Assessing Student Teachers' Ability in Posing Mathematical Reasoning Problems

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∼ Assessing student teachers' ability to pose mathematical reasoning problems within their experiences in teacher education is essential due to their increasing challenges in preparing for 21st-century learning. This study investigates the quality of mathematical reasoning problems posed by student teachers. Thirty-four student teachers at a public university in Surabaya, Indonesia, who attended an assessment lecture posed mathematical problems, where four aspects (suitability of indicators which refers to cognitive behaviour expected from the problems posed, the plausibility of the solution of the problems poses, the correctness of the solution, and language readability) were used to assess the problems posed. The results indicate that more than 70% of the student-teacher participants were successful in posing reasoning problems (either objective or subjective questions) indicated by those which are in accordance with the established criteria. However, most of the posed problems are categorised as 'analyse' problems instead of 'evaluate' or 'create' problems.

Keywords: mathematical reasoning problem, student teachers, problem-posing

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Ocenjevanje zmožnosti študentov, bodočih učiteljev, pri zastavljanju problemov matematičnega sklepanja

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∽   Ocenjevanje zmožnosti študentov, bodočih učiteljev, pri zastavljanju problemov matematičnega sklepanja v okviru njihovih izkušenj v izobraževanju učiteljev je bistvenega pomena zaradi vse večjih izzivov pri njihovi pripravi na učenje v 21. stoletju. Ta študija raziskuje kakovost problemov matematičnega sklepanja, ki jih zastavljajo študentje, bodoči učitelji. 34 študentov učiteljev na javni univerzi v Surabayi v Indoneziji, ki so se udeležili ocenjevalnega predavanja, je zastavljalo matematične probleme, pri čemer so bili za oceno zastavljenih problemov uporabljeni štirje vidiki (ustreznost kazalnikov, ki se nanaša na kognitivno vedenje, pričakovano od zastavljenih problemov, verjetnost rešitve zastavljenih problemov, pravilnost rešitve in berljivost jezika). Izsledki kažejo, da je bilo več kot 70 % udeleženih študentov, bodočih učiteljev, uspešnih pri zastavljanju problemov sklepanja (objektivnih ali subjektivnih vprašanj), kot kažejo zastavljeni problemi, ki so skladni z določenimi merili. Večina zastavljenih problemov pa je razvrščena v kategorijo problemov »analiziranja« namesto problemov »vrednotenja« ali »ustvarjanja«.

Ključne besede: problem matematičnega sklepanja, študentje, bodoči učitelji, zastavljanje problemov

Introduction

Posing mathematical tasks is essential for all mathematics teachers in presenting their instructions (Smith et al., 1996). In this regard, Chapman (2013) included such skills in a setting in which teachers should be able to identify, select, and create mathematically and pedagogically rich tasks. The latter ability is deemed problem-posing ability, in which teachers are encouraged to be knowledgeable of and skilled at problem-posing in order to provide students with learning opportunities that involve it (Cai, 2013). Despite problem-posing being the leading mathematical activity that stimulates mathematical thinking, not every situation of individuals' mathematical work, including teachers, is regarded to encourage their problem-posing activities (Hodnik & Kolar, 2022). In this case, teachers are required to pose mathematical tasks by understanding the level of cognitive demands of the task and the relationship to task objectives in terms of the level of learning and understanding of the mathematics they can promote (Chapman, 2013). Alternatively, the cognitive demands can be interpreted as all cognitive process levels, from the lowest to the highest, as suggested in Bloom's Taxonomy (Krathwohl, 2002). Thus, teachers need to be competent in posing problems for more than the level of remembering, understanding, and application. The higher levels, known as HOTS, comprise logical thinking, critical thinking, and reasoning, which are basic daily life skills (Marshall & Horton, 2011).

More specifically, Bjuland (2007) defined reasoning as five interrelated mathematical thinking processes: sense-making, conjecturing, convincing, reflecting, and generalising. **Furthermore, Boesen et al. (2010) classified math**ematical reasoning as five interconnected processes of mathematical thinking: sense-making, conjecturing, convincing, reflecting, and generalising. Four process standards for reasoning and proof in instructional programmes, from pre-kindergarten through grade 12, proposed by the National Council of Teachers of Mathematics of the United States (2000), recognise reasoning and proof as fundamental aspects of mathematics, making and investigating mathematical conjectures, developing and evaluating mathematical arguments and proofs, and selecting and using various types of reasoning and proof methods. Those processes are also in accordance with the cognitive processes of Bloom's revised taxonomy, which are categorised as analysing (C4), evaluating (C5), and creating (C6) or classified as higher-order thinking (HOT) skills (Anderson & Krathwohl, 2001). The corresponding verbs indicating those three cognitive processes are differentiating, organising, attributing, checking, critiquing, generating, planning, and producing. Those verbs are then used as the basis of

writing indicators of items in many item developments of reasoning problems. In particular, in the current Indonesian curriculum document, those three levels are categorised as reasoning levels. These are the basis of writing items for any national school examination (Setiawati et al., 2019). Furthermore, reasoning problems are promoted in the inclusion of the current national assessment system called Minimum Competency Assessment (MoE, 2021), in which international standard assessment systems such as PISA and TIMMS become the main reference for writing the items.

