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Analysis of the Quality of Problems Posed by Prospective Mathematics Teacher Students when Designing Numeracy Problems

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ABSTRACT

The ability of prospective teachers to design numeracy problems has a crucial role in developing students' mathematical literacy. This study aims to analyze the quality of problems designed by 34 prospective mathematics teachers collaboratively in the context of numeracy. The data was analyzed supervising the solvability aspects, the context used, and the cognitive process level of the problems designed. The findings showed that most of the problems designed by prospective teachers were solvable, with the majority of cognitive processes reaching the applying level and related to personal contexts. The implications of these findings can provide insight into the potential for developing more effective numeracy problem design skills in mathematics teacher education. Suggestions for future research include further research into teaching methods that can improve prospective teachers' numeracy problem design skills, as well as research that explores the direct impact of problem quality on students' mathematical literacy

Keywords: Collaborative Problem Posing, Numeracy, Prospective Mathematics Teachers

INTRODUCTION

Problem posing is an important mathematical practice for a maths teacher [1]. Because of the relevance of issue posing, many scholars in the field of mathematics education have become more interested in examining problem-solving activities in mathematics classrooms. Problem solving and teaching problem solving are key aspects of mathematical education [2]. Several references demonstrated that students, prospective teachers, and instructors continue to struggle with developing problem-solving abilities and should enhance them [3], [4]. Some of the challenges that emerge with posing mathematical questions include the issue being too basic, unsolvable, or including extraneous information.

issue posing, like issue solving, has long been an essential component of developing higher-order cognitive abilities. Many research indicated that problem-solving ability has a strong association with general mathematics abilities. issue presenting allows pupils to improve their ability to pose an issue based on a specific context. This causes pupils to focus not just on fixing current issues, but also on resolving them. This type of competence is required, particularly among potential mathematics student instructors. They are confronted with a scenario in which information and technology are rapidly evolving, necessitating their capacity to generate a challenge from a contemporary phenomena that would pique students' interest in learning.

We can have a thorough understanding of any existing phenomena if we can describe, explain, and make judgements based on available facts. Mathematical literacy, or numeracy, is a person's ability to formulate, apply, and interpret mathematics in a variety of contexts, including the ability to reason mathematically and use concepts, procedures, and facts to describe, explain, and predict a phenomenon [5], [6]. As a result, numeracy is an essential skill for understanding and interpreting phenomena. In contrast, the Indonesian Ministry of Education, Culture, Research, and Technology, which is now developing an autonomous learning programme, considers reading and numeracy to be the key priorities of teaching and learning activities at the elementary, secondary, and postsecondary levels. One of the ministry's programmes is a Teaching Campus (Kampus Mengajar), which includes students in helping to improve reading and numeracy levels, which remain poor in many schools [7]. As a result, every student, particularly student teachers, plays a crucial role in contributing to Indonesia's literacy and numeracy development efforts.

Although it may be claimed that there is a distinction between mathematical literacy and numeracy, the usage of the two words appears to be regional, with certain nations favouring the former and others preferring the latter [8]. Currently in Indonesia, the term numeracy refers to the capacity to think utilising concepts, methods, facts, and mathematical tools to address everyday issues in a variety of situations that are important to individuals as Indonesian and global citizens [9]. This is consistent with the OECD's definition of mathematical literacy in the Programme for International Student Assessment (PISA) framework [10], which defines "thinking" in numeracy in the Indonesian curriculum as the ability to reason mathematically as well as formulate, use, and interpret mathematics to solve problems in a variety of contexts. The actual world. According to [11], students should focus on contextualization rather than abstraction in order to enhance their numeracy skills. Thus, numeracy, as defined by [9], refers to the capacity to use mathematical tools, knowledge, and attitudes in a variety of contexts (including real-world circumstances). In this scenario, contextual factors have a crucial influence in influencing mathematical methods and hence performance [12], which may be proved through aspects of personal life, the job, and civic obligation [6], as well as scientific challenges [9] and [10].

