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Students Mathematical Critical Thinking Skills: Validity and Reliability with Winsteps and SPSS

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ABSTRACT

It is of great importance to conduct validity and reliability testing in a study in order to ascertain the feasibility and effectiveness of the instruments employed. In this study, an analysis is required to ascertain the results of the validity and reliability tests on mathematical critical thinking skills utilising the SPSS and Winsteps applications. The research method employed was quantitative survey research, with a total of 133 high school students in the Jakarta and Depok areas comprising the sample population. The instrument designed to assess critical thinking skills comprises four indicators. The validity test on the mathematical critical thinking ability instrument with the SPSS application indicates that one value (value 11) is invalid, as evidenced by the Pearson correlation value. However, the remaining values meet the requirements for validity. The reliability value obtained through SPSS yielded a result of α = 0.75. The same results are observed when the Winsteps application is employed. One value (value 11) is identified as invalid, while the remaining values meet the criteria for the MNSQ outfit value, ZSTD outfit, and PTMEA-CORR. In addition, the reliability results obtained using Winsteps yielded a Cronbach's Alpha coefficient value of 0.87, indicating a high degree of reliability.

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1. INTRODUCTION

Mathematical critical thinking skills are defined as an individual's ability to understand, analyze, and solve mathematical problems in a systematic, logical, and critical manner, as well as to comprehend complex mathematical concepts and construct logical and consistent arguments. [1][2][3]. Mathematical critical thinking skills include the ability to interpret, analyze, evaluate, and reason, as well as the ability to respond to critical thinking indicators such as focus questions, analysis of arguments, question posing and answering, and others [4][5]. With critical thinking skills, it is expected that students can easily find problems in mathematical problems and find solutions with effective thinking [6].

The development of a comprehensive set of critical thinking skills in mathematics, as defined above, is a critical aspect of the learning process. These skills enhance the overall learning experience and success in mathematics by not only facilitating the memorization of formulas, but also by enabling students to understand mathematical concepts [7], [8]. This ability enables students to confront complex challenges with rational thinking, thereby facilitating the resolution of problems, the communication and integration of concepts, and the deepening of learning in a structured manner [9][10][11]. While mathematical critical thinking skills are undoubtedly important competencies that need to be developed, the reality is that students' mathematical critical thinking skills remain relatively low.

The results of the research conducted by Lestari and Roesdiana [12] indicate that 0% of students possess mathematical critical thinking skills at the very good, good, or sufficient levels. Conversely, 19.44% of students exhibit mathematical critical thinking skills at the poor level, while 80.55% of students demonstrate mathematical critical thinking skills at the very poor level. This indicates that students' mathematical critical thinking skills in Indonesia remain relatively low. This is also corroborated by research conducted by Duri, Lubis and Ahmad [13], which reveals that the mean mathematical critical thinking capability of students on arithmetical lines and rows in Padang Bolak High School only achieves a score of 67.26, classified within the sufficient range. Furthermore, only eight out of ten students were able to respond to all three questions related to mathematical critical thinking ability, while the remaining students were only able to respond to one of the three questions.

Based on the aforementioned discussion concerning the significance of mathematical critical thinking skills and the observation that these abilities are still underdeveloped in the majority of learners, it is imperative to implement strategies to enhance these skills. A potential avenue for improvement is the validation and reliability of instruments used to assess mathematical critical thinking abilities [14]. The validity of a mathematical critical thinking ability assessment instrument can be defined as its capability to accurately and consistently quantify the assessed aspects, thus ensuring reliable and pertinent measurement outcomes aligned with the research objectives [15][16][17].

In the meantime, it can be defined that the reliability of the mathematical critical thinking ability assessment instrument is the capacity of the measurement instruments to generate unwavering and dependable outcomes, thus enabling a foundation upon which evaluations and learning strategies can be established with a reasonable degree of certainty [16][18]. The validation and reliability of research instruments are of great importance in ensuring that the measuring instruments used can accurately and consistently measure students' critical thinking skills. This allows for the generation of reliable and relevant measurement results, which are aligned with the research objectives. Furthermore, it ensures the trustworthiness of the data collected, which can then be used as a basis for the evaluation and development of learning strategies[19][20].

