Development and Validity of Problems with Contradictory Information and no Specified Universal Set to Measure the Truth-Seeking of Pre-Service Mathematics Teachers

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Abstract **– Truth-seeking is a predictor of whether pre-service mathematics teachers have critical thinking dispositions. The effort to familiarize the truth-seeking of pre-service mathematics teachers is realized by giving the problems with contradictory information and the problems with no specified universal set continuously. The aim is to develop the problems that can measure the truth-seeking of pre-service mathematics teachers. The participants were 184 mathematics education students from six universities in Indonesia. The development steps used were define, design, and develop. Data were analyzed by using item response theory. The findings and conclusions were reached and the results indicated that problems were developed are valid to measure the truth-seeking of pre-service mathematics teachers.**

Keywords **– Mathematical problems, Critical thinking disposition, Truth-seeking, Item response theory (IRT).**

1. Introduction

Critical thinking is a reflective and reasonable thinking that focuses on making decisions about what to do or to believe [1]. It is involved in solving problems, formulating conclusions, calculating possibilities, and making decisions [2]. One component of critical thinking is disposition [3], which is the consistent internal motivation to involve problems and make decisions through critical thinking [3], [2] and is a measure of the tendency to think critically [4]. A person must have a disposition to think productively and critically when solving a problem [2].

A person with critical thinking disposition when solving problems has special characteristics, namely, (a) clarifying a problem, (b) diligently finding relevant information, (c) rationally selecting and applying criteria, (d) sequentially performing complex problems, (e) paying attention to the main problem, (f) persevering despite difficulties, and (g) being careful in considering the subject and circumstances [5]. Based on these characteristics, a person tends to engage in truth-seeking activities [6], [5]. Truth-seekers deny that belief is justified or delay judgment concerning the possibility that the knowledge and belief can be justified [7]. They will always verify all the information needed in solving a problem.

Truth-seeking is a habit that requires the best understanding of a particular situation [3], [8]. Truth-seekers (1) strongly emphasize evidence and reasoning even on things that have been recognized as true, (2) question the beliefs of an established person, and (3) do not ignore important details [8]. Truth-seeking is a predictor of whether pre-service mathematics teachers have critical thinking dispositions [9], [10] therefore, mathematics teachers must be familiar with this habit.

Some of the results of the research stated that truth-seeking behavior is not yet possessed by pre-service mathematics teachers as compared with other critical thinking disposition components [9], [10],

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[11], [12]. Furthermore, the tendency of truth-seeking behavior in pre-service mathematics teachers is lower than the pre-service science, social, arts, and language teachers [13], [14]. Some of the causes of truth-seeking unfamiliarity among pre-service mathematics teachers when solving mathematical problems are (1) applied mathematics learning in general has not implemented infusion learning that is integrated with the development of critical thinking [15], [16], (2) the lack of practice to solve problems that require critical thinking in the classroom [17], (3) the perception of the questioner who demands critical thinking is difficult [18], and (4) the absence of mathematical questions or problems developed specifically to familiarize the pre-service mathematics teachers with truth-seeking [9], [19].

The developed mathematical problems that can be used to measure truth-seeking must refer to the four traits and truth-seeking notions and must require the pre-service mathematics teachers to verify all the information and the universe of the discussion set in the question. If a problem contains incorrect information, the pre-service mathematics teachers should discontinue the problem-solving process because of contradiction. Furthermore, a question undetermined by the universal set is an incomplete question; thus, the pre-service mathematics teachers must determine the universal set of conversation before resolving a given problem. Two types of problems are used in this research, namely, problems with contradictory information and problems with no specified universal set.

Problems with contradictory information are problems or mathematical problems that contain conflicting data. Truth-seeker pre-service teachers are accustomed to analyzing the irregularities in a question and checking the truth of the information provided before trusting [20]. Problems with no specified universal set are problems or algebraic problems, but the universe of discussion of the variable is undefined exactly. They are one of the divergent questions that demonstrate the students' understanding in transferring knowledge because they analyze, synthesize, or evaluate [21]. Habits during this time, when the universal set is not written explicitly, are defined as the set of all real numbers [19], [22]. Pre-service mathematics teachers do not think that if the universal set is undetermined at the beginning of each mathematical problem, then the solution to the problem may differ, depending on the determination of the universal set of conversation [22].

