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Research Article

PROSPECTIVE MATHEMATICS TEACHERS' MATHEMATIZATION COMPETENCIES IN SOLVING WORD PROBLEMS

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Abstract
Mathematization competencies among prospective teachers, focusing on their ability to construct and communicate mathematical arguments, are crucial for effective mathematics education. This exploratory study aimed to produce qualitative-descriptive data on prospective teachers' competencies of mathematization in teacher education programs. The study employs word problems based on everyday-life problems that are solved by the mathematization process and assessed based on three indicators of mathematization competencies. The data were collected from three groups of prospective teachers in the first, third, and fifth semesters, respectively, in the mathematics education study program at a public University in Kediri, Indonesia. The findings revealed that while all prospective teachers demonstrated basic skills in identifying assumptions and organizing problems, fifth-year students exhibited better abilities in mathematical argumentation, particularly in generalizing mathematical problems. These advanced abilities included the formulation, analysis, and presentation of proficient mathematical arguments, indicating a deeper understanding and mastery of mathematization that developed progressively throughout their education. The results of this study underscore the importance of sustained and structured learning experiences in mathematics teacher education programs to foster higher-order mathematical competencies. This study enriches the mathematics education literature by illustrating the growth of argumentation skills in mathematization among prospective teachers, highlighting the need for educational curricula that emphasize these advanced skills.

Keywords Mathematization Competencies, Prospective Teachers, Word-Problems

INTRODUCTION

In mathematics education around the world, it is common practice that verbal sentence problems (commonly referred to as word problems) are used to teach and assess students in the domain of quantitative problem-solving from real life (Verschaffel et al., 2009). Word problems are described as verbal portrayals of problem scenarios, usually introduced in an educational setting, where a question is formulated and its solution can be derived by applying mathematical operation(s) to the numbers involved in the problem (Verschaffel et al., 2000). Numerous researches have expressed significant doubts about whether word problems effectively promote or precisely evaluate students' abilities to tackle quantitative issues encountered in daily life (Gellert & Jablonka, 2009; Gerofsky, 2010). Many students face difficulties in reading and understanding the mathematical vocabulary used in word problems, which hinders their ability to solve them effectively (Abdullah et al., 2024). Research indicates that students tend to tackle word problems with a focus on calculations (Thompson et al., 1994) and often overlook the actual conditions outlined in the problem scenarios (Dewolf et al., 2014; Dewolf et al., 2015). This behavior leads to low achievement; students do not understand the problem situation and therefore cannot show their full potential in solving problems from everyday life. Prospective mathematics teachers often rely on algebraic solutions and show limited proficiency in employing non-algebraic strategies to address word problems, which can hinder their ability to diversify problem-solving approaches (Öçal et al., 2020).

In the literature, problems known as real-life problems serve as a bridge between real life and mathematics (Dominguez et al., 2023) and make mathematics a meaningful activity (Sumirattana, 2017; Dedeoğlu, 2022). The process of translating real-world problems into mathematical language is called mathematization (Piñero Charlo, 2020). Mathematization refers to various ways of organizing activities to demonstrate mathematical characteristics, such as generality (generalization), certainty, precision and conciseness (Loc & Hao, 2016). Furthermore, OECD (2016) states that mathematization is the transformation of a real-world problem into a mathematical form that includes organizing, conceptualizing, making assumptions and formulating a model and then interpreting or evaluating the mathematical model related to the problem at hand. However, the abstract nature of mathematics and its significant cognitive load on students can contribute to its perception as a challenging subject (Hidayat et al., 2024), making effective mathematization strategies even more crucial in fostering understanding and engagement. Middle school mathematics teachers often adopt trial-and-error strategies or use the area model when solving problems, but they sometimes misapply variables and symbols, reflecting a need for improved procedural fluency (Gökkurt Özdemir et al., 2018). In the PISA mathematics framework, mathematization is the process of students using the mathematical knowledge and skills they acquire in school or from life experiences to solve real-life problems (OECD, 2009).

The main thing in teaching mathematics is to teach mathematization, not mathematics (Freudenthal, 1968); there is no mathematics without mathematization (Freudenthal, 1973, p.134). Therefore, mathematization, differing from conventional methods in mathematics education, fundamentally involves the structuring of existing information using diverse strategies to facilitate the comprehension of mathematical concepts within real-life contexts. (Rosales, 2015; Dedeoğlu, 2022) and thus achieving mathematical generalization (Freudenthal, 1973). Unfortunately, many individuals experience difficulties in interpreting their mathematical solutions when solving everyday problems (Stillman & Brown, 2014). Both students and teachers play a key role in this process.

