Decision-making Skills of Prospective Mathematics Teachers in Designing Numeracy Tasks: A Study of Medium Level Pedagogical Content Knowledge

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Designing effective, contextual, and meaningful numeracy tasks requires prospective teachers to integrate their pedagogical content knowledge (PCK) with robust decision-making skills. This study aimed to explore the decision-making skills of three prospective mathematics teachers with medium-level PCK. They were purposively selected from thirty-one participants based on an initial numeracy task assessment. The analysis intentionally focused on those with medium-level PCK, as it represents a critical transitional level. After completing the task design, in-depth interviews were conducted, and data validity was ensured through member checking. The findings indicate that the participants' decision-making processes contained notable gaps in several parts of task design. The prospective teachers tended to overlook critical task details, focusing mainly on numeracy aspects while neglecting key components of PCK. Their task designs were generally limited to application-level word problems adapted from textbooks by merely altering the context and lacked opportunities for reasoning and creative thinking. They also determined task difficulty based on personal assumptions rather than students' learning needs. These findings underscore the importance of enhancing teacher education curricula by incorporating learning models that foster PCK-based decision-making skills, thereby supporting the holistic professional development of prospective mathematics teachers.

Keywords • decision-making • designing • numeracy task • prospective mathematics teacher • pedagogical content knowledge

Introduction

In contemporary mathematics education, numeracy is increasingly recognised as a fundamental competence that enables learners to apply mathematical knowledge meaningfully in real-world contexts and to make informed decisions (Cockroft, 1982; Goos et al., 2019; OECD, 2023). Although numeracy is frequently discussed alongside related constructs as mathematical literacy and quantitative literacy, these terms differ in emphasis (Lestari, 2020). Mathematical literacy foregrounds reasoning and interpretation in real-world problem solving, while quantitative literacy emphasises mastering fundamental mathematical skills (Ojose, 2011; Tout et al., 2017). In this study, numeracy is conceptualised as the ability necessary for individuals to confidently employ their understanding of number sense, mathematical reasoning, and contextual understanding to interpret quantitative Information and respond meaningfully to real-world situations. This working definition positions numeracy as a foundational capacity that supports students' proficiency in using mathematical ideas to engage with real-life challenges.

Students' numeracy proficiency enables them to utilise numerical concepts, symbols, mathematical operations, and basic mathematical knowledge to tackle real-life challenges in the future. However, mastering numeracy poses challenges, as traditional mathematics education often emphasises routine problem-solving exercises that may not align with real-world problems. This is reflected in the low academic performance of Indonesian students in both national and international assessments, such as the Minimum Competency Assessment (AKM) and Programme for International Student Assessment (PISA), which assess numeracy or mathematical literacy. Familiarising students with solving numeracy problems through learning mathematics may be a possible solution, as numeracy is not a separate scientific discipline in some countries, such as Indonesia.

Designing learning tasks constitutes a crucial responsibility for teachers aiming to support numeracy development, as tasks shape the nature of students' cognitive engagement and enhance learning opportunities. Different types of tasks offer varying potential for fostering mathematical competencies such as reasoning, problem solving, and modelling (Geiger et al., 2023). Accordingly, in mathematics education, learning tasks are commonly distinguished into routine and non-routine tasks, alongside subcategories such as open-ended, modelling, and contextual tasks (Adleff et al., 2023; Geiger et al., 2023). Routine tasks typically emphasise familiar procedures and require limited higher-order reasoning, whereas non-routine tasks invite exploration, strategy construction, and modelling, often without predetermined solution pathways (Adleff et al., 2023). Research consistently shows that non-routine and open-ended tasks support students' reasoning, problem-solving flexibility, discursive participation, and mathematical creativity (Mellroth et al., 2021; Norqvist et al., 2023; Özen & Köse, 2024). Consequently, teachers must consciously design and adapt tasks to balance cognitive demand with appropriate pedagogical support (Klein & Leikin, 2020). Designing such tasks requires integrating content knowledge with pedagogical considerations about how students learn mathematics more easily or even directly use it to solve problems. This integrated knowledge is conceptualised as Pedagogical Content Knowledge (PCK), which encompasses Knowledge of Content and Students, Knowledge of Content and Teaching, and Knowledge of Curricular (Ball et al., 2008). In numeracy education, PCK plays a critical role in guiding teachers' decision-making, particularly when designing non-routine and contextually meaningful numeracy tasks.

When PCK refers to the knowledge required to design numeracy tasks, decision-making skills help teachers design effective tasks. Decision-making is a complex cognitive process that requires strategic, creative, critical, and reflective thinking to choose a preferred course of action from multiple alternatives based on specific criteria or strategies (Swartz et al., 1998, Lubis et al., 2020). Recent studies in mathematics education further emphasise that decision-making is closely related to analytical thinking and mathematical competence, highlighting its relevance in the contemporary mathematics learning context (Kooloos et al., 2022; Wang et al., 2025). It is also applicable in decision-based systems, where individuals make choices, such as in informatics and cognitive systems, as well as in managerial contexts, where managers make decisions (Obi & Agwu, 2017), in socio-scientific problem solving (Zafar et al., 2017), and in mathematics learning, particularly when individuals attempt to solve incomplete problems (Abdillah et al., 2016).