Problem of the research

The research problem was the unfamiliarity of pre-service mathematics teachers in Indonesia about truth-seeking behavior and becoming critical thinkers when faced with mathematical problems. This underdevelopment and unfamiliarity with truth-seeking is due to the absence of mathematical problems that require them to seek the truth. Therefore, the main focus of this research is to develop mathematical problems that can measure and familiarize the truth-seeking of pre-service mathematics teachers in Indonesia.

Research focus

The research focus is the development and validity of problems with contradictory information and no specified universal set to measure the truth-seeking of pre-service mathematics teachers. The mathematical problems developed refer to the truth-seeking characteristics, which always want the best understanding, strongly emphasize the evidence and reasoning even on the things that have been recognized as true, question the beliefs of an established person, and not ignore important details. This research (1) determines the type of mathematical problems that can be used to measure and familiarize someone with truth-seeking tendencies, (2) determines mathematical learning models based on giving problems with contradictory information and problems with no specified universal set with the aim of encouraging truth-seeking behavior, and (3) gives input to the mathematics curriculum at secondary education or high education to develop critical thinking dispositions, especially truth-seeking.

2. Methodology of the research

General background of the research

As a procedural development, this research was a descriptive research that showed the steps to be followed to produce the final product. The development process referred to the development framework developed by Thiagarajan, namely, 4-D [23]. In this research, mathematical problems that can be used to measure truth-seeking were developed by applying three stages, namely, define, design, and develop.

Participants of the research

The participants were 184 students of fifth- and seventh-semester mathematics education from six different universities in East Java, Indonesia. The participants have diverse academic abilities. The selection of universities was based on grouping three state universities and three private universities in East Java, Indonesia.

Instruments and procedures

The instruments used in this research were test, validation, and assessment procedures. The problems developed refer to the subject in the middle school mathematics curriculum. The test arranged refer to truth-seeking traits according to Insight Assessment [8], namely, (1) always wants the best understanding, (2) strongly emphasizes the evidence and reasoning even on things that have been recognized as true, (3) questions the beliefs of an established person, and (4) does not ignore important details. The two types of issues that were developed were problems with contradictory information and problems with no specified universal set. Therefore, the development of the problems referred to the indicators of truth-seeking when resolving each type of problem as presented in Table 1.

Table 1. Truth-seeking indicators when resolving each type of problems

Truth-seeking characteristics	Truth-seeking indicators	
	Problem with contradictory information	Problem with no specified universal set
1. Always want the best understanding	1) Do the checking process of the correctness of the information in the question before completing the problem.	1) Do the checking process of the universal set in the question before completing the problem.
2. Questions someone's established beliefs	2) Declare/write down that the question given has contradictory/false information.	2) Write down and determine the universal set in the question before working on the problem.
3. Strongly emphasizes the evidence and reasoning even on matters that have been recognized as true	3) Write down the reasons and evidence to support the correct statement. 4) Write down the facts, concepts, principles, and mathematical operations used in the problem-solving process.	3) Write down the reasons and evidence to support the correct statement. 4) Write down the facts, concepts, principles, and mathematical operations used in the problem-solving process.
4. Do not ignore important details	5) Use all the correct information and the universal set given in the problem in the problem-solving process. 6) Write down the process of solving the questions systematically based on the universe of predetermined talks.	5) Use all the correct information and the universal set given in the problem in the problem-solving process. 6) Write down all the solutions based on all the specified universe of conversation.

The problems developed refer to the subject in the senior and junior high school mathematics curriculum with four main subjects, namely geometry, algebra, statistics, and numbers. In detail, the distribution of mathematical subject and mathematical sub-subject used to develop the problems with contradictory information and the problems with no specified universal sets are presented in Table 2.

Table 2. The distribution of mathematical subject and sub-subject

Mathematical subject	Mathematical sub-subject	Number of problems
Geometry	Triangle	2
	Solid figure	1
	Angle	2
Algebra	Function	3
	Matric	1
	Straight line equation	1
	Proportion	1
	Quadratic equation	1
Statistic	Presentation of data	1
Numbers	Exponent numbers	2
	Integers	2
	Complex numbers	1

The total number of problems to be developed to measure truth-seeking in pre-service mathematics teachers is 18, with 13 problems with contradictory information and 5 problems with no specified universal set. The 18 questions are presented in Tables 3 and 4.