From the definition and characteristics explained, reasoning skills, to which the three levels: reasoning, evaluating, and creating are referred, can be investigated by using certain tasks or problems that may include sense-making, reflecting, generalising, investigating conjectures, posing arguments, judging, or proving statements. For example, West (2018) used open-ended tasks to stimulate mathematical reasoning, while Kosyvas (2016) used open-ended problems to investigate the level of arithmetic reasoning. Hence, open-ended problems can be included as tools to investigate and stimulate reasoning. In these particular studies, such tasks were used to promote reasoning. Another type of task (i.e., a non-routine task) is also used to examine students' mathematical reasoning since it can identify the types of reasoning performed by students (Jäder et al., 2017). In this study, the reasoning problems that are expected to be proposed by prospective teachers are considered problems for assessing students' mathematical reasoning. These problems assess students' abilities in analysing, evaluating, and creating where doing so is needed to distinguish, organise, relate, examine, criticise, generate, plan, and produce. In addition, understanding, reflecting, generalising, investigating conjectures, making arguments, judging, or proving the promoted statements are also crucial in reasoning problems.

Prior to implementing mathematics instruction and encouraging students' HOT skills, teachers may consider posing reasoning tasks, such as open-ended or non-routine tasks, as either assessment needs or learning material needs. However, in practice, the application of learning that involves students in HOT skills is challenging to do, as well as the assessment (Zohar, 2004). It is easier for teachers to assess students' calculation skills than to assess HOT skills and reasoning skills (Nortvedt & Buchholtz, 2018; Palm et al., 2011; Schoenfeld, 2007). Therefore, mathematics education students as prospective teachers should be able to pose high-level math problems or reasoning categories problems as a part of the assessment.

The primary key is the ability to pose reasoning problems in mathematics learning. Teachers' ability to pose reasoning problems is required to explore

and evaluate the extent to which students understand the material being taught. In addition, teachers' ability to pose reasoning problems can help students reduce their dependence on textbooks and help them be more involved in learning activities (Lavy & Shriki, 2007). Teachers need to be involved in problem-posing activities to pose mathematical reasoning problems. According to Silver (1994), problem-posing activities refer to generating new problems from a mathematical context and reformulating a given problem. In general, posing a problem is posing a problem in free situations. However, problem-posing activities can also pose problems whose answers are appropriate to give answers containing specific information from graphs, diagrams, and so on, or given mathematical calculations (Lee, 2021). In this study, we focus on the generation of new problems by which the problems were posed based on several conditions: alignment with curriculum outcome (goal, competency, not cognitive demand), reasoning problem, and closed/open (Grundmeier, 2015).

Several aspects used to assess an individual's ability to pose mathematical problems were reported. For example, Silver and Cai (1996) suggested examining the language structure of and the presence or absence of a solution to the problems raised to assess a person's ability to pose problems, while Siswono (1999) and Masriyah et al. (2018) assessed students' posed problem from a given context by focusing on whether the problems can or cannot be solved, the interrelationship of problems with the information, answers to the problems raised, language structure used, and the problems' levels of difficulty. Furthermore, Stickles (2011) analysed problems posed by preservice and in-service teachers and considered a problem to be well defined if it meets criteria by which it will (a) encourage one to simplify and posit the problem oneself and abstract the mathematical representations and (b) where there are no applicable solution methods or procedures to complete the task.

In recent years, the quality of problems posed by teachers, either in-service or preservice, including student teachers, were examined through problem-posing activities to determine whether it reflects teacher subject matter and pedagogical content knowledge (Lee et al., 2018; Yao et al., 2021), curricular knowledge (Cai & Hwang, 2021), and large-assessment scale-based task like in PISA problem (Rosyidi et al., 2020; Tasman, 2020). In fact, this last aspect shows that there is a tendency for research topics to be interested in assessing the quality of mathematics problems by varying the level of cognitive demand according to the demands of the 21st century. However, there are limited studies discussing the problem quality created by teachers regarding the cognitive demand level of reasoning aspect. For example, Rahaju and Fardah (2018) found that several teachers failed to pose higher-order thinking (reasoning) problems

due to confusion over applying analysing problems. This study suggested that, among six levels of Bloom's revised taxonomy, the mathematical problem percentages referred to as the 'analysing' problem the teacher participants created was only 47.06%, while only five participants created the 'applying level' problem. With different contexts, Rahaju et al.(2020) found that 54.71% of the total participants in their study were successful in posing reasoning skills problems ranging from the levels of analysing, evaluating, and creating. However, those studies only took teachers as subjects, and there was no finding discussing the student teachers as subjects. Therefore, this study concerns the performance of student teachers' abilities in posing mathematical reasoning problems.

Based on the previous evidence, the researchers were interested in identifying student teachers' abilities to develop reasoning problems. The reasoning problem criteria could assess, through several aspects, the suitability of the problems (Anderson & Krathwohl, 2001; Bjuland, 2007; National Council of Teachers of Mathematics, 2000); difficulty level of the prepared problem (Siswono, 1999); the problem openness regarding the solution number and solution alternatives (Kosyvas, 2016; West, 2018); the plausibility of the created problem (Silver & Cai, 1996); the correctness of problem (Siswono, 1999); the language suitability of the problem with the students' levels of knowledge (Kohar et al., 2019); and language or sentence structure used in the problems arranged (Siswono, 1999; Zulkardi & Kohar, 2018).