Decision-making, being a task that engages advanced cognitive functions, naturally involves intricate stages rather than straightforward ones. The decision-making process is typically depicted as a multifaceted journey comprising three main phases: (1) pre-selection stage, (2) selection stage, and (3) post-selection stage (Betsch & Haberstroh, 2005). In this study, decision-making was operationalised through the following stages: defining the scope of decision-making, generating ideas, clarifying ideas, evaluating the reasonableness of ideas, and reflecting (Suwarno et al., 2022). For prospective mathematics teachers, decision-making is closely related to their task decision-making skills, a complex professional competency that involves selecting and designing mathematical tasks (Hammer & Ufer, 2023; Taufiq et al., 2023b). This requires consideration of cognitive, pedagogical, and contextual factors. This decision-making process is influenced by a realistic understanding of task complexity (Peled & Balacheff, 2011), teaching experience (Taufiq et al., 2023a), and the ability to align cognitive demands with student learning needs (Marco & Palatnik, 2024). Collaborative and iterative professional development has been shown to be effective in improving teachers' skills in implementing cognitively challenging tasks (Possamai & Allevato, 2024). Task design necessitates a thoughtful approach, wherein teachers creatively explore diverse alternatives, elucidate each option, and evaluate the reasonableness of the chosen approach

Several studies have investigated the design of learning tasks or problems (Lestari et al., 2018; Suryanti et al., 2022; Suwarno, 2019), as well as the decision-making of teachers or prospective teachers (Kosko, 2016; Murtafiah et al., 2019, 2021, 2023). These studies have provided important insights into how educators construct instructional tasks and the types of decisions involved in task design, as well as examined teachers' and students' proficiency in preparing learning tasks. More recent research has extended this work by exploring prospective teachers' task design processes on open mathematical tasks (Lee et al., 2024), and their task design considerations through the lens of didactical situations theory (Daher et al., 2022).

Prior research, however, has largely treated task design and decision-making as separate analytical foci, either by identifying types of decision-making employed when crafting tasks or by evaluating teachers' proficiency in preparing tasks and students' proficiency in completing tasks. Limited attention has been given to how PCK is utilised within the decision-making process itself. Yet, effective decision-making can be achieved when teachers or prospective teachers harness PCK as a cognitive tool to guide their instructional choices (Lestari, 2020; Lestari et al., 2019). Therefore, PCK serves as a pivotal role in shaping the quality of teachers' decision-making when translating mathematical ideas into practical learning tasks.

Based on the description above, an in-depth exploration is necessary to examine the decision-making processes of prospective mathematics teachers in designing numeracy tasks, focusing on how their pedagogical content knowledge (PCK) is mobilised across various stages of task design. This study offers valuable insights that can inform the development and refinement of teacher education curricula, particularly in fostering PCK-based decision-making competencies among prospective mathematics teachers. It also supports the alignment of Graduate Competency Standards within the Indonesian National Qualifications Framework (KKNI) level 6 for the Bachelor of Education. This analysis will be based on an understanding of decision-making informed by PCK. Moreover, it will involve evaluating the outcomes of curriculum implementation to offer recommendations for enhancing teacher education programs in the future. The development of a learning model designed to cultivate PCK-based decision-making represents a long-term objective stemming from this effort.

Methods

The research reported on in this article is a qualitative study aimed at exploring the decision-making skills of prospective mathematics teachers based on their Pedagogical Content Knowledge (PCK). To address this aim, a sequence of research procedures was employed.

Participants and Participant Selection

The participants in this research were 30 prospective mathematics teachers in their seventh semester of the Mathematics Education program at Jember University. These prospective teachers had either completed a microteaching course or participated in a teaching assistant program. They participated in the PCK assessment to select three participants for in-depth interviews. The PCK assessment was conducted in three distinct phases.

1. Pre-planning Phase: PCK was measured through a self-report questionnaire using the PCK Questionnaire Instrument. This instrument was designed to assess the participants' conceptual understanding of pedagogical and content knowledge before they began any lesson planning.
2. Planning Phase: The prospective teachers' lesson planning abilities were observed using the PCK Planning Stage Observation Instrument. This involved an evaluation of the teaching materials they prepared, including lesson plans, teaching modules, instructional aids, student worksheets, educational media, and assessment tools.

3. Implementation Phase: The final phase involved direct observation of the teaching implementation, either in a classroom setting or through recorded instructional videos. The PCK Implementation Observation Instrument was used to assess how effectively participants applied their pedagogical and content knowledge during teaching activities.

After data were collected from these three phases, individual PCK scores were calculated by averaging the results from each phase. Participants were then categorised into three levels of PCK: low, medium, or high. Based on this categorisation, five participants were classified as having low-level PCK, twenty-two as medium-level PCK, and four as high-level PCK. This study intentionally focused on participants with medium-level PCK, as this group represents a critical transitional level in which prospective teachers possess foundational knowledge but still demonstrate limitations in integrating pedagogical and content knowledge. Prospective teachers with medium-level PCK in this research demonstrated an adequate but not yet deep understanding of Knowledge of Content and Teaching (KCT) and Knowledge of Content and Students (KCS). They showed basic understanding of mathematical content and Instructional methods, but experienced difficulties in optimally embedding both. Although they were able to organise and deliver the content, they often struggled to adjust instructional strategies to address students' difficulties and learning needs. To facilitate an in-depth qualitative analysis, three female participants from the medium-level PCK group, who shared similar academic performance (with a GPA above 3.5 on a 4.0 scale), were selected purposively and assigned the initials S1, S2, and S3 to maintain confidentiality.