In consideration of the paramount importance of validity and reliability in the domain of research, the researchers engaged in the testing of the veracity and trustworthiness of students' mathematical critical thinking skills. To this end, they employed the use of two statistical applications, specifically the Statistical Package for the Social Sciences (SPSS) and the Winsteps software. The SPSS (Statistical Package for Social Scientists) is a computer application for the statistical analysis of data, facilitating users in the processing of such material[21][22]. Winsteps is a Windows-based statistical software program that is utilized for the examination of data through a variety of analytical techniques. These methods are employed with the objective of ascertaining the suitability of the data obtained from a given instrument[23][24].

The statistical applications Winsteps and SPSS were selected for use in this study due to their numerous advantages, which are conducive to the attainment of the research objectives. According to

Marsitin and Sesanti [25], SPSS is a valuable statistical analysis tool, particularly in the context of statistical applications. Its intuitive interface makes it simple and easy to understand for those who are new to using the software, including students conducting research data analysis. Conversely, Winsteps has the benefit of offering a linear scale with the same interval, thus enabling the prediction of more accurate data[26].

Moreover, the choice of Winsteps and SPSS as statistical applications in this study is informed by prior relevant research. For instance, Yudha [27], employed Winsteps to assess the validity and reliability of mathematical critical thinking measurement instruments, demonstrating high validity and reliability in authentic assessment instruments used to evaluate the mathematical critical thinking abilities of grade 10 students at Cirebon Vocational High School in relation to geometry. The research conducted by Putri and Erita [18], also employed the Winsteps application to assess the validity and reliability of the instrument. The results indicated that 75% of the questions were valid, and the reliability score was 0.89 on the mathematical critical thinking ability instrument, which was tested at Krinci Junior High School, grade 8. Conversely, the research conducted by Rosmaini [28], identified physical condition, intellectual development, and motivation as factors that influence critical thinking in mathematics. However, it did not mention the use of either SPSS or Winsteps for the purposes of validity and reliability analysis. Furthermore, research conducted by Gumilang, Wahidin, and Tsurayya [29], employed the Ministep application to ascertain the validity and reliability of critical and creative thinking skills in mathematics for junior high school students in South Jakarta. This yielded an Alpha Cronbach value of 0.87 for critical thinking instruments and 0.95 for creative thinking instruments, which represents an excellent reliability for both instruments.

Given the findings of previous studies that are relevant to this research, the decision to use Winsteps and SPSS as statistical applications in this study is further supported. Nevertheless, it can be observed from a review of previous relevant literature, that there are some research gaps. These include the fact that there have been few instances of researchers utilising the combination of SPSS and Winsteps statistical applications to validate and assess the reliability of mathematical critical thinking measurement instruments. Moreover, no researchers have yet conducted such studies in senior high schools, particularly within the context of mathematics.

The objective of this study is to address the aforementioned gaps in the existing research by examining the validity and reliability of students' mathematical critical thinking skills with SPSS and Winsteps. The preceding analysis of the research literature revealed a number of gaps, which formed the basis of the research objectives for this study. The problem formulation for this study was therefore as follows: 1) To examine the validity of students' mathematical critical thinking skills using SPSS and Winsteps; and 2) To assess the reliability of students' mathematical critical thinking abilities using SPSS and Winsteps.

2. RESEARCH METHODS

2.1 The Research Design and Participants

This research is quantitative in nature, with the use of a survey method. The quantitative research survey method is a form of positivist approach in the social sciences. It is used to collect data from research sources or informants in order to conduct observations and interviews on empirical approaches. This is achieved through the use of research instruments such as questionnaires, structured interviews, and documentation. Quantitative/statistical data analysis is then employed to test predetermined hypotheses [30], [31], [32]. In this study, data were collected through the use of specific instruments or measuring instruments with the objective of assessing the variables under study in a systematic and structured manner.

In selecting subjects for the study, a purposive sampling technique was employed. Purposive sampling is a sampling technique based on criteria and subjective judgement of the researcher, with the objective of producing a representative sample [33]. In this research study, the researchers established a number of criteria, namely that the participants were in the 11th grade, had above-average math skills, and were willing to take the math critical thinking assessment. The researchers selected samples that were considered representative of the population in a manner consistent with the stated research objectives. These

objectives included measuring the validity and reliability of the mathematical critical thinking instrument. To generalize results of validity and reliability measures, it is necessary to ensure that the sample is representative. The following Table presents the criteria for the sample. The sample was purposively selected and considered representative of the research population.