In this study, we focused on the following criteria: problem plausibility, language structure, and suitability of task to student ability. Furthermore, we also added another criterion, namely the problem suitability with indicators of the problem, since one of the requirements for any future teacher is being able to translate the cognitive demand provided in the curriculum document into problem design.

Research Questions

What is the quality of mathematics problems posed by prospective teachers regarding the aspects of reasoning problem level, problem plausibility, language structure, and suitability to students' knowledge level?

Method

Research design

This descriptive qualitative research aims to make systematic, factual, and accurate fact descriptions, characteristics, and relationships between the investigated phenomena by drawing from a naturalistic perspective and examining

a phenomenon in its natural state (Kim et al., 2017). Thus, the research design studies the research subjects in their environments to explore their behaviours without outside influence or interventions. The phenomenon in this study is the student teachers' ability to pose mathematics reasoning problems.

The participants were 34 student teachers (14 males and 20 females) from the Department of Mathematics Education, Faculty of Mathematics and Natural Sciences, Surabaya State University, Surabaya, East Java, Indonesia, who were attending an assessment course. The participants were taken from a class consisting of students of both sexes and a variety of mathematical abilities, meaning that relatively balanced numbers of the sexes and levels of mathematical ability were applied in selecting class samples. At the time of taking this data, students had taken several basic pure mathematics courses, such as logic and sets, differential and integral calculus, and elementary number theory, as well as pedagogical courses, such as learning theory, innovative learning, and educational basics.

Data collection

Data were collected from the participant's responses to a problem-posing task, which asked them to pose mathematics problems based on a given situation. Some lectures related to Assessment in Mathematics Education were carried out for 15 meetings. The time for data collection was after students joined the lectures about open-ended questions, types of mathematics questions regarding their structure, which is objective or subjective, and problems that fall into the category of reasoning questions (7th of 15 meetings). The problem-posing activity using the problem-posing task (Table 1) was carried out by the researcher as an assessment lecturer at the 7th meeting assigning students individually to pose reasoning questions at home and collected at the next meeting (8th meeting). Because they worked at home, they were allowed to use literature.

Before working on the problem-posing task, the participants followed a short discussion with the authors to confirm what they needed to do regarding the task through a stimulus. The stimulus was around the class discussion regarding the concept of mathematical reasoning guided by the lecturer. The discussion is directed at the potential problems exemplified by participants to be developed to a higher level of problems. In this situation, the first author, who acted as the lecturer at such a discussion, guided the student participants to identify the characteristics of the reasoning problem as explained in the introduction section of the present paper (i.e., understanding, reflecting, generalising, investigating conjectures, making arguments, judging, or proving the promoted statements are also crucial in reasoning problems), exemplifying

examples and non-examples of reasoning problem, and asking students to pose mathematical questions from a given stimulus in a problem-posing activity. In addition, the participants also discussed how to derive indicators of the mathematical problem, which represent the cognitive demand of the problem, from the basic competencies for school mathematics published by the Ministry of Education (MoE), namely Permendikbud No 24 2016 (MoE, 2016).

Table 1

The problem-posing task

Task Instrument

You are asked to pose two mathematics problems with the following instruction.

1. Choose a pair of Knowledge or Skills Basic Competency from several Basic Competencies of the 2013 Curriculum for junior, senior, or vocational school level, then determine an indicator* of the problem you created.
   * The indicator of the problem indicates a description of behaviour that can be observed and measured to show that a student has engaged in some cognitive demands to achieve specific competence. Indicators of problem are a marker of achievement of Basic Competencies, which are indicated by measurable behavioural changes, including attitudes, knowledge, and skills. This measurement is known as a crucial part of the current Indonesian curriculum for school subjects (Anggraena et al., 2022).

2. Based on the indicators that you formulate, choose one indicator to pose two problems with reasoning categories (one objective question and one subjective question) ** accordingly.
   ** Objective questions are those requiring a specific answer, having only one potential correct answer, leaving no room for opinion, while subjective questions are those requiring answers in the form of explanations such as essay responses, short answers, definitions, and opinion or argumentation.

Data analysis

The posed problems were then analysed considering indicators for reasoning problems, namely analysing, evaluating, or creating. These are the three highest levels of Bloom's taxonomy (revision) for the cognitive process dimensions, so the three-level problems are often referred to as higher-order thinking (HOT). Anderson & Krathwohl's (2001) dimension of cognitive processes referring to those three levels was used to classify the problem posed by the participants, whether it is a reasoning problem or not. The following stages describe how the posed problems were analysed and reported.