Table 3. Problems with contradictory information

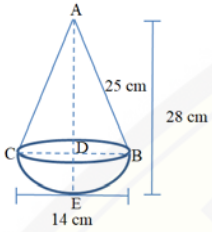
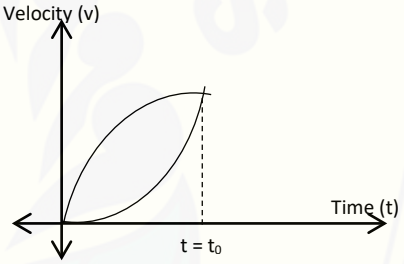
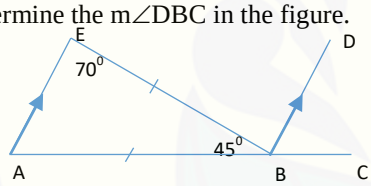
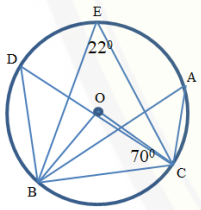
No	Problem with contradictory information	No	Problem with contradictory information
1	In an ABC right triangle, where m∠B = 90^o, m∠C = 30^o, AB = 3 cm, and BC = 4 cm, drawn by a high line BD such that obtained AD = 1 cm, investigate whether the area can be determined triangle BCD. If yes, what is the area of the BCD triangle?	8	Given B = {1, 3, 5, 7, 9, 11, 13, 15}. If there are values p, q, r, s ∈ B such that p + q + r + s = 31, then investigate whether there are values of p, q, r, and s that fulfill. If yes, specify the values of p, q, r, and s.
2	Determine the volume from the following: 	9	Given the complex number z = 1 + 2i is more than 0, determine whether it is a statement.
3	Given p, q, r ∈ R, with $p^3 = 6$, $q^2 = -2$, and r = 4, investigate whether $p^3 + q^4 - r^2$ has a value. If yes, specify the value of $p^3 + q^4 - r^2$.	10	Based on the velocity and time graph below, determine the position of cars 1 and 2 when t = t_0. 
4	Determine the m∠DBC in the figure. 		
5	Let the ratio of Bima and Adi's money be 5:4 and Adi's money is Rp 70,000 more than Bima's money. What is the amount of their money?	11	Determine the circumference of a triangle that measures 3 cm, 6 cm, and 10 cm in length.
6	Look at the following figure. Given m∠BCO = 70^o and m∠BEC = 22^o, determine the value of m∠ BDC + ∠ BAC. 	12	If 0 < a < b, $a^2 + b^2 = -4ab$, then specify the value of (b – a) / (a + b).
7	The following are the names of the seventh-grade students of Merdeka Middle School who are ranked in the bottom 10 with their birth dates: Andi (12), Rina (23), Siska (28), Junia (30), Edo (9), Rico (18), Cinta (27), Laura (31), Rista (32), and Fahmi (17). Present the data into tables, line diagrams, and bar charts.	13	Given p + 3q + 7r = 50 with p = 2a + 1, q = 2b + 1, and r = 2c + 1, with a, b, c ∈ N, investigate whether there are values of p, q, and r. If yes, specify the values p, q, and r.

Table 4. Problems with no specified universal set

No.	Problem with no specified universal set	No.	Problem with no specified universal set
14	Suppose that $f(x) = 2x + x^2 - 15$ intersects on the x-axis at two points, namely, $(x_1, 0)$ and $(x_2, 0)$. Determine the value of $x_1^2 + x_2^2$.	16	Determine the inverse function $f(a) = a^2$.
15	Determine the values of x and y given the following matrix equation: $\begin{bmatrix} 2 & x \\ 4 & 5 \end{bmatrix} + \begin{bmatrix} 7 & -9 \\ y & 13 \end{bmatrix} = \begin{bmatrix} 9 & -5 \\ 2 & 18 \end{bmatrix}$	17	Draw a graph of $2x + y = 12$.
		18	Determine the solution of the quadratic equation $s^2 = 1$.

The validity of the problems developed was carried out with two types, namely, content validity and construct validity. The content validity was validated by three validators from three state universities in East Java. Three components of the assessment of the questions were developed, namely, substance, construct, and language, with the assessment criteria 1 to 4. The construct validity was done using factor analysis. Factor analysis aims to identify the relationship between variables by looking at the eigenvalues in the covariance-variance matrix based on computational results. The collected data was analyzed to find out whether the questions developed were suitable for factor analysis. The instrument construct validity was determined using principal component analysis.

The third instrument was the assessment procedure for measuring the truth-seeking of pre-service mathematics teachers when solving the problems with contradictory information and problems with no specified universal set. The scoring procedures in this research are presented in Table 5.