Because context is so crucial in numeracy problems/tasks [13], it is critical to consider how the context is chosen for the issue asked by the teacher/prospective teacher during problem-posing activities. The problem in constructing such activities is to translate the situation into a series of real challenges that meet the idea of numeracy [14], [15]. This may be seen as a method for determining how realistic a problem scenario is [16], where the realistic degree of issues presented in mathematics learning corresponds to the actual tasks that occur in society to be mimicked [17]. These requirements indicate the level of use of context in mathematical tasks, which necessitates the inclusion of context in the cognitive process when solving a problem, both when formulating the problem into mathematical form and solving it mathematically, and when interpreting mathematical results and validating the interpretation in the context of a given problem [10], [18].

Based on the rationale above, and given the tight association between students' numeracy urgency and prospective teacher students' numeracy capabilities, a research is needed to evaluate prospective teacher students' abilities to ask numeracy-type questions. In response, research indicates that no generic strategy to classroom activities has been expressly designed to demonstrate how to construct numeracy issues [19]. Similarly, [20] said that there is no cutting-edge generic framework for issue presenting, such as the problem-solving procedure based on Polya's four phases [21]. Thus, it can be stated that designing a universal method that can be applied throughout the problem-solving process is critical. The problem-posing learning model (PPLM) is a model used in the problem-posing process [22]. In this concept, the learning environment is designed to help participants develop their problem-solving skills. Because of its generic character for a variety of issues, particularly problem submissions originating from structured problems, PPLM is naturally appropriate for special categories of challenges, such as numeracy difficulties.

As a result, this study will look into ways to build numeracy-type problem-posing abilities in future mathematics teacher students through collaborative problem-posing learning. In collaborative problem posing, participants, specifically future mathematics teacher students, collaborate with other participants to construct numeracy problems based on the problem-posing tasks assigned.

THEORETICAL FRAMEWORK

Problem Posing

Most research on the subject utilise or refer to one of two definitions for issue posing. Problem posing as an activity results in new issues (problem creation) and problem reformulation [23]. Silver adds that both actions might take place before, during, or after the problem-solving process. A second understanding of the term is that it refers to "the process in which, based on mathematical experience, students construct personal interpretations of concrete situations and formulate them as meaningful mathematical problems." [24]. Stoyanova and Ellerton classify situations as free, semi-structured, or structured based on their level of structure. A scenario is an unstructured issue in the sense that its aim cannot be specified by all of the available pieces and linkages [25].

In terms of the problem-posing process, [26] suggested a phase model based on a teacher-learning program (see Figure 1). As a result, this phase model is preceded by educational requirements and objectives.

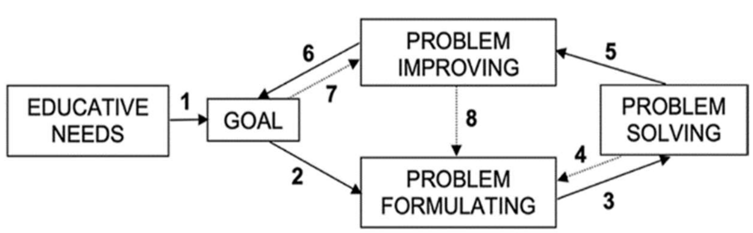

Figure 1: Phase model of problem posing [27]