Prospective teachers often lack adequate comprehension of real-life word problems, including critical skills like using mathematical notations, constructing models, and generalization methods, suggesting a need for focused improvement in teacher education programs (Çalışkan-Dedeoğlu, 2022). Students require mathematical skills not only to solve mathematical problems or problems in daily life but also to learn mathematics, as mathematization is an essential aspect of the learning process (Biccard & Wessels, 2015; 2017). Additionally, the importance of comprehending mathematization has numerous practical applications in various fields. Mathematization involves constructing formal mathematical concepts from informal concepts, making it a fundamental element of developing mathematical knowledge. Moreover, the orientation, coherence, and explicitness of knowledge regarding word problem-solving can vary significantly between in-service and pre-service teachers, with in-service teachers showing a more coherent approach but sometimes overlooking reasoning in their choices (Ramos et al., 2020). For students to be able to mathematize, (prospective) mathematics teachers are expected to have good mathematization skills.

Studies have shown that engaging in mathematization activities significantly improves prospective teachers' strategic competence and procedural fluency (Dedeoğlu, 2022). Besides, during the activity, the inability of students enrolled in the mathematics education program, who are training to become mathematics teachers, to construct mathematical models from the given maximum or minimum problems indicates a lack of proficiency in mathematization, especially in horizontal mathematization (Jupri et al., 2021). These findings suggest that opportunities for students to dive into mathematics and undertake mathematization can help them think deeper in constructing mathematical models. The mathematization competencies of prospective primary mathematics teachers in the mathematical modeling process have been studied, finding that, to a certain extent, these teachers understand what is mathematical modeling, but they still cannot make models general enough to cover all situations (Yılmaz & Tekin-Dede, 2016).

Research has identified that the pedagogical approach adopted in classrooms plays a crucial role in developing mathematization competencies. Child-centered teaching practices, as opposed to teacher-directed methods, are linked with better problem-solving outcomes among students (Pakarinen & Kikas, 2019). This finding suggests that prospective teachers should focus on acquiring mathematics skills and adopting teaching methodologies that foster student engagement and independent problem-solving.

Despite the progress made in understanding mathematization, several research gaps remain, particularly concerning how prospective mathematics teachers develop these competencies across different academic levels. Studies such as those by Lestariningsih et al. (2018) and Stillman & Brown (2014) have pointed out that prospective teachers struggle with mathematization, yet there is limited research on how these skills evolve throughout their academic journey. Furthermore, while research has emphasized the importance of pedagogical competence in teaching mathematization (Asrial et al., 2019), there is insufficient data on how this competence varies across different semesters in teacher education programs.

A distinguishing aspect of this study is its focus on the progression of mathematization competencies across different academic levels within teacher education. While prior research has predominantly analyzed these competencies in general terms, this study offers a unique longitudinal perspective by examining how these skills develop among first-, third-, and fifth-semester students. By situating this analysis within the context of a structured teacher education program, this research addresses a critical gap in the literature, providing both theoretical insights and practical implications for curriculum design.

Another gap lies in the assessment of mathematization competencies. Although some studies, such as Schulz (2023), have developed tools to measure these competencies, there is a lack of comprehensive evaluations that account for both strategic and procedural aspects of mathematization. Moreover, while the literature highlights the importance of mathematization in improving mathematical understanding and teaching effectiveness, few studies have examined how different academic levels influence the ability of prospective teachers to apply these competencies in classroom settings.

The objective of this study is to analyze the mathematization competencies of prospective mathematics teachers at different academic levels, specifically those in their first, third, and fifth semesters. By analyzing how well these individuals apply mathematization competencies to solve word problems, the study aims to provide insights into the development of these competencies over time. This research addresses a critical gap in the literature by exploring the evolution of mathematization competencies within teacher education programs, an area that has received limited attention despite its importance.

The novelty of this study lies in its focus on comparing mathematization competencies across different academic levels. While previous research has examined mathematization in general terms, this study provides a more detailed analysis by categorizing prospective teachers according to their semester of study. Doing so offers a unique perspective on how these competencies develop over time and the factors that influence this progression. The scope of this study is limited to prospective mathematics teachers enrolled in undergraduate programs, emphasizing those in their early to mid-stages of academic training.

RESEARCH METHOD

This study employs an exploratory research design and a qualitative research approach to generate descriptive data by describing prospective teachers' mathematization competencies in solving word problems based on everyday life problems. In contrast to more narrowly focused research, exploratory research is designed to explore broader phenomena. The research aimed to explore how these teachers identify assumptions, organize problems, and create mathematical models within the context of their education. The study's procedures involved administering two narrative problem-based questions previously validated by four master's level lecturers in mathematics education, each with at least eight years of teaching experience. These questions were designed to assess the practical application of mathematization skills among the participants. At different times and locations, participants were divided into three groups, namely first-, third-, and fifth-semester of university students. Each group was tasked with solving the problems provided and writing their responses on the answer sheets provided. The researcher then corrected the results of their answers, grouping responses using similar procedures. Afterward, the researcher selected the most appropriate answer in each group, describing it in detail in relation to the participants' mathematization. This allowed for an overview of their mathematization competencies to be obtained.