Data Collection

The three participants (S1, S2, and S3) selected were asked to design numeracy learning tasks. Once these tasks were completed, semi-structured interviews were conducted to investigate the decision-making processes involved in their task designs, with a particular focus on their awareness and utilisation of PCK during the decision-making process.

The validity of the research instruments was established through expert judgment. The numeracy task design task and the semi-structured interview protocol were reviewed by three mathematics education experts to examine their content relevance, clarity, alignment with the study objectives, and suitability for eliciting prospective teachers' decision-making processes. Revisions were made based on the experts' feedback to ensure that the instruments captured the intended constructs.

The interviews were designed to explore the following indicators of decision-making (Suwarno et al., 2022):

1. Defining the decision-making scope: How the participants identify and outline the goals of their task designs.
2. Generating ideas: The process of brainstorming and considering different possibilities for the task.
3. Clarifying ideas: How the participants refine and elaborate on their chosen ideas.
4. Evaluating the reasonableness of ideas: The consideration of practical constraints and the appropriateness of the task for the target students.
5. Reflecting on the process: An assessment of their decisions in hindsight, and how their understanding of PCK influenced their choices.

Data Validity

The validity of the data was ensured through a member-checking process. After each interview, the participants were provided with summaries of their responses to confirm the accuracy and authenticity of the information captured. This step was crucial in ensuring that the findings represented accurately the participants' experiences and reflections.

Data Analysis

The data collected from the interviews and task designs were analysed qualitatively using the following stages.

1. Data reduction: focusing on key themes related to decision-making and PCK.
2. Data display: organising the data into visual or written displays to identify patterns and relationships between the participants' decision-making processes and their PCK levels.
3. Conclusion drawing and verification: synthesising the findings to draw conclusions about the nature of decision-making among prospective teachers with low levels of PCK. These conclusions were continually verified through comparison with the raw data and literature.

The entire data analysis process was guided by the indicators of decision-making, ensuring that the study's findings provided a nuanced understanding of how PCK influenced decision-making in numeracy task design. Table 1 shows the indicators used to explore the decision-making of prospective teachers, adapted from Suwarno et al. (2022). This adaptation extends the reflection phase by highlighting how they might improve the task if given the opportunity to do it again.

Table 1.
Indicators of Decision-making Skills

Phase of Decision Making	Indicators
Defining the scope of decision-making	1. Identifying and defining decision-making objectives (developing numeracy task design)
	2. Formulate the basic information needed to make the assignment decision
Generating ideas	1. Listing ideas based on the formulated basic information to develop a level-appropriate numeracy task design
	2. Explaining the details of the ideas
Clarifying ideas	1. Explaining the assumptions/arguments of the generated idea
	2. Comparing the possibility of one idea with other ideas.
Evaluating the reasonableness of ideas	1. Determine the suitability of the idea (e.g. content of the material and the context of the problem/story raised, as well as the numbers involved) with the cognitive development of students
	2. Make logical predictions of ideas through testing the reliability of ideas by completing the developed numeracy task design.
Reflecting	1. Reconsider the appropriateness of decision-making results based on established criteria (Numeracy Problem)
	2. Considering/reviewing the decision-making stages of development of numeracy task design

Findings

This section presents the findings from an analysis of the decision-making processes of prospective mathematics teachers with medium-level PCK as they designed numeracy tasks. The findings are based on an in-depth interview of three participants and are discussed in relation to key stages of decision-making, including defining the scope of the task, generating and clarifying ideas, evaluating feasibility, and reflecting on the task design. The focus is on how prospective teachers at a medium level of PCK navigated each of these stages and the challenges they encountered during the task design process.

Decision-making Skills of Participant S1

The numeracy task design created by Participant S1 is presented in Figure 1. The following subsections describe Participant S1's decision-making process across the five stages, drawing on both the task artefact and interview data.

NUMERATION PROBLEMS

Material :Sequence and series

Level :SENIOR HIGH SCHOOL

Class :XI

Problem :

Every day Ayu gets pocket money from Dad amounting to IDR 20,000. In the first month, Ayu saved IDR 2,000/day. In the second month, save IDR 4,000/day. In the third month, save IDR 6,000/day. In the fourth month, save Rp. 8,000/day and so on for up to one year (calculating that one month = 30 days). After one year, Ayu's savings will buy an electric motorbike for IDR 4,599,000.

a. Write down the sequence pattern.
b. Is the sequence pattern an arithmetic sequence? If true, how is the solution to this problem?
c. Is the sequence pattern a geometric sequence? If true, how is the solution to this problem?
d. Can Ayu buy an electric motorbike for IDR 4,599,000 in one year?