Table 1. Research samples

Demographics	Description	Code	Amount
Class	XI	A	133
Age	16	B	10
	17	C	109
	18	D	12
	19	E	2
Domicile	Bogor	F	1
	Depok	G	23
	Jakarta	H	109
Gender	Male	I	49
	Female	J	84

Table 1 demonstrates that a total of 133 Grade XI students were sampled, of which the majority (109 students) were 17 years of age. The majority of these students reside in Jakarta (109 students). Furthermore, the gender distribution indicates that 49 students are male, while 84 students are female. These findings indicate that the selected sample encompasses age, domicile, and gender variations that are relevant for the purpose of this study.

2.2 Instrument

The instruments employed in this study were designed to assess mathematical critical thinking skills, as indicated by a number of key indicators, given along with their descriptions and scoring, ranging from 0 to 4.

Table 2. Indicators of mathematical critical thinking ability instruments

Indicator	Description	Scoring				
		4	**3**	**2**	**1**	**0**
Interpretation	The response failed to provide the requested information or to address the known issues.					✓
	Write exactly what is known and what is asked in the problem.				✓	
	Write exactly only what is known or only what is asked.			✓		
	Write exactly what is known from the problem, but incomplete.		✓			
	Write exactly and completely what is known and what is asked in the problem.	✓				
Analysis	No attempt at formulating the problem into a mathematical model was made.					✓
	The mathematical model developed for the given problem is inaccurate.				✓	
	Make a mathematical model of the given problem correctly, but without providing an explanation for the model made.			✓		
	The mathematical model of the given problem is correctly constructed, but the explanation provided for the model is incomplete or inaccurate.		✓			
	The student correctly creates a mathematical model of the given problem and then provide an accurate and comprehensive explanation for the model created, demonstrating a deep understanding of the subject matter.	✓				
Evaluation	The individual does not employ effective strategies in solving problems.					✓
	Uses strategies in solving the problem, but the strategies used are incorrect				✓	

Indicator	Description	Scoring				
		4	3	2	1	0
	and incomplete.					
	Used the correct strategy in working on the problem but did not complete the problem, or used an inappropriate strategy but managed to complete the problem completely.			✓		
	Using the correct strategy and solving the problem completely, but there are errors in the calculation or explanation.		✓			
	Using the right strategy in solving the problem, with complete and correct calculations and explanations.	✓				
Inference	Did not provide a conclusion from the solution.					✓
	Formulate conclusions that are unsubstantiated and incongruous with the context of the problem.				✓	
	The conclusion is reached in a manner that is not appropriate given the context of the question.			✓		
	It is necessary to infer accurately and in context, but not to provide a comprehensive analysis.		✓			
	It is necessary to make accurate inferences within the context and to provide a comprehensive account of the relevant material.	✓				

Source : [34]

As outlined in Table 2, the four indicators of mathematical critical thinking ability are interpretation, analysis, evaluation, and inference. In relation to the interpretation indicator, it can be reasonably expected that students will possess the requisite abilities to comprehend and express the meaning of a problem in a coherent and meaningful manner. In the analysis indicator, students must demonstrate their ability to identify the relationships between different statements, questions, concepts, descriptions and so on. With regard to the evaluation indicator, students are expected to demonstrate the ability to assess the credibility of a statement and to verify the truth of relationships between various statements, questions, concepts, descriptions and other elements. In addition, students are expected to demonstrate their ability to draw conclusions or provide reasons for the steps taken in the inference indicator [35].

The instruments employed in this study have undergone a process of content validation. As defined by Puspitasari and Febrinita [36], content validity represents a process employed to ascertain the congruence between the content of an instrument, such as a questionnaire, a questionnaire scale, or any other measuring instrument, with the research objectives and predetermined criteria. The objective of this process is to ensure that the contents of the instrument are relevant, accurate, and effective in measuring the variables under study [36]. The validation process was conducted by two experts, namely lecturers and mathematics teachers, and the validation results demonstrated improvements.

As a consequence of the validation process, improvements were made in terms of the language and mathematical units used in the questions.