Following the establishment of clear educational objectives (1), a problem development stage (2) begins. This stage generates an issue, which is subsequently solved (3). If the problem cannot be resolved, it may need to be reformulated (4). The solved problem is expanded upon in the rising problem-type stage (5). The complexity of the problem is adjusted for the study group and compared to the objectives (6 and 7). If the comparison reveals that the problem is improper, the assignment is revised (8) or rejected as inappropriate. [33] An investigation of the problem-posing process in an unstructured scenario revealed five distinct phases: setup, transformation, formulation, evaluation, and final assessment. Such settings include defining a situation's mathematical context and reflecting on the information needed to grasp it. This evaluation acts as the foundation for the rest of the procedure. During transformation, issue situations are analysed, and potential changes are discovered, considered, and implemented. The formulation summarises all processes associated with task formulation. This entails considering and evaluating various issue formulations. In assessment, a suggested problem is evaluated in a variety of ways, such as whether it fits the initial requirements or if more changes are required. The final evaluation reflects on the issue-posing process and evaluates the problem itself, such as its complexity and interest. In their study, they analysed the problem-posing procedures of experts and beginners, discovering distinct trajectories, namely transitions between phases. [28] identified four steps that were seen in the context of two effective problem-solving activities: (1) During the warm-up phase, a typical problem related to a specific circumstance is provided as a starting point. (2) During the phase of looking for intriguing mathematical phenomena, participants focus on specific parts of the provided assignment to uncover fascinating characteristics that may be applied to future issues. (3) Because the aim is to generate an intriguing issue formulation, problem makers attempt to conceal the task's creation to possible solvers during the concealment phase of the problem-posing process. (4) Finally, during the review step, issue authors assess the challenge using individual criteria such as level of difficulty or appropriateness for a certain target audience.

Numeracy Problem Design

Content and Context in Numeracy Problems

There are four categories of mathematical content in Numeracy Problem Design [9], namely:

1. ***Change and relationships***
Change and relationships relate to understanding the fundamental types of change that require mathematical modeling to explain and predict phenomena. Mathematically, this content relates functions and equations, as well as creating, interpreting, and translating between symbolic and graphical representations of mathematical relationships.

2. ***Space and shape***
Space and form relate to phenomena formed from the visual and physical world such as patterns, visual shapes, properties, position, and direction of objects, interpreting visual information, and dynamic interactions with real forms.

3. ***Quantity***
Numbers are related to the relationship between numbers and number patterns, including the ability to understand size, number patterns, and everything related to numbers in everyday life, such as counting, interpreting, and measuring certain objects.

4. ***Uncertainty and data***
In everyday life, uncertainty and data content are often encountered, such as data about population growth in an area, opinion poll results, weather forecasts, and so on. Probability/uncertainty and data relate to the domain of statistics and chance.

One of the important aspects of mathematical literacy skills is the involvement of mathematics in problem-solving in various contexts. Being able to work in various contexts is an important requirement for a good problem solver. There are three contexts for numeracy-type problems:

a. Personal
The problems that are focused on in the personal context are problems related to personal, family, and peer group activities. The real problems involved include food, personal health, shopping, games, sports, travel, and problems related to personal finances and scheduling.

b. Societal
The general context relates to the use of mathematical knowledge in social life, whether local, national, or global. This context can be public transportation issues, government, public policy, demographics, advertising, national statistics, economic issues, and so on.

c. Scientific
The scientific context in numeracy problems is specifically related to more abstract scientific activities and in-depth mastery of the theory used in carrying out mathematical solutions. The scientific context is also related to the application of mathematics in nature, issues, and topics related to science and technology, such as weather or climate, ecology, medicine, space science, genetics, measurement, and the world of mathematics itself. When a problem only involves

mathematical constructions without any connection at all to real-world problems, then this problem is classified in a scientific context.

METHODS

This research used a quasi-experimental design to investigate the quality of problems designed by prospective mathematics teacher students in designing numeracy problems. This design was chosen because the research was conducted in an educational environment and utilized groups of students who had received learning in posing numeracy problems collaboratively.

The research subjects consisted of 34 students who were taking assessment courses. They have undergone intensive learning in creating numeracy problems collaboratively. At the end of the lesson, subjects were given the task of designing numeracy problems individually.