Steps:

1. Provide explanations to students regarding sequence and series material.
2. Relate the concept of sequences and series to problems in everyday life.
3. Provide examples of contextual problems related to sequence and series material.
4. Provide explanations to students in understanding the problem, planning a solution, solving the problem according to plan, then writing conclusions based on calculations.
5. Provides practice on numeration questions related to sequences and series.
6. Direct students to use the completion steps according to point 4 which has been explained.
7. Appoint one of the students to present the results of their work and discuss it with the other students.

Figure 1. Numeracy task design by Participant S1.

Skill in formulating decision-making space

At this phase, Participant S1 began by identifying and defining the objectives for developing the numeracy task design. S1 explained that her first consideration was determining the relevant content, opting for the topic of sequences and series. She then attempted to connect these mathematical concepts to real-life situations, aiming to make the task more relatable to students. Her considerations, however, remained surface-level, focusing mainly on content relevance rather than the broader pedagogical or cognitive needs of the students. When asked about the information necessary for decision-making, S1 indicated that she relied primarily on indicators from textbooks and journal articles, without considering critical aspects such as character values mandated by the curriculum that could enhance the learning experience. These findings suggest that S1's decision-making process at this stage was somewhat mechanical, prioritising content selection over pedagogical strategies that integrate PCK components, such as student understanding and curriculum design.

Skill in generating ideas

In generating ideas for the task, S1 outlined several key strategies: (1) presenting problems at varying levels of numeracy difficulty, (2) aligning the content with students' prior knowledge of sequences and series, (3) using contexts that are familiar to students, (4) providing problems after first explaining the material and allowing students to practice related questions. The motivation behind these ideas was to identify student difficulties in numeracy and assess the mathematical concepts students had mastered. The ideas, however, remained limited to application-level problems, which primarily involved routine exercises adapted from textbooks. Participant S1 failed to incorporate more complex problem-solving or reasoning activities that challenge students' deeper understanding. This indicates a gap in PCK, where the task design lacked the integration of Knowledge of Content and Students (KCS) and Knowledge of Content and Teaching (KCT), which are crucial for fostering numeracy skills that extend beyond rote application.

Skill in clarifying ideas

When clarifying her ideas, S1 made several assumptions about student capabilities, predicting potential challenges: (1) students might struggle with story-based problems due to literacy issues, (2) not all students would solve the problems completely, and (3) some students might skip critical steps in their solutions. These assumptions were based on S1's perception of students' general weaknesses, particularly in reading comprehension and persistence in problem-solving. Participant S1 did not, however, explore alternative approaches or ideas that could mitigate these anticipated difficulties. Moreover, she did not provide concrete solutions or scaffolding strategies to help students overcome these challenges, indicating a narrow application of PCK that overlooks the importance of instructional differentiation and formative feedback.

Skill in evaluating the reasonableness of ideas

In evaluating the reasonableness of her ideas, S1 assessed the task's appropriateness solely based on students' cognitive levels, deducing that students' age would correspond to their cognitive development. Additionally, she sought informal feedback from a peer who is a mathematics teacher to validate whether the task was solvable by students. S1 did not, however, employ a comprehensive evaluation approach, such as conducting trials or gathering more nuanced student feedback, which could have provided more meaningful insights into the task's effectiveness. This lack of robust evaluation reflects a limited application of Knowledge of Content and Students (KCS), as the decision-making process did not sufficiently account for diverse learner profiles or varying student needs.

Skill in reflecting on the decision-making process

During the final stage of reflection, S1 admitted that she had not revisited or critically reflected on her task design. She did not systematically review her decisions or assess the effectiveness of her design in enhancing numeracy learning. In fact, through the interview, S1 expressed her confidence in the design she created, stating that she did not need any improvements to her design, except for the addition of illustrative images. This confidence, while positive, hindered her from revisiting the effectiveness of her decisions and evaluating how well the design aligned with the intended learning outcomes. S1's failure to engage in this reflective process revealed a gap in her ability to develop her PCK fully, potentially limiting her ability to adapt teaching strategies for optimal numeracy learning.

Overall, S1's decision-making process revealed several areas of weakness in integrating PCK into the design of numeracy tasks. While she demonstrated a basic understanding of content selection and student familiarity, her approach lacked depth in terms of pedagogical strategy and cognitive alignment. The absence of creative, reasoning-based problems and reflective practices suggests that S1's decision-making was primarily content-driven, with limited consideration of broader pedagogical frameworks. These results underscore the need for enhanced PCK training, particularly in fostering reflective practices and deeper engagement with student learning needs in the task design process

Decision-Making Skills of Participant S2

Figure 2 presents the numeracy task designed by Participant S2. The analysis below outlines Participant S2's decision-making process across the same five stages, informed by the task design and task-based interview.

NUMERATION PROBLEMS ASSIGNMENT

Material: Linear Program

Level: High school

Class: XI

Problem:

Miss Dewi has 2 part-time jobs, namely as a tour guide and tutoring teacher. When guiding tourists, Miss Dewi is paid Rp. 90,000.00 per hour. Meanwhile, when teaching tutoring, Miss Dewi was paid Rp. 150,000.00 per hour. Miss Dewi will soon need IDR 1,200,000.00 to pay the house installments. If Miss Dewi is unable to work more than 10 hours, then how many hours should Miss Dewi work for each job?

a. Write down the mathematical model.
b. Is the mathematical model a system of linear inequalities?
c. If the problem above is a system of linear inequalities, how is the problem solved?
d. Can Miss Dewi get the money she needs just by teaching for 4 hours?
e. Can Miss Dewi get the money she needs if she works 9 hours?
f. How many hours does Miss Dewi have to work for each job?