Table 5. Scoring procedures

Answer	Truth-seeking indicators that are fulfilled	Score
No answer	No answer	0
Wrong	Does not meet all the indicators	0
Right	Meet 1–2 indicators	1
Right	Meet 3–4 indicators	2
Right	Meet 5–6 indicators	3

This research used three of the four stages of Thiagarajan's development, namely, define, design, and develop. The define phase has four activities, namely, front-end analysis, student analysis, material analysis, and task analysis. First, the front-end analysis activities are carried out by referring to the results of the literature on examples of mathematical problems used in universities to measure the truth-seeking of pre-service mathematics teachers. Second, the characteristics of pre-service mathematics teachers are analyzed as an illustration for the design and development of problems with contradictory information and problems with no specified universal set. Third, the material analysis is used to identify, detail, and systematically compile relevant material according to the secondary school mathematics curriculum especially related to truth-seeking or critical thinking dispositions. Fourth, the characteristics of truth-seeking to be used in designing tasks to be completed by prospective mathematics teachers are identified.

At the design stage, developing problems that can measure truth-seeking involves designing the construct in the form of a problem. The activities at this stage are divided into three parts. First, analyze the main purpose of teaching and learning mathematics education curriculum in Indonesia. The content is characterized according to scientific knowledge and skills, especially the development of critical thinking. Second, describe the truth-seeking indicator of each type of problem, the type of problem to be developed, and the scoring procedure. Third, write down the problems in the form of tests using Indonesian language.

Data analysis

Item response theory (IRT) mostly seeks to model responses to items and assessment of educational tests [24]. It is a modern analysis of items. The reason for using item response theory is that the level of ability of an examinee is accurately estimated by a series of items measured. There are research objectives mentioned above. The content validity was done using the V Aiken formula [24], and the construct validity was done using factor analysis. Factor analysis is part of item response theory analysis.

In construct validity, the exploration approach was used to see how many factors were needed to explain the relationship between a series of indicators by observing a greater load factor. The initial stages of construct validity presented in this research are (a) check the corresponding values of the Kaiser-Meyer-Olkin (KMO) and Bartlett's sphericity and (b) check the exact value of the anti-image correlation on varimax rotation. This stage was carried out to identify the feasibility of data to be able to continue further analysis using basic assumptions. This theory is a dimension, which means items of test size

are only one ability. It shows that problems with contradictory information and problems with no specified universal set are only measures of truth-seeking. The data collected was calculated in SPSS 16. The items that do not match the graduation score at each stage of analysis are not stored in the subsequent analysis.

3. Results of the research

Content validity

An analysis of content validity was carried out qualitatively by educational experts using the Aiken index [25]. In this research, the initial draft of 18 items of problems to be developed was validated by three experts from three state universities in East Java, Indonesia. The experts validated the suitability of the problems developed based on the content. The aspects or components used to validate the instruments developed were substance, construct, and language. The results of content validation by the three validators are presented in Figure 1.

In Figure 1., the red line represents the critical value of receiving items in the analysis of content validity. Based on the index, the item is valid if Aiken V is more than of 0.87 [25]. Based on Figure 1., all item values are above the red line or the value is more than 0.87. It indicates that 18 items that developed at the initial stage can be used in the subsequent analysis.

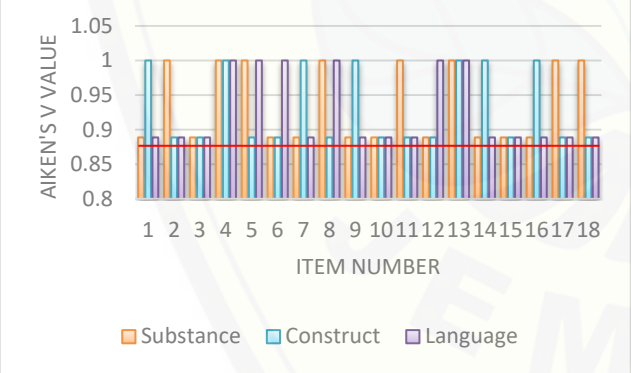


Figure 1. The graph of Aiken's V value

Construct validity

In this research, construct validity was carried out five times. Each stage of an item is issued and cannot be used because it does not meet the standard value of the anti-image correlation values. Terms of analysis of IRT in this dimensional test can be carried out if the Kaiser Meyer Olkin measure of sampling adequacy value is fulfilled, which must be greater than 0.5, and Bartlett's test of sphericity has significance less than 0.05 [40]. If the KMO value is less than 0.5, then check the anti-image correlation value on each item [26].