This research variable consists of the independent and the dependent variables. The independent variable is learning to create numeracy problems collaboratively. The dependent variable is the quality of individually designed numeracy problems, which can be seen from the solvability of the numeracy problems, the context used, the level of context, and the cognitive processes used in the numeracy problems.

The research procedure begins with the implementation of assessment learning in which training in creating numeracy problems is carried out in groups of 4 to 5 students. The training involved creating numeracy problems that pay attention to solvency, application of context (personal, social, or scientific), level of context (zero, first, or second levels), and cognitive processes used.

At the end of the learning, subjects were given a task to design numeracy problems individually. They are given the freedom to choose the context (personal, social, scientific) and asked to create problems that measure students' numeracy abilities. Numeracy problems designed by students are tested regarding their solvency, context used, level of context, and cognitive processes.

The research instrument involves a rubric for assessing the quality of numeracy problems and a task for designing numeracy problems. The assessment rubric covers aspects of solvency of numeracy problems, the context, level of context, and cognitive processes used in designing problems.

The data were analyzed quantitatively using descriptive statistical techniques. The analysis focuses on the average quality of numeracy problems, the level of solvency, and the distribution of contexts used by students. The context of the numeracy problems designed by students will be analyzed based on their categories (personal, social, scientific). The cognitive processes used in creating problems will also be identified, whether they include understanding, analysis, or reasoning.

RESULT AND DISSCUSION

Result

Distribution of Posed Problem Tasks

There were 80 problems created by prospective math teachers, and interestingly, all of these problems could be solved. This study then proceeded to analyze the context level and cognitive processes of these problems. The results of the analysis provide further insight into the difficulty and complexity of the problems designed by prospective mathematics teachers, as well as provide insights into students' numeracy problem-solving abilities. This is an important contribution to understanding the quality of problems posed by prospective mathematics teachers, as well as identifying aspects that need to be improved to increase the effectiveness of mathematics learning. The results of the problems posed can be summarized in Table 1 as follows.

Table 1: Distribution of posed problem tasks

	Understanding	Applying	Reasoning	**The contexts level**
Zero-order	2	2	0	**4**
First-order	20	34	16	**70**
Second-order	2	2	2	**6**
The cognitive process	**24**	**38**	**18**	**80**

Table 1 of the study reveals that prospective teachers are more likely to make problems with the level of cognitive process of applying, which amounted to 38 out of a total of 80 problems produced. In the context of the level of problems, it is known that the prospective teachers more often use the first-order context level, with a total of 70 out of 80 problems. This indicates a tendency to focus on the application of mathematical concepts in designing problems, and most problems are designed at the basic context level.

Distribution of the Task's Context

Three contexts become the reference in developing numeracy problems based on the Minimum Competency Assessment in Indonesia, namely personal, socio-cultural, and scientific contexts. The following picture presents the distribution of the use of context in the problems made by prospective teacher students

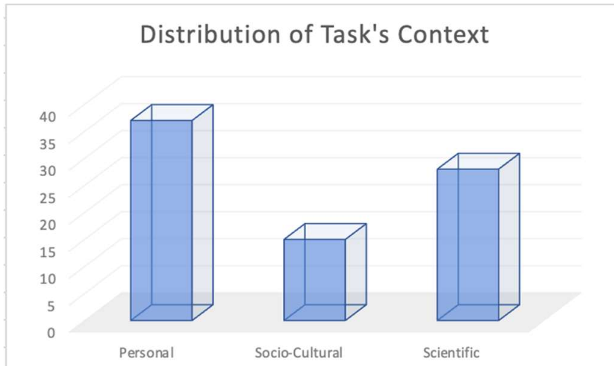

Figure 1: Distribution of Task's Context

From the analysis of the figure provided, it can be seen that prospective mathematics teacher students tend to use personal contexts more often in formulating numeracy problems, reaching a proportion of 46.25%. This shows a tendency to include elements that are personal or relevant to individual experiences in the formulation of mathematical problems. On the other hand, the socio-cultural context has a lower contribution, only 18.75%, indicating that the use of cultural aspects in designing numeracy problems is less dominant. Meanwhile, the scientific context was used at a proportion level of 38%, reflecting the interest in linking numeracy concepts with scientific approaches. This analysis provides insight into the preferences and approaches of prospective mathematics teachers in designing numeracy problems, which can serve as a foundation for the development of more effective learning strategies in the future.