Steps:

1. Explain the concept of linear inequalities
2. Explain how to apply the concept of linear inequality to linear programming.
3. Provides numerical problems related to linear inequalities and linear programming.
4. Discussion of the results of the assignment on numeracy problems

Figure 2. Numeracy task design by Participant S2.

Skill in formulating decision-making space

At this phase, Participant S2 began by identifying problems from everyday life that could be adapted into numeracy tasks. S2's primary goal was to enable students to apply the mathematical concepts they had learned to real-world problems. The first step in S2's process was to compile material related to linear programming and inequalities. S2 also considered how students might better understand these mathematical concepts when applied to realistic scenarios, such as determining work hours based on financial goals and available time.

S2's focus, however, remained mostly on content development and application, without broader consideration of how the task could support the development of key educational values, such as those outlined in the curriculum. This omission suggests that S2's decision-making space was limited to technical aspects of task creation, rather than incorporating a more holistic, student-centered approach rooted in the development of broader skills like critical thinking and citizenship

Skill in generating ideas

In generating ideas, S2 outlined several strategies for task design, including involving multiple mathematics content, varying the cognitive difficulty of the questions, and ensuring that the problem contexts were relatable to students. S2 aimed to assess the mathematical knowledge that students had not yet mastered by creating tasks embedded in familiar contexts. For example, the task designed by S2 required students to calculate how many hours Miss Dewi must work at her two part-time jobs to meet financial goals, integrating mathematical concepts with real-life problem-solving.

While the task was designed with the goal of identifying student difficulties, the scope of the problems was largely limited to application-level tasks, which are routine and primarily focused on problem-solving skills without requiring higher-order thinking. This suggests a gap in integrating more complex numeracy tasks that could challenge students to engage in deeper reasoning or to explore multiple solutions, a key component of Pedagogical Content Knowledge (PCK).

Skill in clarifying ideas

When clarifying the ideas for her task, Participant S2 made several assumptions about student behavior. These assumptions included: (1) students dislike story problems due to excessive reading, (2) students may struggle with solving basic-level problems despite being able to solve more complex problems, and (3) students may dislike certain types of mathematical content.

These assumptions reflect S2's recognition of potential challenges for students, such as low reading engagement or preferences for certain types of problems. S2 did not, however, explore alternative strategies for addressing these challenges, such as introducing scaffolding to support students' reading comprehension or interest in the task. Additionally, S2 did not consider using differentiated instruction or presenting multiple types of problems to accommodate diverse learning styles. This indicates that S2's process of clarifying ideas was incomplete, relying on assumptions without a reflective exploration of other possible solutions

Skill in evaluating the reasonableness of ideas

In evaluating the reasonableness of her ideas, S2 assessed whether the task was appropriate for students, primarily based on their age and cognitive development. Participant S2 believed that the task should be solvable by students and confirmed its feasibility by asking a peer to attempt the task. However, S2 did not employ a more rigorous method to evaluate the task's appropriateness, such as piloting it with students or gathering feedback from teachers.

This limited evaluation process suggests a narrow view of Knowledge of Content and Students (KCS). S2's decision-making was based on general assumptions about cognitive development, without considering students' diverse needs, background knowledge, or prior experiences. This oversight indicates an area where further development in PCK is necessary, as a more comprehensive evaluation could have revealed how the task aligns with students' varying abilities.

Skill in reflecting on the decision-making process

At the reflection stage, Participant S2 admitted that she did not revisit her task design or critically evaluate her decision-making process. There was no systematic review of the effectiveness of her task in promoting student learning or aligning with pedagogical goals. In addition, during the interview, S2 stated that she had no idea when asked to suggest improvements to the design of the assignment that had been made. S2 only said that she needed to be more detailed in the steps of giving her assignments to help in the implementation of learning later. S2's inability to critically assess her task design shows a lack of reflection, highlighting a critical gap in S2's development of PCK, as effective teachers continuously reflect on their teaching practices to improve and refine their instructional strategies.

The analysis of S2's task design and decision-making skills reveals several strengths, including the integration of real-life contexts in the task and a focus on assessing students' understanding of mathematical concepts. The process, however, also shows significant limitations in the depth of decision-making, particularly in terms of reflecting on and evaluating the task's effectiveness. S2's approach was largely content-driven, with limited consideration of broader pedagogical strategies, such as differentiated instruction or higher-order thinking tasks. These findings emphasise the importance of developing a more reflective and student-centered approach in future task designs to enhance the integration of PCK components.

Decision-making Skills of Participant S3

Figure 3 displays the numeracy task developed by Participant S3. Participant S3's decision-making process is presented according to the five stages, based on the analysis of the task artefact and interview data.