The research was conducted at a State University in Kediri, East Java, Indonesia. Data collection was conducted in different rooms for each group of participants. The data collection period spanned from October to December 2023, or in the Odd Academic Year 2022/2023.

The research was conducted at a Kediri, East Java, Indonesia state university. Data collection took place in separate rooms for each group of participants. Participants were selected from the 1st, 3rd, and 5th semesters of a Bachelor of Mathematics Education program, which typically spans four years. A purposive sampling method was used to select participants, focusing on those who had demonstrated the skill to provide detailed and effective responses to tests based on real-life word-problems given. Additionally, participants with strong communication skills (which have been presented in daily lectures conducted by researchers with participants) were chosen to ensure the depth and quality of responses during in-depth interviews. This is conducted during the lecture process, whereby the researcher also fulfils the role of lecturer in the class they are attending. The participants involved in this study were grouped according to their academic semester. In data analysis, each participant was given a unique code according to their semester, which is shown in table 1 below:

Table 1. Coding of Participants Group

Participants	Code
1st semester	G1
3rd semester	G2
5th semester	G3

Data were collected using test results and in-depth interviews. The main instrument was two word-problems-based questions set in different contexts. The problems were related to common decision-making scenarios encountered in everyday life. The participants' responses were analyzed for accuracy and their ability to demonstrate mathematical competencies. After this analysis, the responses that showed the most through mathematization process were chosen from each group for closer examination. These selected responses were then discussed further in in-depth interviews to gain more insight into the participants' thinking and methods.

The data collected from the tests and interviews underwent a thorough content analysis. The initial phase of analysis involved tests evaluation of the participants' responses to assess their practical application of mathematization competencies. This was followed by qualitative analysis, where interview transcripts were coded to identify emerging indicators and patterns. These indicators and patterns provided insights into the development of mathematization competencies across different academic levels.

Several validation techniques, including data triangulation, were applied to ensure the data's validity. Data obtained from tests and interviews were compared to check the findings' consistency. In addition, expert validation (peer debriefing) was conducted, where peers or other lecturers who were not involved in the study reviewed the analysis results to ensure objective and accurate interpretations.
The following indicators shown in Table 2 were specifically analyzed to measure the mathematization competencies:

Table 2. Mathematization Competencies Indicators

Matematization Competencies	Indicator
Identifying assumptions	• Write down relevant quantity relationships • Write the relationship between quantities
Organizing the problem according to mathematical concepts	• Using mathematical notation • Expressing problems in visual, algebraic and other forms
Creating mathematical models and communicating mathematical arguments	• Explaining the reason for the choice of model • Understand the limitations of the model

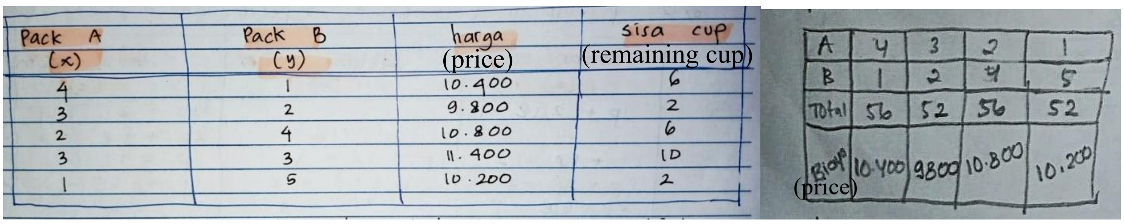
RESULTS AND DISCUSSION

In this section, we examined the underlying mathematization competencies of prospective teachers when presented with mathematical word problems. This involved identifying assumptions, organizing problems related to mathematical concepts, creating mathematical models, and communicating mathematical arguments. Furthermore, prospective teachers enrolled in semesters 2nd, 4th, and 6th are designated as group 1, 2, and 3, respectively. The presentation below summarises the participants' responses with the best performance in each group on problems 1 and 2.

Prospective Teachers' Explanation of Problem 1

First, the participants were asked to determine the number of packs to buy (at least 50 cups) with the constraint that pack A contains 12 cups and pack B contains 8 cups. After reading and understanding the problem, the prospective teacher from Group 3 and Group 1 identified the assumption by calculating the price per cup of each cup, namely that Pack A with a price of 2.200 IDR contains 12 cups, so the price per cup is 183 IDR (2.200/12), whereas Pack B with a price of 1600 IDR contains 8 cups, so the price per cup is 200 IDR (1.600/8). She then said that Auntie Dina could buy packs A and B, having estimated the number of cups in each pack to find the number closest to 50 (cups) at the cheapest price. Since the price of the cups in Pack A is lower, the estimated purchase is based on the number of cups in Pack A rather than the number of cups in Pack B. In addition, the prospective teacher presents the estimate in the form of a table.