Figure 1. (a) Before validation; (b) After validation

Figure 1 illustrates the modifications that were implemented before and after the validation process. In Figure 1(a), the problem employs units of length and textile materials. In contrast, Figure 1(b) presents a simplified version of the problem, with a more general context. This context concerns the purchase of fruit parcels with units of kilogram weight. These modifications include the introduction of more precise language to elucidate the question's intent and the reduction of mathematical units to facilitate comprehension.

3. RESULTS AND DISCUSSION

3.1 Validity and Reliability Using SPSS

The instrument's validity is demonstrated by the accuracy of its measurements, which allows us to ascertain the suitability of measuring an ability [37]. The first step in testing the validity of the instrument designed to assess students' mathematical critical thinking ability in this study was carried out utilising SPSS. Previously generated data can be analysed using the SPSS application by entering the data into the SPSS worksheet, then conducting a validity analysis by selecting the "Analysis" menu, then "Scale", and then "Reliability Analysis". The results of this analysis will demonstrate the instrument's capacity to accurately assess students' mathematical critical-thinking abilities with a high level of precision. The results of the analysis indicate that the SPSS validity results are as shown in the following table.

Table 3. The SPSS validity result

Item	Pearson Correlation
I 11	0.316
I 12	0.666
I 13	0.640
I 14	0.571
I 21	0.582
I 22	0.719
I 23	0.734
I 24	0.640
I 31	0.688
I 32	0.741
I 33	0.758
I 34	0.718

Table 3 contains one invalid question, namely I 11. This is due to the Pearson correlation value of 0.316. According to the established criteria, a question is considered invalid when its value falls within the negative range of 0.40, which is classified in the very low to low category [38]. Consequently, other statements can be employed in research to assess the extent to which students possess mathematical critical thinking skills.

Furthermore, to ensure the consistency of the instrument in measuring mathematical critical thinking ability, a reliability analysis was conducted using SPSS. This reliability analysis aims to measure the consistency of measurement results when conducted repeatedly with the same instrument [37]. The data generated previously can be analysed using the SPSS application to check reliability by calculating the Cronbach's Alpha value. A Cronbach's Alpha value > 0.50 indicates that the instrument exhibits good consistency, indicating that the items in the instrument consistently measure the same construct. Based on this analysis, the SPSS reliability results are obtained as shown in the following table.

Table 4. Result of the SPSS reliability test

Cronbach's Alpha	N of Items
0.758	13

Table 4 indicates that the mathematical critical thinking ability instrument employed in this study exhibits a Cronbach's Alpha value of 0.758, thereby confirming its reliability. In accordance with the established criteria for instrument reliability, an instrument is deemed reliable when its Cronbach's Alpha value > 0.50 [38].

3.2 Validity and Reliability Using Winsteps

The validity test in this study was also conducted using the Winsteps application. It is important to note that when utilising Winsteps, it is necessary to pay close attention to both the item and the person. An

instrument is deemed fit for purpose if its items and persons function properly for measurement and meet the MNSQ Outfit, ZSTD Outfit, and PTMEA-CORR criteria [17].

Table 5. Result of the validity of Winsteps items

Item	Outfit MNSQ	Outfit ZSTD	PTMEA-CORR
I 11	**1.95**	**5.7**	**0.34**
I 12	1.05	0.3	0.55
I 13	1.05	0.4	0.63
I 14	1.06	0.4	0.58
I 21	0.93	-0.5	0.71
I 22	1.01	0.1	0.64
I 23	0.93	-0.5	0.70
I 24	0.75	-1.4	0.61
I 31	0.79	-1.7	0.74
I 32	0.84	-1.1	0.65
I 33	0.75	-1.7	0.67
I 34	0.75	**-2.1**	0.74

Table 5 presents the values of the Outfit MNSQ, Outfit ZSTD and PTMEA-CORR statistics, along with their respective ranges. It should be noted that certain numbers have been highlighted in bold font, which indicates that the item in question does not meet the criteria set out in reference [38]. The item at I 11 fails to meet the criteria set forth because it does not align with the predetermined range, specifically the values of Outfit MNSQ, Outfit ZSTD, and PTMEA-CORR. A total of ten items were deemed to meet the stipulated criteria (I 12, I 13, I 14, I 21, I 22, I 23, I 24, I 31, I 32, and I 33), while the remaining item (I 34) satisfied at least two of the stipulated criteria, and this should therefore be maintained [17]. Of the items under consideration, only one, item I 11, does not fit the criteria. The remaining eleven items are fit.