NUMERATION PROBLEMS

Material : System of Linear Equations with Three Variables (SPLTV)

Level/Class: SMA/X

Problem:

Ana, Dita and Naya went to the traditional market together to shop for vegetables, rice and corn. Ana bought 4 bunches of vegetables, 2 tubs of rice, one plastic bag of corn for a total price of IDR 64,000.00. Dita bought one bunch of vegetables, 3 tubs of rice, and 2 plastic bags of corn for a total price of IDR 55,000.00. Naya bought 3 bunches of vegetables, a tub of rice, and a plastic bag of corn for a total price of IDR 45,000.00. How much does a bunch of vegetables, a tub of rice and a plastic bag of corn cost from these purchases?

Steps to using problems in learning:

1. Provide explanations to students regarding SPLTV material.
2. Provide examples of daily life problems related to SPLTV material.
3. Linking SPLTV learning concepts to everyday life problems
4. Directing students to understand the problem, plan a solution, solve the problem according to plan, and look back at the results of the solution.
5. Providing numeracy problems related to SPLTV material as a form of practice.
6. Directing students to apply problem solving strategies to make it easier to solve problems.
7. Discuss together the results of problem solving obtained by students.

Figure 3. Numeracy task design by Participant S3.

Skill in formulating decision-making space

At the initial stage, S3 defined the scope of the numeracy task design by focusing on real-life applications of mathematics. The participant prioritised creating a task that would relate closely to students' everyday experiences. The first consideration was selecting the relevant mathematical content, in this case, the System of Linear Equations with Three Variables (SPLTV), which could be applied in practical situations. S3 then identified examples of problems familiar to students, such as shopping scenarios, to make the content more accessible and relatable.

Although S3 succeeded in formulating decision-making objectives tied to the integration of numeracy in everyday life, a noticeable gap remained in considering the broader educational values. The task design focused narrowly on mathematics content and its immediate application, missing the opportunity to cultivate critical values like collaboration, civic awareness, and problem-solving beyond mathematical contexts. This reflects a limitation in fully integrating Pedagogical Content Knowledge (PCK), as the task did not address the holistic development of students beyond their mathematical competencies.

Skill in generating ideas

In this phase, Participant S3 generated ideas around key aspects of numeracy task design, including content, context, and student cognitive abilities. S3 outlined a strategy to develop problems that were not only mathematical but also embedded within personal and socio-cultural contexts familiar to students. For example, the shopping scenario used in the task resonates with students' real-world experiences, making the task more relatable and fostering engagement.

Although S3 succeeded in creating contextually relevant tasks, the cognitive demands of the tasks remained limited to routine problem-solving. The emphasis on application-level problems (which are standard and typically do not require deeper reasoning) indicates a lack of higher-order cognitive engagement. In a top-tier publication, it is crucial to showcase task designs that challenge students to engage in analysis, synthesis, and evaluation, rather than merely applying problems. S3's numeracy tasks, while relevant to students' lives, fell short in prompting students to explore complex problem-solving or creative reasoning, which are essential components of advanced numeracy skills.

Skill in clarifying ideas

During the clarification stage, Participant S3 made several assumptions about student behavior and performance. These assumptions included:

1. Students may not be familiar with or inclined to solve word problems that require significant reading.
2. Students may struggle to analyse and comprehend problems presented in formats other than equations (such as tables or images).
3. Students are likely to prefer numerical data over contextualised story problems.

These assumptions reflect a realistic understanding of potential student difficulties. S3 did not, however, propose alternative strategies to mitigate these challenges, such as integrating scaffolding techniques to support literacy in mathematics or providing diverse problem formats to accommodate different learning preferences. Furthermore, S3 did not explore other possible task designs that could serve as a comparative alternative to the initial ideas. This narrow focus on potential difficulties without addressing broader instructional solutions suggests that S3's approach to clarifying ideas remained reactive rather than proactive, missing opportunities to enhance students' overall problem-solving abilities.

Skill in evaluating the reasonableness of ideas

In evaluating the reasonableness of the numeracy task, S3 primarily considered the cognitive development of the students, assessed through age and general cognitive abilities. S3 assumed that students could complete the task but might require assistance from peers. This evaluation approach relies heavily on external support systems rather than fostering student independence in problem-solving. Additionally, S3's evaluation did not involve piloting the task or gathering feedback from teachers or students, a process that could have provided deeper insights into the task's appropriateness and effectiveness.

This highlights a gap in S3's Knowledge of Content and Students (KCS), a critical component of PCK. Effective task evaluation should account for diverse student abilities, prior knowledge, and the potential need for differentiated instruction. Without a more nuanced evaluation process, it is challenging to determine whether the task aligns with students' diverse cognitive abilities or fosters equitable learning opportunities.

Skill in reflecting on the decision-making process

At the reflection stage, Participant S3 indicated that no formal reflection or review of the task design had been conducted. S3 did not reassess the effectiveness of the design in fostering student learning or evaluate the decision-making process itself. Participant S3 believed that the assignment design was well-prepared and did not require any revisions. S3, however, acknowledged that it could be enhanced by incorporating additional learning tools. This recognition of supplementary materials shows a willingness to consider improvements, but the absence of deeper reflection on the decision-making process and its alignment with pedagogical goals indicates a missed opportunity. The absence of a reflective practice is a significant limitation, as reflection is crucial for ongoing improvement in instructional design. In failing to engage in reflective evaluation, S3 missed an opportunity to refine the task and make iterative improvements based on potential gaps in student understanding or engagement.