1. Each of the student teachers' responses was examined by authors in a forum group discussion to determine whether it meets the criteria of reasoning problem, problem plausibility, understandable language structure, suitability of the cognitive demands (indicated by stated indicator), and suitability to students' level of knowledge. A problem is classified as a reasoning problem if it meets the criteria of analysing, evaluating, or creating a problem in the Revised Bloom's Taxonomy. Meanwhile,

language suitability is the degree of familiarity of the language used in the texts provided in the problem regarding the readers, which in this case are students at secondary school.

2. The number of problems meeting the criteria was changed into a percentage as compared to the number of students who completed the task.

3. The percentage of each criterion was reviewed and analysed according to the success criteria of competent students in posing reasoning problems. Thus, the authors set four criteria to analyse the problem posed by the students: (1) the problems are in accordance with the indicators of the problem set out by students, (2) the problems posed by students have a solution, (3) the solution of the reasoning problems posed by the students is correct, and (4) the structure of the sentences used in the problem is in accordance with the students' levels of knowledge. Regarding Criterion (1), an example of a problem that does not reflect the indicator set out by the participants is as follows.

Indicator: evaluate the correctness of a statement related to a proportional reasoning problem.

Question: If one litre of gasoline can be used to travel as far as 30 kilometres, then three litres of gasoline can be used to travel as far as… km.

Although the problem indicates the use of proportional reasoning, it does not reflect the cognitive behaviour demanded as written in the indicator, which encourages a solver of the problem to evaluate the correctness of the proportional reasoning-related statement. Thus, it is coded as an unsuitable problem with indicators. Furthermore, regarding the level of cognitive process, this problem cannot be coded as a reasoning task since this problem only requires the solver to apply simple proportional reasoning directly without the need for further assumptions or further analysis of the information provided.

The number of problems posed by students that met each criterion was compiled. Then, the number of problems meeting the criteria was changed into a percentage, as compared to the number of students who completed the task. The percentage of each criterion was reviewed and analysed according to the success criteria of competent students in posing reasoning problems.

4. Some examples of each criterion are described by providing the student teachers' responses.

Results

The analysis results of problems posed by students in essay and objective types are given in Tables 2, 3, and 4.

Table 2

Achievement percentage of the criteria for problems posed by students

No.	Aspect	Problem Type	Percentage (%)
1	Problems posed by students in accordance with the indicators	Subjective	88.23
		Objective	91.18
2	The problems posed meet the reasoning problem criteria	Subjective	82.35
		Objective	79.41
3	Problems can be solved	Subjective	85.29
		Objective	94.12
4	The solutions to the reasoning problems arranged are correct (plausible)	Subjective	79.41
		Objective	94.12
5	The problems made are in accordance with the level of knowledge of students.	Subjective	100
		Objective	100
6	The language or sentence of the problem posed is effectively understandable	Subjective	91.17
		Objective	91.17

Table 3

Difficulty level percentage of problems posed by student teachers

No.	Difficulty Index	Problem Type	Percentage (%)
1	Difficult	Subjective	26.47
		Objective	14.71
2	Medium	Subjective	58.82
		Objective	70.58
3	Easy	Subjective	14.71
		Objective	14.71

Table 4

Percentage of reasoning problems, including open problems or not

| Open Problem	Problem Type	Percentage (%)
Yes	Subjective	70.58
	Objective	82.35
No	Subjective	29.42
	Objective	17.65

The following indicates some examples of the work of participants in posing the reasoning problems.

The problem that was not in accordance with the indicator

a.   Indicator: Find a comparison of three similar triangles

Figure 1

*The triangles used as an example of Problem 1 are not based on the indicator*
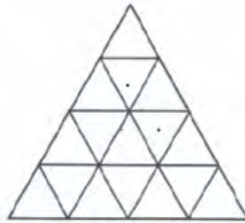
Problem 1: Determine the ratio of the number of triangles above that have different sizes (Figures 1 and 2)

Solution:

Figure 2

The ratio of the number of the triangle in different sizes, (a) 16 triangles with one unit length, (b) 7 triangles with two units of length, (c) 3 triangles with three units of length, and (d) 1 triangle with four units of length

a

b

c

d
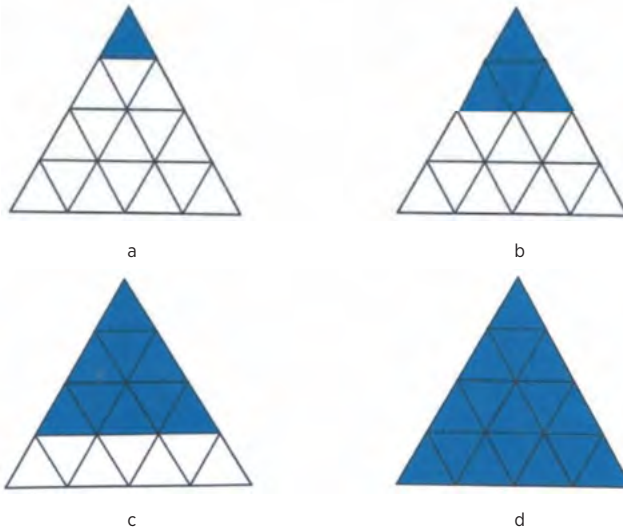
Therefore, the ratio of the number of triangles with 1 unit length: 2 units: 3 units: 4 units was 16: 7: 3: 1.