In the Figure 1 (the left picture), we can see that the table created contains variables x and y, where x is the number of packs A purchased and y is the number of packs B purchased. Then there is a price column, which shows the price to be paid for the purchase, and the remaining cups column, which is intended to take into account the number of cups remaining since only 50 cups are needed. Based on the table, Aunt Dina can decide to buy 3 packs A and 2 packs B because the price is the cheapest with the fewest cups left.



Pack A (x)	Pack B (y)	harga (price)	sisa cup (remaining cup)
4	1	10.400	6
3	2	9.800	2
2	4	10.800	6
3	3	11.400	10
1	5	10.200	2

A	4	3	2	1
B	1	2	4	5
Total	56	52	56	52
Biaya (price)	10.400	9800	10.800	10.200

Figure 1. Representation table formed by group 3 (left) and group 1 (right)

Then, in building a mathematical model, the prospective teacher writes what is in the table in algebraic form, as follows.

Group 3: 4x + y = 10.400 *with 6 cups left* 3x + 2y = 9.800 *with 2 cups left* 2x + 4y = 10.800 *with 6 cups left* 3x +3y = 11.400 *with 10 cups left* 3x + 5y = 10.200 *with 2 cups left*	Group 1: costs incurred = 3.pack A + 2.pack B = 3 (2200) + 2 (1600) = 6600 + 3200 = 9800

Group 2:

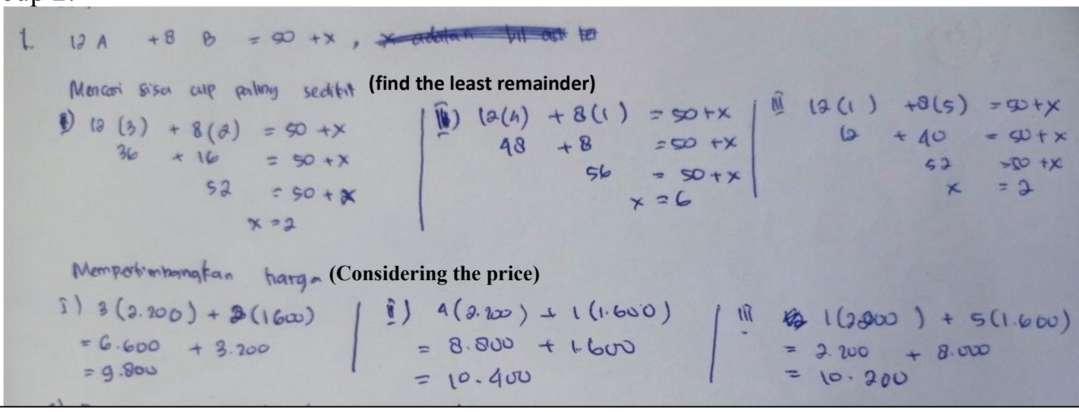


Figure 2. The algebraic forms of 3 groups

The model created cannot be used for all cases (generalization). She (G3) said that a one-by-one calculation without an example in the form of an equation, as she had written in the previous stage, would take a long time and be less efficient for Auntie Dina to work out how many packs of A or B to buy. According to her, the mathematical form can already take into account the purchase of the number of packs A and B based on the price limit and the remaining cups.

On the other hand, the answers of group 2 differed from the answers of participants in groups 1 and 3, as described above. When identifying the assumptions, the participant wrote Pack A (12 cups) = 2200 IDR and Pack B (8 cups) = 1600 IDR, which was then continued by noting the problem in algebraic form or mathematical equation.

Furthermore, in response to the question that required them to write a generalization or mathematical model of the given problem, group 1 did not provide an answer. In contrast, groups 2 and 3 wrote their responses as shown in Figure 3 below. The figure shows that group 3 wrote the inequality for the first problem and described the model they created.

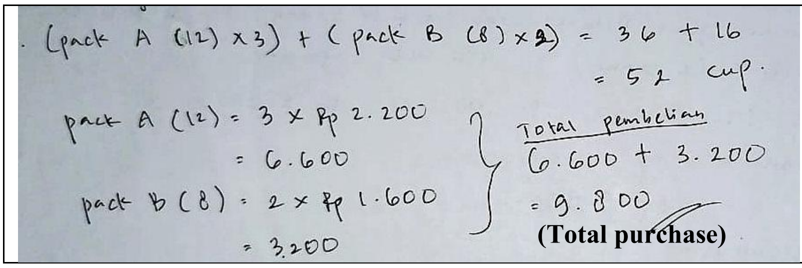
	To calculate the number of cups to buy using a mathematical model: $12x + 8y \geq 50$, for x = pack A and y = pack B. Then the minimum number of cups is closest to or equal to 50

Figure 3. Mathematical model of group 2 (left) and group 3 (right)

Moreover, at this point the participant also said that she wrote her mathematical model in a non-formal form because the participant did not use any variables. The picture shows that the participant in Group 2 (G2) immediately wrote down the answer that was asked. The researcher then asked her:

R: Why did you find the numbers 3 and 2? How did you suddenly think of it?
G2: I had tried it before on another paper and I found the answer that Aunt Dina can buy 3 pack A and 2 pack B to get 52 cups (close to 50) at the minimum price.
R: Oo, have you done trial and error before?
G2: Yes, ma'am...