The analysis of Participant S3's task design process reveals a solid foundation in integrating numeracy tasks into familiar, everyday contexts, which is essential for fostering student engagement. However, several key areas of development remain: (1) Limited cognitive challenge: The tasks designed by S3 are routine application problems, which do not push students to engage in higher-order thinking, (2) Lack of holistic development: The task design does not incorporate broader educational goals, such as fostering critical thinking, collaboration or civic awareness, (3) Missed opportunities for scaffolding: While S3 identified potential student challenges, there were no strategies developed to address these difficulties proactively, (4) Inadequate evaluation and reflection: S3's evaluation process was superficial, relying on assumptions rather than empirical testing, and there was no reflective analysis to inform future improvements.

Discussion and Implications

The findings of this study illustrate the decision-making of mathematics prospective teachers with PCK in the medium category in designing numeracy tasks is depicted in Figure 4.

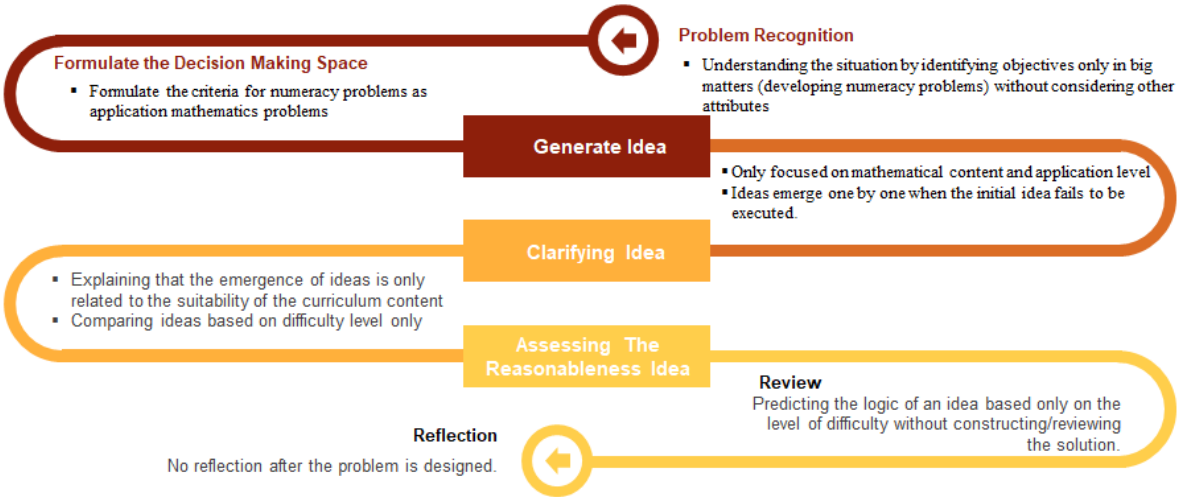

Figure 4. Decision making of mathematics prospective teachers in designing numeracy tasks.

At the problem recognition stage, prospective mathematics teachers tended to interpret numeracy tasks primarily through a mathematical lens, focusing on content objectives while overlooking other essential attributes, such as socio-cultural context and literacy demands. This finding aligns with previous studies that highlight how conceptual understanding often forms the foundation of task design (Hill et al., 2008; Shulman, 1987). Neglecting socio-cultural and contextual elements, however, may result in routine tasks with limited cognitive challenge. Research suggests that tasks reflecting the cultural backgrounds of students enhance relevance, engagement, and opportunities for collaborative meaning-negotiating in fostering deeper conceptual understanding (Radmehr, 2023; Thompson, 2014). Therefore, emphasising the importance of integrating socio-cultural contexts in task design is needed. Prospective teachers should be encouraged to incorporate real-world scenarios and consider the cultural backgrounds of students, as this promotes relevance and engagement. Practical workshops on designing culturally sensitive tasks could help bridge this gap and foster deeper engagement with numeracy concepts (Goos et al., 2019).

In the generating ideas stage, prospective teachers predominantly proposed application-level problems, without engaging in deeper reasoning or prediction activities. This pattern aligns with prior research, which shows that the tasks posed to prospective mathematics teachers involved in the study primarily reached the application level, with only a few identified as reasoning tasks (e.g., Sari et al., 2024). Although they could create application-based problems, they often overlooked the importance of engaging students in critical thinking, a crucial component of complex numeracy tasks. Many prospective mathematics teachers begin their education training with a limited understanding of problem characteristics, which may hinder their ability to teach problem-solving skills effectively (Piñeiro et al., 2022). Such tendencies reflect limitations in knowledge of teaching (Ball et al., 2008). Furthermore, the ideas emerged sequentially, reflecting a lack of ability to explore multiple alternative solutions or to approach the task design creatively. A lack of emphasis on critical thinking in teacher training can lead to a cycle where students are not adequately prepared for future challenges (Badescu & Stan, 2020). Of course, this finding could be anticipated, as teacher training programs can significantly enhance their ability to foster critical thinking in students (Badescu & Stan, 2020; Margulies, 2022). For example, 1) encourage exploration beyond application-level tasks by designing scenarios that require higher-order thinking, such as reasoning and prediction, 2) support prospective teachers create tasks that incorporate multiple solution pathways, promoting creativity and flexibility in problem-solving, 3) incorporate reflective activities in training programs to improve prospective teachers' understanding of critical thinking as a core component of effective numeracy tasks.