The Level of Context in Numeracy Tasks

Several instances of tasks produced by participants concerning their level of context usage are respectively presented in Figure 2, Figure 3, and Figure 4

Seorang siswa berdiri diatas permukaan tanah. Dia melihat helikopter terbang tepat diatas gedung dengan sudut elevasi 53° terhadap helikopter, dan 37° terhadap gedung. Jika jarak anak tersebut ke gedung 10 meter maka ketinggian helikopter di atas gedung tersebut adalah..

a. 7,5 meter
b. 8,5 meter
c. 10 meter
d. 13,5 meter
e. 16 meter

Figure 2: The examples of zero-order

Translation: A student is standing on the ground. He sees a helicopter flying directly above the building at an elevation angle of 53° to the helicopter, and 37° to the building. If the distance from the student to the building is 10 meters, the height of the helicopter above the building is...

Figure 2 shows that problems posed in personal contexts with zero order levels are based on the use of helicopter contexts. This context provides a direct action or inference that can be drawn from the instructions contained in the math problem. However, it should be noted that in this problem, the helicopter context was not used to interpret the mathematical results or support the argument. Even without utilizing the helicopter context, students were still able to solve the problem. This suggests that the use of context at the zero-order level while providing a direct situation, may not have a significant impact on students' ability to solve mathematical problems. Therefore, further evaluation of the effectiveness of using context in improving the understanding and application of mathematical concepts can be considered for the development of more effective mathematical problems.

Kebutuhan omega 3 untuk Pria dewasa adalah minimal 1600 mg per hari. Anshori ingin memenuhi kebutuhan omega 3 dengan baik. Jika Anshori sudah mengonsumsi 5 udang pada pagi hari, Maka untuk menu makan siang dan malamnya ia harus mengonsumsi…

Figure 3: The examples of first-order task

Translation: The omega 3 requirement for adult men is at least 1600 mg per day. Anshori wants to fulfill his omega-3 needs well. If Anshori has consumed 5 shrimps in the morning, then for lunch and dinner he must consume...

Figure 3 shows a numeracy problem designed by student teachers, where the problem uses a personal context related to the need for omega-3 nutrition. This problem can be categorized as a problem with a first-order context level. This is due to the use of context at the first level, which allows the identification and selection of relevant information, variables, or relationships to formulate a mathematical problem. The personal context in this case refers to the need for omega 3 nutrients, providing a concrete basis for formulating the related mathematical problem. In addition, the context also provided enough information to determine the desired mathematical outcome. Therefore, this numeracy problem illustrates the application of the first-order context level which combines the relevance of the personal context with the sufficiency of mathematical information.

Pada saat makan malam, Keluarga Andi menyediakan 3 ikan, 2 udang dan 1 ayam. Keluarga Dimas menyediakan 1 ikan, 4 udang dan 2 ayam. Sedangkan keluarga Bayu menyediakan 4 ikan, 2 udang dan 3 ayam. Pernyataan berikut yang tepat adalah…

A. Omega 3 dalam hidangan keluarga Andi lebih besar dari pada omega 3 yang ada dalam hidangan Keluarga Bayu
B. Omega 3 dalam hidangan keluarga Andi lebih besar dari pada omega 3 yang ada dalam hidangan Keluarga Dimas
C. Omega 3 dalam hidangan keluarga Bayu lebih kecil dari pada omega 3 yang ada dalam hidangan Keluarga Andi
D. Omega 3 dalam hidangan keluarga Andi samadengan 2 kali lipat omega 3 yang ada dalam hidangan Keluarga Bayu
E. Omega 3 dalam hidangan keluarga Andi sama dengan omega 3 yang ada dalam hidangan Keluarga Bayu

Figure 4. The examples of second-order task

Translation: At dinner time, Andi's family provides 3 fish, 2 shrimp, and chicken. Dimas' family provides 1 fish, 4 shrimp, and 2 chicken. Bayu's family provided 4 fish, 2 shrimp, and 3 chicken. The following statement is correct...