Furthermore, when asked to give a mathematical argument related to the answer above, the participant said as in the following interview.

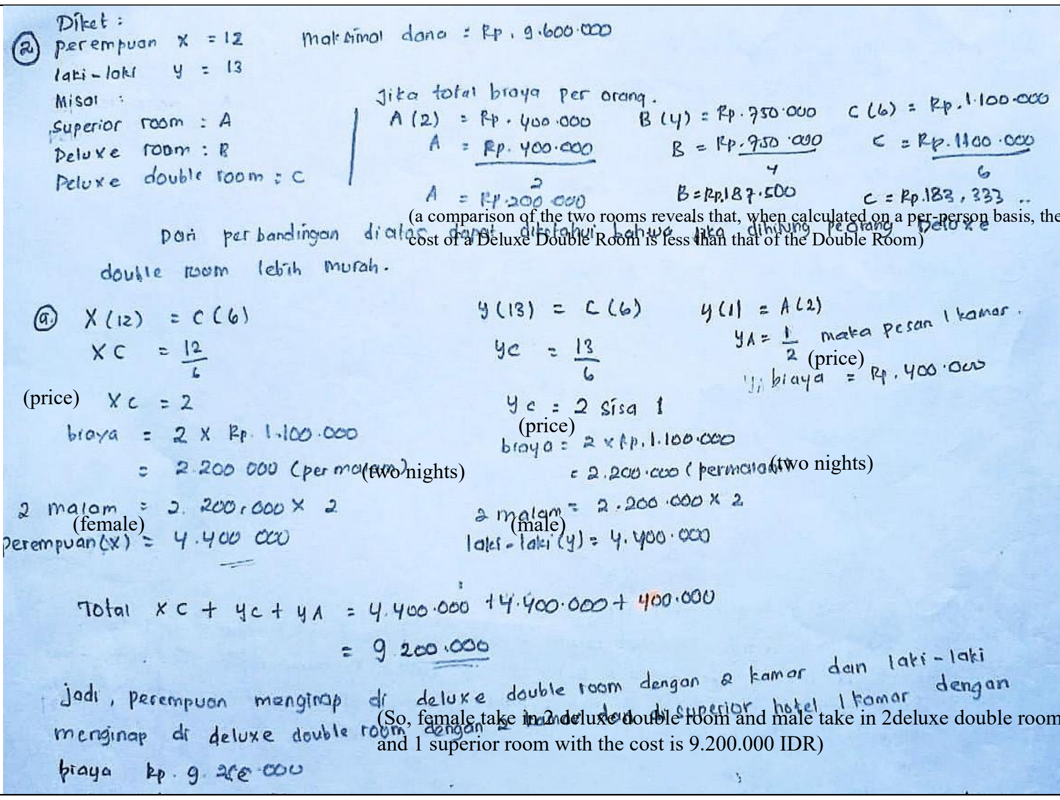
R: Can Aunt Dina buy another combination of the number of packs other than the answer (3 packs A and 2 packs B)?
G2: No, because the price of Pack A is cheaper than the price of Pack B, so we have to buy more Pack A to get the minimum cost. However, it would help if you still bought pack B to adjust the number of cups you need to avoid leaving too many cups unused.
R: How do you know that the cup price in pack A is cheaper than pack B?
G2: Because pack A contains 12 cups at 2,200 and pack B contains 8 cups at 1,600.

When asked if there was another way to buy the cups other than the one previously found, the participants answered no and gave reasons by comparing the price per cup of each pack. In contrast, in groups 1 and 3, this statement was used at the initial stage, i.e. to identify assumptions.

Prospective Teachers' Explanation of Problem 2

In the second problem, they are asked to determine the number of hotel rooms that should be booked given a choice of 3 types of rooms with different capacities and prices. In addition, the choice of room must be separated between male and female employees. In the second problem, the competence of participants in groups 1 and 3 identified assumptions by calculating the price per person per room.

Based on the solving problem (Figure 4), it is evident that the most economical room per individual is the Deluxe Double room, priced at 183.333 IDR, followed by the Deluxe Room at 187.500 IDR, and the Superior Room being the most expensive at 200.000 IDR per person per night. Also, it is evident that the most economical room per individual is the Deluxe Double room, priced at 183.333 IDR, followed by the Deluxe Room at 187.500 IDR, and the Superior Room being the most expensive at 200.000 IDR per person per night. Consequently, the participants recommended prioritizing booking the Deluxe Double Room (DDR). In case of unavailability, the Deluxe Room (DR) is the next preferred option, while the Superior Room (SR) is to be booked only if there is no other choice. Furthermore, participants in the two groups estimated by creating tables and algebraic equations.