In the first stage, the value KMO was found at 0.491 and Bartlett's test of sphericity had significance equal to 0.000; thus, the anti-image correlation value on each item should be checked. Of the 18 items, there were 9 whose value was below 0.5 and the lowest item was in item 10 with a value of 0.377. Therefore, item 10 must be discarded and not included for the next analysis.

In the second stage, the KMO value found was 0.513 and Bartlett's test of sphericity had significance equal to 0.000; thus, the data was feasible for factor analysis. However, upon checking the value of anti-image correlation on each item, there were 7 out of 17 items whose value was below 0.5 and the lowest value was in item 10 of 0.449. Therefore, item 9 must be discarded and not included for the next analysis.

In the third stage, the KMO value found was 0.528, and Bartlett's test of sphericity had significance equal to 0.000; thus, the data was feasible for factor analysis. However, upon checking the value of anti-image correlation on each item, there were 4 from 16 items whose value was below 0.5 and the lowest value was on item 14 of 0.459. Therefore, item 14 must be discarded and not included for the next analysis.

In the fourth stage, the KMO value found was 0.544 and Bartlett's test of sphericity had significance equal to 0.000; thus, the data was feasible for factor analysis. However, upon checking the value of anti-image correlation on each item, there were 2 out of 15 items whose values were below 0.5 and the lowest value was in item 7 of 0.494. Therefore, item 7 must be discarded and not included for the next analysis.

Calculation in the last stage after being 14 items without items 10, 9, 14, and 7 is presented in Table 6. From Table 6., it can be interpreted that the data feasible factor analysis for KMO values were found for 0.548. Furthermore, the value of Bartlett's test of sphericity had significance equal to 0.000, and the value was below 0.05; thus, the analysis factor can be done for the next analysis phase.

Table 6. KMO and Bartlett's test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.548
Bartlett's Test of Sphericity	Approx. Chi-Square	178.069
	df	91
	Sig.	.000

In the last stage, the value of the anti-image correlation was analyzed after the KMO and Bartlett's test of sphericity values were received. The anti-image of each item that amounted to 14 items had a range of values from 0.508 to 0.649. There was no

anti-image value that was below 0.5; therefore, it showed that it had a high contribution to the factor structure of the instrument developed. This implied that there were no items issued and 14 items were acceptable; thus, the factor analysis could be continued.

Unidimensionality assumption tests were carried out after the KMO test results, Bartlett's test of sphericity, and anti-image value were accepted for factor analysis. Unidimensionality can be tested using two approaches, namely, exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Exploratory factor analysis is used when the measurement model is from an instrument construct still sought and explored [27], while confirmatory factor analysis is done when the measurement model has a theory so that the construct of the instrument remains proven or confirmed [27]. To prove construct validity, CFA specifically uses a measurement model. The EFA approach was conducted to determine the number of the factors that appeared to measure truth-seeking. Therefore, to find out whether an exploratory factor analysis approach can be done, the KMO value must be met with a graduation score. If the KMO value is lower than 0.50, then an exploratory factor analysis approach cannot be taken [28]. The KMO value was 0.548, resulting in an EFA approach. The results of the unidimensionality assumption test are presented in Table 7.

Table 7. The results of the unidimensionality assumptions test

Component	Initial eigenvalues	
	Total	% of Variance
1	1.802	12.870
2	1.680	12.001
3	1.396	9.971
4	1.192	8.516
5	1.141	8.152
6	1.039	7.419
7	0.911	6.504
8	0.853	6.095
9	0.814	5.814
10	0.773	5.522
11	0.681	4.867
12	0.646	4.618
13	0.577	4.124
14	0.494	3.527

Based on Table 7., there are six eigenvalues whose values are more than 1.000, resulting in six factors formed. Therefore, referring to Kaiser's criteria [28], variants of six factors emerged as responses of test participants to problems developed to measure truth-seeking. These six factors can account for about 58.929% of the total variance. As a result of this method, six factors are identified on a scale. It implies that there are components or dominant factors that are referred to as abilities that are measured by instruments of problems to measure truth-seeking [29]. Thus, both problems with contradictory information and problems with no specified universal set developed have quantitative skills as the dominant factor.