This problem was not in accordance with the indicator because it reads, 'Find a comparison of three similar triangles.' This means what will be achieved is to determine the ratio between the length of the side and the area or the circumference of several equilateral triangles, while the problem asked was to determine the ratio of the number of triangles with different-sized sides. However, it is included as an example of a reasoning problem. This is indicated by the demand for investigating conjectures related to the geometrical shapes (triangles) and the number of each triangle with different sizes.

b. **Indicator: Solve problems related to tangents outside two circles (Figure 3).**

Problem 2:

Figure 3
The astronaut problem used as Example 2 is not based on the indicator
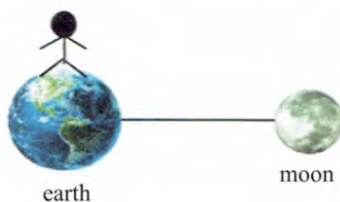
An astronaut wants to go to the moon. However, he was confused about how much fuel was needed for the rocket. One litre of fuel can be used for a distance of 80 metres. If the radius of the earth is 6,300 km, the radius of the moon is 1,700 km, and the distance between the earth and the moon is 384,000 km, then the amount of fuel that the rocket needs to get to the moon is ….
A. $32{,}492 \times 10^2$ litres
B. $31{,}352 \times 10^{-1}$ litres
C. $31{,}352 \times 10^{-2}$ litres
D. $31{,}249 \times 10^{-3}$ litres

This problem was not in accordance with the indicator because the indicator was 'Solve problems related to tangents outside two circles', while, in this problem, the question was how much fuel the rocket needed to reach the moon. Finding the answer to this problem does not require calculating the length of the tangents outside the two circles. Regardless of whether it is in accordance with the indicator selected, this problem can be considered a reasoning problem since those solving it need to build their sense-making on the contextual information and reflect it into a relevant mathematical procedure (i.e., the distance between two spheres) and the judge the amount of fuel needed by the rocket.

The problem that is in accordance with the indicator
Problems 3 and 4 represent examples of reasoning problems posed by student teachers. While Problem 3 indicates the cognitive demand for investigating conjectures of number patterns in simple remainder problems, Problem

4 indicates the cognitive demand for sense-making in a piece of information related to geometrical shapes and spaces. Meanwhile, Problems 5 and 6, although not consistent with the indicators created, are considered reasoning problems.

a.   Indicator: Determine the unit number of a power number

Problem 3: What is unit number 3^{1999}?

Solution:
$3^1 = 3$, the unit is 3
$3^2 = 9$, the unit is 9
$3^3 = 27$, the unit is 7
$3^4 = 81$, the unit is 1
$3^5 = 243$, the unit is 3
$3^6 = 729$, the unit is 9
.
.
.
The unit numbers form a sequence of repeating numbers as follows:
3, 9, 7, 1, 3, 9. . .
If it continues until 3^{1999}, the pattern will continue to repeat and
$1999 = 4\,(499) + 3$
So, the unit number of 3^{1999} is 7

b.   Indicator: Determine the distance from a point to a line in space

Problem 4: Given: Cube of ABCD.EFGH
The distance of point A to the HB line is ……
A. $2\sqrt{6}$
B. $2\sqrt{2}$
C.   3
D. $6\sqrt{2}$

The following was an example of a problem that was incompatible with the indicator of a reasoning problem.

c.   **Indicator: Solve problems in daily life related to the two-variable linear equation system**

Problem 5: The price of a pair of shoes is twice the price of sandals.

Ardi bought two pairs of shoes and three pairs of sandals at a price of IDR 420,000.00. If Dony buys three pairs of shoes and two pairs of sandals, Dony must pay as much as ……..
A.   IDR 180.000,00
B.   IDR 360.000,00
C.   IDR 480.000,00
D.   IDR 540.000,00

This problem cannot yet be categorised as a reasoning problem. Instead, it is included as an application problem since the cognitive demand of this problem is only to apply simple mathematical operations related to solving a system of linear equations with two variables directly in a word problem. However, the level of this problem can be upgraded into a reasoning problem by changing what is asked from only asking the price of some pairs of sandals and shoes to asking about the change that should be given to the buyers within the transaction. This adds to the chain of reasoning, at least with regard to the number of required mathematical operations. Following is what it means.

The price of a pair of shoes is twice the price of sandals.
Ardi bought two pairs of shoes and three pairs of sandals at a price of IDR 420,000.00. If Dony buys three pairs of shoes and two pairs of sandals, and he has IDR 500.000,00, how much is the change?

The problem also can be developed into a reasoning one and include an evaluation problem if it is revised as follows.

The price of a pair of shoes is twice the price of sandals.
Ardi bought two pairs of shoes and three pairs of sandals at a price of IDR 420,000.00. Dony also wants to buy shoes and sandals at the shop, and he brings as much as IDR 500,000.00. How many pairs of shoes and sandals can he buy as much as possible to get as little change as possible, and how much is the change?

The reasoning problems posed by students were generally included

in the analysis categories (71.43%). The evaluation problems posed were 25%, while the creating problems were only 1.46%.