During the clarifying ideas stage, prospective mathematics teachers justified their ideas solely in terms of curriculum alignment, without utilising educational technology to enhance the task design. For example, the use of digital tools to facilitate reasoning and deepen students' understanding of mathematical concepts is often overlooked (Bali et al., 2023). This occurs despite extensive research emphasising the importance of integrating technology into teaching and learning (Mishra & Koehler, 2006), as technology integration can create holistic numeracy tasks, promote interactive and relevant learning (Geiger et al., 2011) and fosters students' critical thinking and mathematical skills (Geiger et al., 2015). Therefore, prospective mathematics teachers should integrate technology-focused training to encourage the use of digital tools in task design. This will enhance students' interaction, reasoning, and engagement with numeracy tasks.

At the assessing the reasonableness of ideas stage, prospective mathematics teachers assessed task feasibility primarily based on assumptions rather than strong evidence, such as comprehensive problem-solving steps. The prospective mathematics teachers tended not to compile supporting evidence about students' cognitive development to strengthen their decision-making in designing tasks. Therefore, the identification of difficulties in problem-solving is frequently inadequate, as prospective teachers struggle to analyse the specific challenges students may face (Burgos & Godino, 2022). It could lead to difficulty in ensuring that the tasks were appropriate for the students' cognitive level (Cohen & Cohen, 2024) and assessing students' reasoning difficulties (Säfström, et al., 2023). Prospective mathematics teachers need to train in evaluating tasks based on documented cognitive and developmental benchmarks. Training programs in teacher education should encourage data collection and analysis to help teachers make informed decisions, thereby improving their ability to tailor tasks according to students' reasoning skills.

Finally, at the reflection stage, no further reflection was conducted to improve decision-making for future task designs. It indicated that prospective mathematics teachers constructed the task without a strong theoretical framework. The lack of a theoretical framework could lead to students' misconceptions because of incomplete information or overly simplistic problems that did not challenge students' thinking processes (Suryanti et al., 2022). The absence of reflection indicates that the students lacked the ability to evaluate their own decision-making processes, thus missing opportunities to develop their pedagogical skills through a continuous cycle of evaluation and improvement (Schön, 1983). Using a theoretical framework for reflection could encourage prospective mathematics teachers to think more deeply about their choices, improving future task designs. They could be encouraged to maintain a reflective journal to document learning and areas for improvement, contributing to a cycle of continuous professional growth.

Despite these contributions, this study has several limitations that should be acknowledged. First, the in-depth analysis focused exclusively on prospective mathematics teachers with medium-level PCK. Therefore, the findings do not represent the decision-making characteristics of prospective teachers with low or high levels of PCK. Future research may extend this work by examining and comparing decision-making processes across different PCK levels to provide a more comprehensive understanding.

Conclusion and Future Directions

The findings of this study highlight significant gaps in the decision-making processes of prospective mathematics teachers with a medium level of PCK when designing numeracy tasks. Across the five key stages—defining decision-making space, generating ideas, clarifying ideas, evaluating the reasonableness, and reflecting—students demonstrated limited integration of PCK components, particularly in promoting deeper reasoning and critical thinking among students.

1. Surface-level Task Design: In defining the decision-making space, the students tended to focus on content selection and real-life application problems but overlooked the integration of broader educational values and cognitive challenges. Their designs were largely content-driven, failing to align with students' holistic development or the critical competencies required in modern numeracy education.
2. Limited Creativity and Complexity: When generating ideas, students relied primarily on routine application problems without incorporating higher-order thinking tasks. This lack of creativity and engagement with deeper reasoning indicates a gap in their PCK, particularly in fostering students' analytical and problem-solving skills.
3. Narrow Reflection and Evaluation: The evaluation of the feasibility of task designs was largely based on assumptions rather than empirical testing or feedback from students. Furthermore, students failed to engage in reflective practices that could improve their task designs over time. This lack of reflection highlights a missed opportunity for continuous improvement and adaptation of teaching strategies, essential components of effective PCK development.
4. Pedagogical Implications: These results underscore the need for more comprehensive training in teacher education programs to enhance prospective teachers' decision-making skills. Specifically, there is a need to cultivate reflective practices, encourage creative task design, and integrate technology and educational strategies that align with broader pedagogical goals. Addressing these gaps will better prepare future teachers to design numeracy tasks that not only engage students but also foster their critical thinking and problem-solving abilities.

In conclusion, while prospective teachers demonstrated a basic understanding of content and application in task design, there remains a crucial need for deeper integration of PCK components, reflective practices, and student-centered approaches to ensure the development of effective numeracy tasks. These findings show gaps in each step of the decision-making process for designing numeracy tasks, indicating the need for more comprehensive development of PCK, especially in integrating socio-cultural aspects, promoting higher-order thinking, utilising technology, and fostering reflective teaching.

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Competing interests

The authors declare there are no competing interests.

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