Table 6. Result of Winsteps person validity

No	Person	Outfit MNSQ (0.5 - 1.5)	Outfit ZSTD (-2.0 - +2.0)	PTMEA-CORR (0.4 – 0.85)
1	071ACGJ	**6.66**	**6.5**	**-0.16**
2	001ACHI	**2.85**	**2.2**	**0.18**
3	013ADHJ	**3.15**	**3.7**	**0.04**
4	023ACHJ	**2.53**	**3.0**	**-0.14**
5	034ACGI	**2.43**	**2.1**	**0.09**
6	130ABHJ	**1.85**	1.8	**0.31**
7	056ACHJ	**1.74**	1.4	**0.21**
8	055ACHJ	**1.74**	1.6	**0.37**
9	063ACHJ	**1.63**	0.9	**0.15**
10	106ADHJ	**1.91**	1.7	**0.31**
11	009ACGJ	**1.53**	1.2	**0.03**
12	048ACHI	**1.51**	1.2	**0.01**
13	120ACGJ	**0.30**	**-2.2**	0.78

Table 6 reveals that a number of responses deviate from those anticipated by Rasch Model analysis. This suggests that the response provided differs from the range indicated by the Rasch model [38]. This study indicates that of 102 respondents, 89 (87.25%) meet three and two criteria, respectively. In this analysis, 35 respondents (34.31%) exhibited MNSQ Outfit scores that fell outside the range of 0.5 to 1.5, while 67 respondents (65.69%) exhibited scores that fell within the aforementioned range. Furthermore, six respondents (5.88%) exhibited ZSTD Outfit scores outside the range of -2.0 to +2.0, while 96 respondents (94.12%) were within this range. The analysis also demonstrated that 27 respondents (26.47%) exhibited PTMEA-CORR values that were not within the range of 0.4 to 0.85, while 75 respondents (73.53%) demonstrated values within the aforementioned range. The results of this study indicate that the items were

suitable for 89 respondents (87.25%), which is a relatively satisfactory outcome for assessment using Rasch analysis.

The next step is to do a reliability test with the help of the Winsteps method. The aim of a reliability test is to determine the degree of trustworthiness and consistency of an instrument in the measurement of the variables that are being investigated. In the section on the reliability of the instrument, the output of the Summary Statistics in Winsteps is used for this purpose. This information presents the results of the reliability measurements, including an examination of the reliability of the items (questions), the reliability of the persons (respondents), and the interaction between respondents and items. [17].

Table 7. Reliability results of the Winsteps

Statistics	Value
(KR-20)	0.87
The Reliability of Person	0.84
The Reliability of Item	0.98
Person Separation	2.31
Item Separation	6.52

Table 7 indicates that the instrument utilized in this study to assess mathematical critical thinking skills exhibits a Cronbach's Alpha (KR-20) value of 0.87. The analysis also revealed the following reliability values: person reliability (0.84), item reliability (0.98), person separation (2.31), and item separation (6.52). This indicates that the instrument exhibits good reliability. In accordance with the stipulated criteria, an instrument is deemed reliable if it meets the standards set forth in the "good" category [38].

4. CONCLUSIONS

A validity analysis of the indicators of mathematical critical thinking ability was conducted using Winsteps and SPSS. The Rasch model (Winsteps) revealed that one item (I 11) was invalid and that one item (I 34) only met one criterion but was retained. The remaining items met three criteria and were therefore declared valid. The validity test on SPSS with the Pearson correlation value also indicates that one item (I 11) is invalid, while the remaining items are valid. Both methodologies reached the conclusion that one item (I 11) was invalid and required revision or deletion. Consequently, other items may be employed in research to assess the extent to which students demonstrate mathematical critical thinking skills.

In addition to the assessment of validity, the reliability of the instrument is also a significant factor in the overall evaluation of its quality. The results of the reliability calculations, conducted using the Winsteps and SPSS software, yielded similar Cronbach’s alpha values, with 0.87 and 0.758 respectively. Both values met the pre-established reliability criteria [38]. The instrument is therefore deemed reliable for measuring students’ mathematical critical thinking skills.

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