Problem elaboration: Analysing, evaluating, and creation

The following problems were successively given as an example of problems made by students for the categories of analysis, evaluation, and creation.

The problem with the 'analyse' category

Problem 6 indicates an example of an analysis problem, and students should carry out an analysis by identifying the elements that are most important and relevant to the problem (attributing process), then proceed with building the appropriate relationship from the information that has been given (organising process). This is in accordance with the characteristics of the analysis problems that involve cognitive processes: attributing and organising.

Problem 6: Fauzan goes from city A to city B. If in 1 hour he rides 1.5 km more, then he only needs 0.8 times the usual time he uses. If in 1 hour he goes 0.5 km slower, then he only takes 2.5 hours longer than the time he used. What is the distance between city A and city B?

A.   120 km
B.   165 km
C.   170 km
D.   200 km

The problem with the "evaluate" category

Problem 7 indicates two examples of evaluation problems because students should check which steps are correct and logical (checking process). In addition, students need to assess these steps based on certain criteria and standards that are appropriate (critiquing process). This is in accordance with the criteria for evaluation problems that involve cognitive processes: checking and critiquing.

Problem 7:
a. Observe the following work. Which steps in the row are incorrect?

$$(-2)^3 = (-2)^{\frac{1}{2} \times 6}$$
$$= (-2)^{6 \times \frac{1}{2}}$$
$$= ((-2)^6)^{\frac{1}{2}}$$
$$= (64)^{\frac{1}{2}}$$
$$= 8$$

b. Hary will give his mother a birthday present and put it in a square-shaped base that has a volume of 64,000 cm³. This gift box will be wrapped in gift paper with one motif. There are two gift paper motifs that Hary has chosen with their size and price as follows. In order to use the minimum cost, which paper should Hary choose? (Figure 4)

Figure 4
Gift paper for Hary's mom's birthday present, (A) motives 1, and (B) motives 2

To answer these problems, students must calculate how much paper is needed for each motif, determine the overall price, and then determine that one requires lower costs.

c. A sphere-shaped iron is placed in a cube-shaped box with sides 10 cm long. If the volume of the water box is 900 cm³ and the radius of the sphere-shaped iron is 3 cm, will the water in the bathtub over-flow? Give your reason.

To answer this problem, students must calculate the volume of each object (cube and sphere), then evaluate (i.e., consider) and examine the quantity of water and sphere volume associated with the volume of the cube.

The problem of the 'create' category
Problem 8 indicates two examples of evaluation problems because students need to think in a divergent manner, which is the essence of creative thinking (generating process). In addition, students need to plan to solve the problems given, which leads to producing new procedural knowledge (producing process). This is in accordance with the characteristics of creating problems that involve cognitive processes: generating and producing.

Problem 8: Explain the relationship between the formulas of surface area and the volume of the tube mathematically.

In this problem, students are asked to think of something new that can be used to solve problems, namely, deriving new formulas from existing formulas. The solution starts by writing the formula of the surface area and volume of the tube as follows.

$L = 2(\pi r^2 + \pi rt)$

$V = \pi r^2 t$

From $V = \pi r^2 t$, we have $\pi r^2 = \dfrac{V}{t}$, and $\pi rt = \dfrac{V}{r}$

From $V = \pi r^2 t$, we have $r = \sqrt{\dfrac{V}{\pi t}}$ ……… (Formula 1)

Then from $L = 2 (\pi r^2 + \pi rt)$, we have $L = 2(\dfrac{V}{t} + \dfrac{V}{r})$ … (Formula 2)

So, the relationship between the formulas of the surface area and the tube volume was $L = 2(\dfrac{V}{t} + \dfrac{V}{r})$, and we can determine the surface area of the tube with known volume, height, and base perimeter using Formulas 1 and 2.

The following are given examples of reasoning problems posed by students that cannot be solved due to insufficient information (**Problems 9 & 10**).

Problem 9: Every morning, Dina would run around her housing complex three times. However, every Sunday morning, he would run around the housing complex five times. If counting starts today, how many times will Dina run around the complex for the next 30 days?

The problem cannot be answered with certainty because it depends on the day. If today is Sunday, Monday, Tuesday, Wednesday, or Thursday, then in the next 30 days, there will be 4 Sundays and 26 non-Sunday days, so Dina goes around as much as $(4 \times 5 + 26 \times 3)$ times = 98 times. If today is Friday or Saturday, then in the next 30 days, there will be 5 Sundays and 25 non-Sunday days, so Dina goes around as much as $(5 \times 5 + 25 \times 3)$ times = 100 times.

Problem 10: In the case study about students' impressions of the three subjects, namely, Mathematics, English, and Sports, the following data were obtained.

There are 14 students who like English, 15 students who like math, and ten students who like sports. In addition, there are seven students who like

math and English, six students who like English and sports, two students who like all three, and only 21 students who do not like any of the three subjects. Based on this information, please find the number of students who

    a. like math and sports.

    b. like exactly two subjects?

    c. like exactly one subject?

    d. like at least two subjects?

This problem cannot be solved because the total number of students in the study was unknown. Thus, the number of students who like certain subjects is also determined by the total number of students surveyed.