The results of the factor analysis can also be seen through the screen plot. The screen plots in Figure 2. can visualize eigenvalues with the number of components maintained being a factor. The screen plots indicate that there are six dominant factors formed. In this case, because the results of the analysis of the factors produced have been able to explain the variance of more than 20%, the test of unidimensional assumption or factor analysis can be fulfilled [29]. Thus, problems with contradictory information and problems with no specified universal set can be used to measure the truth-seeking of pre-service mathematics teachers.

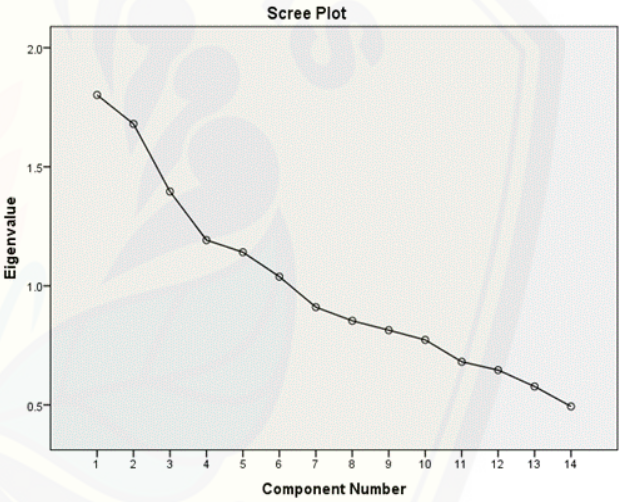


Figure 2. The screen plot of factor analysis

4. Discussion

This research aims to develop and validate problems with contradictory information and problems with no specified universal set to measure the truth-seeking of pre-service mathematics teachers. This research begins with a literature review of truth-seeking tendencies of pre-service mathematics teachers and the types of problems that can be used to measure truth-seeking and familiarize the pre-service mathematics teacher with it. In the viewpoint of experts regarding the process of validating content, all the problems developed have a high level of validity by giving scores between 3 and 4. Experts also agree that 4 items are excluded from the 18 items formed at the beginning based on the results of construct validation.

At the end of the data analysis process, there were six factors that formed 14 items and there are two factors that have a high correlation with values of 0.695 and 0.773. The two factors that have a high correlation were determined using the rotation method: varimax with Kaiser normalization. In this case, two factors can explain 14 items of problems developed with a high correlation in measuring the truth-seeking of pre-service mathematics teachers. Therefore, it can be said that the instrument of problems developed in the context of truth-seeking measures of pre-service mathematics teachers fulfills high valid criteria.

The criterion of validity obtained not only has adequate statistical support but also has adequate theoretical support. The factors extracted through exploratory factor analysis and validated through confirmatory factor analysis also had similar references in empirical studies. The factors of truth-seeking measurement when solving mathematical problems are also used in previous studies, especially indicators of truth-checking before solving questions [9], [12]. Truth-checking indicators are also the main indicators possessed by people who have critical thinking disposition when faced with problem-solving and questioning [5].

In this research, the researchers used procedures to develop problems with contradictory information and problems with no specified universal set in truth-seeking measures that are valid and reliable; however, there are still two limitations. The first limitation is that both factor enhancement techniques such as exploratory factor analysis and confirmatory factor analysis are quite specific sample sizes. The researchers had the right rationale and literature support to apply this technique; however, to get better results, a larger sample size was suggested. Furthermore, additions, modifications, and revisions can be made to the issues that have been developed in this research. The second limitation is that there has not been a triangulation process toward the emergence of truth-seeking when resolving problems with contradictory information and problems with no specified universal set. However, statistically, it can be said that problems with contradictory information and problems with no specified universal set can measure truth-seeking prospective mathematics teachers. Suggestions for the next research are to be able to present triangulation to see facts surrounding truth-seeking tendencies that can arise when solving problems with contradictory information and problems with no specified universal set.

5. Conclusions

The findings of this research ensure that problems with contradictory information and no specified universal set developed have a high level of validity. Overall, there are 14 problems with contradictory information and no specified universal set developed is suitable to measure the truth-seeking of pre-service mathematics teachers. Thus, researchers believe that the problems with contradictory information and no specified universal set could be used to measure the truth-seeking of pre-service mathematics teachers.

The valid problems with contradictory information and no specified universal set can be applied in the learning process using the infusion approach to improve the critical thinking dispositions especially truth-seeking of pre-service mathematical teachers.

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