Translate:
Female (x) = 12
Male (y) = 13
Maximal purchase = Rp. 9.600.000
For example, Superior room = A; Deluxe room = B; Deluxe double room = C

If the total cost per person:

A(2) = Rp. 400.000	B(4) = Rp. 750.000	C(6) = Rp. 1.100.000
$A = \frac{Rp. 400.000}{2}$	$B = \frac{Rp. 750.000}{4}$	$C = \frac{Rp. 1.100.000}{6}$
$A = Rp. 200.000$	$B = Rp. 187.500$	$C = Rp. 183.333$

A comparison of the two rooms reveals that, when calculated on a per-person basis, the cost of a Deluxe Double Room is less than that of the Double Room.

X(12) = C(6)	$y(13) = C(6)$	$y(1) = A(2)$
$XC = \frac{12}{6} = 2$	$yC = \frac{13}{6}$ $yC = 2\ left\ 1$	$yA = \frac{1}{2}$ So, order one room: Price= Rp. 400.000
Price= $2xRp. 1.100.000$ $= Rp. 2.200.000\ per\ night$ 2 night = $2.200.000\ x\ 2$ Female(x) = 4.400.000	Price= $2xRp. 1.100.000$ $= Rp. 2.200.000\ per\ night$ 2 night = $2.200.000\ x\ 2$ Male(y) = 4.400.000	

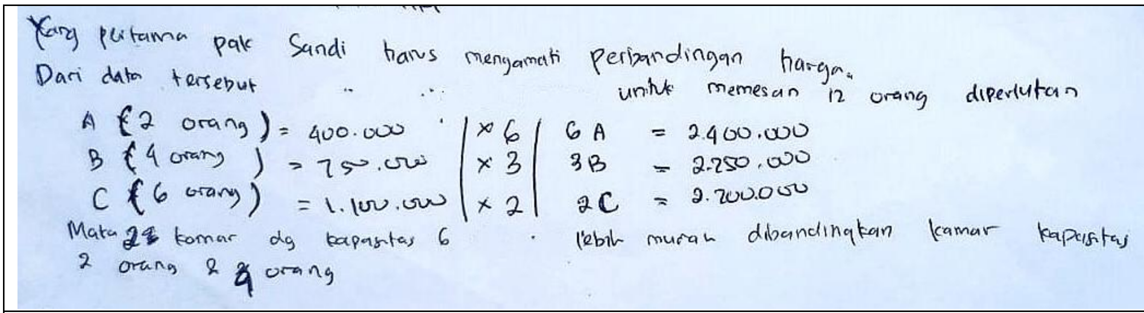
Total = $XC + yC = yA = 4.400.000 + 4.400.000 + 400.000 = 9.200.000$
So, female take in 2 deluxe double room and male take in 2deluxe double room and 1 superior room with the cost is Rp. 9.200.000.

Figure 4. Solving problem number 2 by group 1

Since the most economical room per individual is the Deluxe Double Room, priced at 183.333 IDR, followed by the Deluxe Room at 187.500 IDR, and the Superior Room being the most expensive at 200.000 IDR per person. Therefore, the participants (group 3) said that the booking of the Deluxe Double Room (DDR) should be maximized, if there is a shortage, then the Deluxe Room (DR) is chosen, while the Superior Room (SR) is the last choice. Furthermore, participants in the two groups estimated by creating algebraic equations, transcripts of interviews with Group 3(G3) are presented below.

R: How is the number of required rooms determined?
G3: Based on the known price per person for each room, it has been found that the most economical options are the deluxe double room and the double room. Therefore, priority will be given to booking rooms in these two categories. After this, the cheapest possible price can be achieved through a process of trial and error. To determine the best room arrangement for 13 male guests based on occupancy, the following options were recorded: (1) 7 single rooms (SR); (2) 2 double rooms (DR) and 1 deluxe double room (DDR); (3) 2 DDR rooms and 1 SR room; or (4) 3 DR rooms and 1 SR room. After calculating the nightly rate for each option (2.800.000 IDR, 2.600.000 IDR, 2.600.000 IDR, and 2.650.000 IDR), it was determined that the second and third options were the most cost-effective.

Furthermore, when determining the number of rooms required for 12 female employees, groups 1 and 2 reached a similar answer, i.e. 2 DDR rooms. Groups 1 and 3 arranged the problem using algebraic mathematical notation. However, group 2 identified the problem and arranged it using mathematical notation in the form of equations to achieve the solution. The cost was computed by multiplying the maximum number of people per room by a factor yielding 12. This indicates that there were 12 women, as illustrated in the following figure.