A. The omega 3 in Andi's family's dish is greater than the omega 3 in Bayu's dish.

B. The omega 3 in Andi's family dish is greater than the omega 3 in Dimas' family dish

C. Omega 3 in Bayu's family dish is smaller than omega 3 in Andi's family dish

D. Omega 3 in Andi's family dish is equal to 2 times the omega 3 in Bayu's family dish

E. Omega 3 in Andi's family dish is the same as omega 3 in Bayu's family dish

In the problem given by the student teachers, each family provided the number of fish, shrimp, and chicken at dinner. The problem creates a personal context that requires an understanding of the omega-3 content in these foods. This problem belongs to the second-order context level, as it requires additional assumptions or knowledge related to the weight of the fish to determine the comparison of omega-3 content between family meals. The use of second-order context allows the identification of the fish weight variable as a relevant factor in formulating the mathematical problem. The context becomes the basis for evaluating the adequacy of mathematical results and arguments used in solving related problems.

The Level of Cognitive Processes in Numeracy Tasks

Figure 5 presents several task examples created by prospective teachers, showing different levels of cognitive processes.

Pada saat makan malam, Keluarga Dina menyediakan 3 ikan, 2 udang dan 1 ayam. Keluarga Anshori menyediakan 1 ikan, 4 udang dan 2 ayam. Sedangkan keluarga Meli menyediakan 4 ikan, 2 udang dan 3 ayam. Matriks yang sesuai untuk menyatakan hidangan ketiga keluarga tersebut adalah…

Figure 5. Understanding task 1

Translation: At dinner time, Dina's family provides 3 fish, 2 prawns, and 1 chicken. Anshori's family serves 1 fish, 4 prawns, and 2 chickens. While Meli's family provides 4 fish, 2 prawns, and 3 chickens. The appropriate matrix to express the dishes of the three families is...

This problem is included in the cognitive level of understanding of matrix material because it requires students to apply their knowledge of matrix concepts in a real context. Students need to understand how to organize information about the number of fish, shrimp, and chicken from each family into a matrix form. The process involves understanding the basic concept of a matrix, which is arranging the data in rows and columns according to the type of variable represented by the matrix. Therefore, this problem not only tests basic knowledge of matrices but also students' ability to apply the concept to represent the given information.

Figure 4 depicts this problem falls into the reasoning level category as it requires students to do logical thinking and make inferences based on the information provided. First, we need to understand that omega-3 content is not directly related to dishes such as fish, shrimp, or chicken. Therefore, the best answer can be found by analyzing the given statements. After examining Andi, Dimas, and Bayu's family meals, we are not given any information about the omega-3 content in the meals. Therefore, it is not possible to conclude the comparison of omega-3 content between Andi's, Dimas', and Bayu's families based on the information given. Thus, the correct answer is undetermined because there is not enough information to assess the comparison of omega-3 content between Andi's, Dimas', and Bayu's families. Thus, an assumption is needed to be able to answer the problem.

DISCUSSION

The research on the quality of problems formulated by prospective mathematics teacher students in the context of designing numeracy problems provides significant insights into both the pedagogical preparedness of these future educators and its potential impact on students' mathematical literacy. By analyzing the solvability aspects, context usage, and cognitive process levels of the problems designed, the study contributes to our understanding of effective mathematics education. This discussion contextualizes the research findings with existing literature and theoretical frameworks.

