead, it unfolds along a continuum marked by varied positions and uneven integration of beliefs, mathematical knowledge, and pedagogical practice. Four developmental positions emerged from the data: procedural-symbolic, representational-symbolic, transitional, and exploratory-reflective. These positions capture differences in how pre-service teachers interpret number concepts, select instructional strategies, use representations or concrete media, and engage children in learning.

This study examined the beliefs held by pre-service early childhood teachers about numeracy instruction and showed how those beliefs were reflected in their teaching orientations. Across the qualitative and quantitative phases, the findings indicate that belief orientation and pedagogical-mathematical knowledge are closely related, but not interchangeable. The study contributes to the literature by showing that the belief-practice relationship in early numeracy is best understood as an enactment issue: beliefs guide pedagogical direction, but pedagogical knowledge enables those beliefs to be translated into meaningful classroom action. First, the qualitative findings show that belief orientation functions as a cognitive filter for early numeracy instruction. Participants with a Platonist orientation tended to emphasize symbols and structured transmission, whereas those with a problem-solving orientation were more likely to value manipulatives, contextual tasks, and active child participation. Instrumentalist profiles emphasized rehearsal and procedural correctness. These patterns are consistent with Ernest's (1989) framework and reinforce the argument that teachers' views of mathematics are closely tied to the forms of instruction they consider legitimate (Pajares, 1992; Beswick, 2012). They also align with recent studies showing that beliefs continue to shape what teachers notice and prioritize during mathematics instruction (Fukaya et al., 2024; Dağlı & Buldur, 2025).

Second, the study demonstrates that pedagogical-mathematical knowledge is a central resource for instructional enactment. Participants who showed stronger pedagogical understanding were better able to connect number principles, representations, and scaffolding strategies. In the quantitative phase, this pattern was reflected in the stronger correlation between knowledge and practice and in the larger

standardized regression coefficient for pedagogical-mathematical knowledge. This finding aligns with research on mathematical knowledge for teaching, which emphasizes that effective instruction depends not only on disciplinary understanding, but also on knowing how learners encounter, misunderstand, and reconstruct mathematical ideas (Ball et al., 2008; Hill et al., 2008). It is also consistent with recent early mathematics studies showing that topic-specific pedagogical knowledge predicts instructional quality and classroom mathematics opportunities more directly than broad reform-oriented commitments alone (Orcan-Kacan et al., 2023; Li et al., 2024; Satan et al., 2024).

Third, the integrated model clarifies the relationship between belief and practice. The findings do not suggest that beliefs are unimportant. On the contrary, beliefs were a significant predictor of instructional practice. However, the stronger role of pedagogical-mathematical knowledge indicates that belief alone is not enough. Teachers may hold child-centered or inquiry-oriented views, yet without sufficient pedagogical resources they may still rely on narrow routines, especially in foundational domains such as number. In this sense, beliefs help explain why teachers move in a particular instructional direction, whereas pedagogical knowledge explains how successfully they can move in that direction. This interpretation supports recent arguments that teacher learning should be understood in terms of enactment capacity rather than belief change alone (Grigaliūnienė et al., 2025; Joaquim et al., 2025).

These results have direct implications for teacher education. Programs that focus only on changing beliefs without deepening pedagogical knowledge may produce rhetorical commitment without strong classroom enactment. Pre-service teachers need structured opportunities to study number concepts in depth, analyze misconceptions, design representational sequences, and test those sequences in practice. Coursework and practicum should therefore be connected more explicitly so that conceptual understanding, pedagogical reasoning, and classroom implementation develop together. Recent professional-development studies point in the same direction: teachers benefit most when content, pedagogy, and reflective analysis of enacted practice are integrated rather than separated (Parviainen et al., 2024; Elmalı et al., 2025).

The study also carries broader implications for early childhood mathematics education in Indonesia and comparable contexts. When early numeracy is taught mainly through symbol rehearsal, children may appear fluent in surface routines while lacking robust conceptual understanding. Strengthening pre-service teachers' pedagogical knowledge can help prevent this mismatch by enabling instruction that links counting, quantity, representation, and meaning. In other words, improving early numeracy teaching requires more than encouraging teachers to value child-centered pedagogy; it requires equipping them with the knowledge needed to enact it effectively.

Several limitations should be noted. The study used a cross-sectional design, so it does not establish causal development over time. The qualitative phase involved only six participants, which limits breadth of representation even though it supported rich case comparison. In addition, the quantitative dimension relied on self-reported instructional practice, which may not capture classroom enactment as directly as observation-based measures. Although the instrument demonstrated strong item-level validity and internal consistency, future studies could strengthen construct validation through factor-analytic procedures and additional robustness checks. Longitudinal designs, larger multi-site samples, and direct classroom observations would further strengthen the evidence base.

CONCLUSION

This study shows that pre-service early childhood teachers hold distinct belief orientations toward number instruction and that these orientations shape how they approach teaching. However, pedagogical-mathematical knowledge emerged as the stronger predictor of instructional practice. The mixed-methods evidence suggests that beliefs provide pedagogical direction, whereas pedagogical-mathematical knowledge enables that direction to be translated into effective classroom action. Strengthening pedagogical knowledge in teacher education is therefore essential for improving the quality of early numeracy instruction. More broadly, the findings suggest that improving early numeracy teaching requires attention not only to what teachers believe, but also to the topic-specific pedagogical resources that allow those beliefs to be enacted well.

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AUTHOR CONTRIBUTIONS

Conceptualization, S.W., T.E.Y.S., W., and N.M.; methodology, S.W. and T.E.Y.S.; validation, T.E.Y.S., W., and N.M.; formal analysis, S.W.; investigation, S.W.; data curation, S.W.; writing, original draft preparation, S.W.; writing, review and editing, T.E.Y.S., W., and N.M.; supervision, T.E.Y.S., W., and N.M. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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