The following is an example of a reasoning problem with a subjective type made by a student that can be resolved, but the solution given is not entirely correct (**Problem 11**). In this case, although the student teachers were not asked to solve their posed problems, some tried to give the solution to the problems to clarify the plausibility of the problems.

Problem 11: Determine the value of m that causes the function graph $y = (m - 3) x^2 + 4x - 2 m$ entirely located above the x-axis!

Solution:

The function graph is above the x-axis if $D < 0$ and $a > 0$.

This means: $m - 3 > 0$ and $4^2 - 4(m - 3) (-2m) < 0$

Because $m - 3 > 0$ then $m > 3$ ……. **(1)**

$4^2 - 4(m - 3)(-2 m) < 0$

$\leftrightarrow 16 + 8 m^2 - 24m < 0$

$\leftrightarrow m^2 - 3m + 2 < 0$

$\leftrightarrow (m - 2)(m - 1) < 0$

$\leftrightarrow 1 < m < 2$ ……. **(2)**

Therefore, the solutions are: $1 < m < 2$ or $m > 3$

The final solution made by the student was wrong because the value of m must meet **(1)** and **(2)**, i.e., $m > 3$ and $1 < m < 2$. Therefore, the correct solution was: 'There was no value of m, which was the solution to the problem'. This means her/his trials to provide the solution to the problem do not help his/her ability to pose a mathematics problem.

Discussion

Generally, Table 4 showed that all percentages of criteria achieved by student teachers were 70%. For the criterion of problem suitability for the level of knowledge, students reached the highest percentage: 100%. This means that students have a good understanding of how to pose problems that fit their level of students' understanding in secondary school.

In fact, both students and teachers also learn the curriculum subject in school mathematics, where the learning trajectory of any mathematical topic is studied across levels from primary to senior high school. Regarding the relatively good achievement regarding the participants' ability to pose problems meeting the intended problem indicator, the study results indicate that they have successfully learned and practised how to arrange indicators to achieve basic competencies for learning mathematics material for middle and high school students. The intended indicator is an achievement marker of basic competencies marked by measurable behaviour change (Harvey & Green, 1993). The indicator serves as a guide to developing learning material. Thus, the problems made by the teacher to measure the students' understanding of the achievement of the learning material must be in accordance with the indicators that have been formulated. Those statements showed that students already have experience in posing problems assigned by the lecturer.

Our findings indicated that while most of the mathematical problems that participants posed relatively met the reasoning problem criteria, most of them were in the lowest level of reasoning category, namely the level of analysing (71.43%). Meanwhile, the higher levels (i.e., 'evaluating' and 'creating' problems) are relatively low. This fact showed that the higher level of the reasoning problem, the more challenging effort for a problem designer to design a reasoning problem. This is in line with the findings of Zulkardi & Kohar (2018), stating that novice task designers such as student-teachers meet difficulties in a design problem that elicits students' mathematical competencies, as suggested in the reasoning problem. To explain this phenomenon, we argued that encouraging teachers in problem-posing practice is not a matter of simply asking them to pose their problems. As novice problem designers, according to Murtafiah et al. (2020), they might be influenced by the type and the way mathematical problems are presented in any mathematics textbook or without giving focus attention to whether the context of the problem is familiar or not with targeted students. In this case, there is a concern that the math problems they refer to from their selected textbooks do not show problem models in the category of reasoning.

In this regard, Crespo and Sinclair (2008) argued that mathematics students and teachers commonly had few opportunities and experiences to pose their problems. Conversely, similarly to higher education students, they tend to solve the problems posed by their lecturers or by textbooks. In addition, since lecturers in any university often deal with solving educational problems in mathematics, they are likely to have more experience in working with learning sources from school mathematics textbooks. Therefore, when teachers are given opportunities to pose their own problems, it makes sense to assume they will generate mathematical problems that are similar to what a school mathematics problem should look like, such as regarding either linguistics complexity or difficulty levels. This argument comes from the typical problems posed by the study participants, as mentioned by Problem 5, where the finding solution idea of a linear system with two variables with one solution through 'camouflage context' is commonly found in Indonesian mathematics textbooks. This indicated that student teachers, in their first trial, tended to pose mathematical problems that were mostly on the topic of arithmetic, required a one-step solution, and had only one correct solution (Leavy & Hourigan, 2019).

The findings of this study also highlight the fact that despite the problems posed by the students meeting the criteria of reasoning by more than 70%, it is still suggested to give more concern to the quality of the problem posed by the participants as there were still some students who failed in posing reasoning problems. This is aligned with a study that showed that teachers' created tasks promoting reasoning problems were infrequent (McMillan, 2001). In addition, the study of Akhter et al. (2015) stated that, although teachers were very enthusiastic about learning that involves students' reasoning, especially in problem-solving, implementing learning that promotes reasoning skills, which in this case is providing reasoning tasks as one of their learning resources, was not an easy task for prospective teachers.

Table 3 shows the percentage of the difficulty level of reasoning problems posed by students, both for essay and objective questions. In general, students made problems in the medium category, neither difficult nor easy. This indicated that the students tended to pose mathematical problems that were in line with the level of mathematics knowledge that they obtained during their school learning experiences. However, our findings showed that in each difficulty level, there were at least some problems made by students. Thus, the problem difficulty was evenly distributed.