Translate:
First, Mr. Sandi have to compare the cost. From the data, to order room for 12 employees:
Provided from the data:
A (2 employees) = 400.000 | x6 | 6A = 2.400.000
B (4 employees) = 750.000 | x3 | 3B = 2.750.000
C (6 employees) = 1.100.000 | x2 | 2C = 2.200.000
So, room with a capacity of six people are more economical than rooms with a capacity of two or four people.

Figure 5. Mathematical notation in problem number by group 2

Moreover, Group 3 constructed a mathematical model using a two-variable inequality. They identified the variables based on the assumptions in question and the relations among the identified variables, creating a model of $400x + 750y + 1.100z \leq 9.600$. However, the minimization method was not used to solve the model. The participant simply replaced numbers obtained through trial and error or guessing in their model. All three groups had the same response when questioned about other potential strategies or answers that could be used to find the cheapest price: there was no other way.

The table 3 provides a summary of the solution approaches of the process participants when assessing their mathematization competencies.

Table 3. Summary of the solution approaches of the mathematization competencies

Identifying assumptions	Organizing the problem according to mathematical concepts	Creating mathematical model
Problem 1:		
• Pack A: Price per pack = 2.200, Pack contents = 12 cup • Price per cup (Pack A) = 2.200 / 12 = Rp. 183,33 per cup • Pack B: Price per pack = 1.600, Pack contents = 8 cup • Price per cup (Pack B) = 1.600 / 8 = Rp. 200 per cup	x: the number of Pack A to be purchased y: the number of Pack B to be purchased The algebraic forms in Figure 2	• $12x + 8y \geq 50$ $(constructed\ by\ group\ 3)$ • $2.200x + 1.600y \leq capital\ cost$
Problem 2:		
• Superior room (SR): 400 k / 2 = 200k /person • Deluxe Room (DR): 750k / 4 = 187,5k /person • Deluxe Double Room (DDR): 1100k / 6 = 183,33k /person It can be said that the cost per person is the cheapest if you choose the DDR room so the booking should be maximized in the DDR room, then DR then SR.	x: Number of SR to reserve y: Number of DR to reserve z: Number of DDR to reserve	$400x + 750y + 1.100z \leq 9.600$ $2x + 4y + 6z \geq 13$ $2x + 4y + 6z \geq 12$ $(Created\ by\ group\ 3)$

The study investigated the mathematization competencies of prospective teachers using three indicators: identifying assumptions, organizing problems according to mathematical concepts, and creating mathematical models. The concept of mathematization involves using mathematical methods to organize and examine various aspects of reality, emphasizing the importance of translating real-world problems into mathematical representations (Yilmaz & Dede, 2016). Representation is important because it can make it easier to solve word problems and to communicate ideas through signs, words, symbols, phrases, or pictures (Nasrun et al., 2021). Mathematics learning should also integrate contextual concepts and objects from the surrounding environment, enabling students to model and describe them through sensory experiences, which are then processed cognitively to construct mathematical understanding (Sarnoko et al., 2024). The intention is that students should not just follow routine procedures but also earn mathematics through exploration (Pratiwi et al, 2022).

The results reveal that while all groups showed comparable competencies in the first two indicators, the group 3 demonstrated exceptional aptitude in creating mathematical models. Teachers who employ word problems to facilitate student engagement in exploring, formulating, analyzing, and interpreting mathematical models based on real-world scenarios can effectively encourage active participation and conceptual understanding among students (Botha & Putten, 2018). The process of mathematizing pedagogical knowledge involves reducing it to a mathematical format for precise and structured analysis, classification, and representation, which has become a pivotal aspect of the modernization of pedagogical definitions (Perminov, et al., 2016). It aligns with the study of Campbell et al. (2014), which highlights the significance of cultivating pedagogical skills and mathematical content expertise among potential educators.

Mathematization involves the process of modeling a phenomenon mathematically or establishing the concept of a phenomenon (Mariani & Hendikawati, 2017). It encompasses two main types that are horizontal and vertical mathematization. The process of horizontal mathematization starts with problem understanding and extends to problem-solving. This involves translating real-world problems into mathematical representations. The important steps include planning and coordinating teacher training and mathematics courses for prospective university-level teachers to discuss representational translation comprehensively (Nurrahmawati et al., 2021). Vertical mathematization is the process of refining and integrating mathematical models to solve problems within the mathematical domain itself (Suaebah et al, 2020). Students justify the conclusions of arguments using formal mathematical truths (Tristanti et al., 2023). Based on results, those in groups 1 and 2 were able to identify assumptions and organize the problem, but lacked an understanding of how to relate it to mathematical concepts. At the outset of the solution, the students employed a trial-and-error approach to identify the correct answer. Nevertheless, they were unable to devise an equation or inequality that could be used to generalize the solution to the problem. This suggests that these two groups had reached the vertical mathematization stage, but could not create a mathematical model. Whereas group 3 showed good mathematization skills up to the stage of making mathematical models. It indicates significant cognitive and practical growth during their education. An individual's cognitive process be shaped significantly by personal experiences, leading to the consideration of potential results (Lathifaturrahmah et al., 2023). It is crucial to comprehend the relationship between the mathematical solution and the real-world situation and to contextualize the solution in terms of the problem's context (Garfunkel & Montgomery, 2016).