The observation that all 80 problems created by prospective math teachers were solvable aligns with the foundational premise that effective learning experiences require problems that students can successfully navigate. This resonates with the principles of Vygotsky's Zone of Proximal Development (ZPD), emphasizing the importance of tasks that challenge students without overwhelming them. The ability of prospective teachers to craft solvable problems reflects their understanding of the balance between challenge and attainability, a crucial aspect in fostering mathematical literacy [29].

The dominance of the applying level in the cognitive process analysis underscores the practical application of mathematical concepts in the problems designed. This finding aligns with Bloom's Taxonomy, suggesting that the majority of problems are designed to engage students in applying their knowledge, a crucial step towards achieving a deeper understanding [30]. However, it is noteworthy to consider the need for a balance across cognitive levels to foster a holistic development of students' thinking skills, as emphasized in contemporary educational theories [31].

The analysis of context usage reveals a preference for personal contexts (46.25%) among prospective mathematics teacher students. This finding resonates with the theory of situated cognition, which posits that learning is most effective when situated within authentic contexts relevant to learners' experiences [32]. The inclination toward personal contexts aligns with constructivist principles, emphasizing the importance of connecting new knowledge to prior experiences for meaningful learning [33]. The lesser emphasis on socio-cultural contexts (18.75%) and the moderate usage of scientific contexts (38%) indicates a potential area for enhancing the diversity of context incorporation in problem design.

This research result underscores the need for targeted interventions in mathematics teacher education programs. Although the ability to create solvable numeracy problems is laudable, strategies are needed that can guide prospective teachers in designing numeracy problems at multiple cognitive levels and in diverse contexts. This is in line with the principles of pedagogical content knowledge, which emphasize the intersection between subject matter knowledge and teaching strategies [34]. Educators must foster a balance that ensures the depth and breadth of students' skills in designing high-quality numeracy problems.

CONCLUSION

Based on those research results, we conclude that the quality of problems posed by prospective mathematics teacher students in designing numeracy problems offers valuable insights into their pedagogical preparedness and the potential impact on students' mathematical literacy. The study, encompassing the collaborative efforts of 34 prospective teachers, sheds light on several key aspects.

Firstly, the findings reveal that all of the numeracy problems crafted by these prospective teachers are solvable, reflecting a commendable level of proficiency in translating mathematical concepts into practical problems. This proficiency bodes well for the development of students' problem-solving skills, as solvability is a fundamental criterion for effective learning experiences.

Secondly, the cognitive process analysis indicates that a substantial portion of the designed problems engages learners at the applying level. This suggests a depth in the cognitive demands of the problems, fostering critical thinking and analytical skills among students. It signifies a positive inclination towards encouraging a higher-order understanding of mathematical concepts, beyond mere rote memorization.

Furthermore, the prevalent use of personal contexts in the formulated problems is noteworthy. This inclination towards personalization demonstrates an awareness of the significance of relatable, real-world scenarios in enhancing students' comprehension and application of mathematical principles. It aligns with contemporary pedagogical approaches emphasizing contextualized learning experiences.

The implications of these findings are far-reaching. Understanding the strengths and areas for improvement in prospective mathematics teachers' problem-design skills can inform targeted interventions and enhancements in teacher education programs. By addressing specific needs identified in this application, teacher training programs can better equip educators to design diverse, engaging, and effective numeracy problems that resonate with students.

As a suggestion for future research, a deeper exploration into teaching methodologies that specifically target the refinement of numeracy problem design skills among prospective teachers would be beneficial. Additionally, investigating the direct correlation between the quality of problems designed by teachers and their impact on students' mathematical literacy can contribute further evidence to inform educational practices and policies. In essence, the analysis serves as a foundation for ongoing efforts to elevate the effectiveness of mathematics education through the continuous improvement of the problems posed by prospective mathematics teacher students.

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