Furthermore, problems posed by students have more than one solution or solution method. Table 4 showed that most students created an open problem both in the essay (70.58%) and in objective-type problems (82.35%). This

was reasonable since the presence of open-ended problems in a mathematics class is one of the characteristics of learning that involves Higher Order Thinking (HOT) (Yee, 2000). In addition, some research has shown good results in implementing open-ended learning in fostering students' reasoning (Bernard & Chotimah, 2014; Widiartana, 2018; Yee, 2000). Likewise, the non-routine problem was also limited to problems with concern on the complexity of employing formal mathematical structure as exemplified by Problem 7b, where judging which has optimum size causes minimum cost concern more on working on evaluating mathematical equation related to area and perimeter of a rectangle. Meanwhile, judging and reflecting on the position of a mathematical model which fits with any contextual information are not found in the tasks created by participants. Using this type of problem, teachers can more freely assess the extent to which students use heuristic strategies or just imitations of algorithms that often cause students to fail to complete assignments (Jäder et al., 2017).

The results of this study give a broader insight into how the teachers were prepared to be future mathematics teachers through a teacher education programme in a university curriculum. The insight was around the current situation of student teachers' knowledge of posing a 'good' mathematical problem, in which the revised Bloom's taxonomy may become indicators of the quality of the problem posed. The finding that the higher level of Bloom's taxonomy and the less proportion of mathematical problems posed by student teachers indicates that they need to be engaged in some interventions that can improve their performance. The interventions are not only needed to engage teachers to pose problems that satisfy the reasoning category, but also those encourage them to enhance their understanding of the mathematical topics behind the problem they would like to pose. This is due to the findings that the quality of teacher-posed problems is also influenced by teachers' conceptions of understanding certain mathematical content, where poor conceptions correlate with the low quality of the posed questions (Cai et al., 2015; Ma, 1999). Moreover, teacher beliefs are also considered to affect teacher performance problem-posing. In this regard, Li, Song, Hwang, and Cai (2020) found that teacher participants could perform well in problem-posing and had a number of different beliefs about the advantages and challenges of teaching through problem-posing. In addition, the intervention programme should also consider how research in problem-posing processes gives benefits the curriculum structure of training preservice teachers to pose practical mathematical problems due to the existing recommended problem-posing-related research concern about investigating connections between problem-posing and problem-solving and how individuals, including teachers, proceed the connections to pose mathematics problem

(Papadopoulos et al., 2022). In this regard, some intervention designers suggested that teacher educators improve student teachers' problem-solving skills to improve problem-posing skills (Leavy & Hourigan, 2019; Silver, 1994).

Furthermore, it is essential for teacher educators to encourage them to pose various mathematical problems covering real-life contextual, non-routine, and open-ended problems rather than routine problems (Unver et al., 2018). Crespo (2003), in this sense, asserted that teacher educators should provide student teachers with a learning environment that facilitates experience with non-traditional mathematical problems and encourages collaborative problem-posing activities.

Conclusion

The mathematics education students in this research were competent in the posing reasoning category, especially essay and objective question types. All the criteria used to conclude that the students were competent were fulfilled well. Both essay and objective questions corresponded to the indicators. The problems were arranged according to the criteria of reasoning ones, the problems which may have (a) solution(s), the completion of the reasoning problems made was correct, and the language used was in accordance with the understanding of students' levels.

The results of this study are also expected to have an impact on new insights about how to assess the quality of questions made by teachers more critically so that they can have an impact on the right form of intervention to improve the problem-posing ability of prospective teachers. We argue that the variations in the responses given by the respondents provide sufficient examples to distinguish which ones are at the level of reasoning and which are not.

The lecturers who teach assessment and evaluation lectures should try, as often as possible, to train all students to make the problems that meet the criteria of a reasoning problem, especially in the form of open problems with many solutions, so that they can apply this skill when they teach in school. Besides being trained to make the problems, the students should always be asked to check the truth of the problem by making an answer key or an alternative solution and checking whether or not the problems are solved.

The practical benefit of the results of this study is that readers, especially teachers, can realise the importance of using reasoning problems in learning mathematics. In addition, they have more learning experience about making math problems through studying examples of problems made by students presented in this paper. Teachers gain insight into how to write questions that meet

the criteria for reasoning problems while still considering the use of effective and understandable sentences and questions that can be solved by paying attention to student prerequisite knowledge. Furthermore, they can also learn how to make questions according to the indicators of the demanded questions.

Contribution to science

As implications of this research to teacher education, it is suggested that teachers design more questions at the evaluation level and think creatively because this is used to support student reasoning. Specifically for pre-service teacher education, prospective teachers also need to be given more and more profound opportunities to develop their problem-posing abilities more systematically in the education curriculum for prospective mathematics teachers. This is also supported by an emerging agenda related to evaluation models and current task design models, which are used as tools for assessing essential mathematical abilities, such as numeracy and problem-solving, specifically PISA model questions that are centred on students' authentic mathematics skills on problems from the real world to the formal world of mathematics.

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