The capacity of student teachers to identify assumptions and organize problems was similar across all groups, indicating that the fundamental mathematical concepts were effectively taught early in the program. Although the acquisition of fundamental principles is crucial at the outset, a well-planned advancement towards acquiring advanced practical skills, particularly modelling, must be undertaken in the later semesters. Wen (2018) supports this view, pointing out that Bruner's learning theory in mathematics teaching helps students master the structure of mathematical knowledge through active discovery, thinking, and representation. Moreover, if the learning process is implemented procedurally, students may struggle to develop their creative thinking abilities, limiting their potential during teaching and learning activities (Syutaridho et al., 2023). This endorses Niss's (2003) standpoint, which accentuates the necessity of integrating the application of concepts in actual contexts as an integral part of the teacher training process.

The study emphasizes the need for an integrated mathematics teacher education curriculum that balances theoretical knowledge with practical application. Continuous and incremental learning of mathematical skills, particularly through practical application and technological integration, should be a focal point. The quality of pre-service teacher training (PTT) plays a critical role in shaping the effectiveness and professional competence of graduates, ultimately influencing the overall quality of learning and education (Suprihatiningrum et al., 2024). Continuous professional development for practicing mathematics teachers is also crucial to ensure they remain adept and responsive to evolving educational demands.

The findings from this study underscore the need for mathematics teacher education programs to emphasize the gradual development of mathematization competencies. Starting with fundamental skills such as identifying assumptions and organizing problems, teacher training should progressively incorporate advanced skills like mathematical modeling to align with the cognitive growth observed among prospective teachers. Furthermore, integrating real-world problem-solving scenarios into the curriculum could enhance engagement and practical understanding, preparing educators for the dynamic needs of modern classrooms.

This research has several limitations that should be addressed in future studies. First, it focuses exclusively on a single institution, which may not reflect broader educational contexts. Second, the qualitative nature of the study, while rich in descriptive insights, limits the generalizability of the findings. Lastly, the study does not fully explore how external factors, such as cultural or institutional differences, might influence the development of mathematization competencies.

Finally, this study suggests the need for a more dynamic and adaptive approach to mathematics teacher education. Building on this, a training program grounded in conceptual understanding principles significantly enhances mathematics teachers' pedagogical knowledge, focusing on teaching strategies and understanding students' thinking to improve teacher performance (Amal et al., 2023). The concept of mathematization, which involves using mathematical methods to organize and examine various aspects of reality, plays a critical role in this process (Yilmaz & Dede, 2016). Corrêa and Haslam (2021) emphasize the importance of integrating various pedagogical approaches and highlight the evolving nature of teacher competencies in response to new educational challenges and advancements in the field. Based on the findings from these journals, a more exploratory and project-based approach may be more effective in advanced semesters to support the development of mathematization competencies, aligning with contemporary needs and trends in mathematics education.

Further research should explore the implementation of exploratory and project-based approaches in diverse educational and cultural settings to validate the findings of this study. Additionally, the development of innovative assessment tools to measure the progression of mathematization competencies is critical. Assessments should be designed to measure learning outcomes comprehensively and serve as tools for learning, fostering reflection and improvement in both teaching and learning processes (Citrawan et al., 2024). Teacher education programs should consider interdisciplinary collaborations to design curricula that better integrate conceptual understanding and real-world applications, ensuring educators are equipped to foster problem-solving skills in diverse classroom environments.

CONCLUSION

This study provides insights into mathematization competencies among prospective mathematics teachers, revealing that while all student groups effectively identify assumptions and organize problems, advanced skills in constructing mathematical models are predominantly evident in the fifth-semester cohort (Group 3). These findings emphasize the significance of a progressive and comprehensive curriculum that balances foundational concepts with advanced skills, particularly mathematical modeling, to prepare educators with theoretical understanding and practical application capabilities. By analyzing the development of mathematization competencies across academic levels, this study contributes to the existing literature and addresses critical gaps, offering a new perspective on how teacher training programs can better equip future educators. Furthermore, the study implies that fostering mathematization competencies enhances teaching effectiveness and promotes critical thinking and problem-solving skills applicable in broader educational and professional contexts. It recommends the integration of real-life problem-solving scenarios, exploratory teaching methods, and project-based learning in mathematics teacher education programs. This approach aligns with the evolving needs of contemporary education and calls for continuous curriculum improvement, professional development for in-service teachers, and innovative assessment methods to ensure sustained progress in mathematical education.

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AUTHOR CONTRIBUTIONS

Author one: conceptualization, methodology, writing – original draft preparation. Author two: methodology, data curation, validation, review, and supervision. Author three: formal analysis, supervision. Author four: validation.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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