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Developing Assessment Instruments of Students' Critical Thinking Ability in Trigonometry Material Mathematics Subjects

M. Ikhwanul Hakim✉, **Kartono, Wahyu Lestari**

Universitas Negeri Semarang, Indonesia

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Abstract

The preliminary study found that the teacher did not yet have a practical instrument to assess students' critical thinking skills in mathematics. This study aims to develop assessment guidelines for students' critical thinking skills in practical mathematics subjects. The development model refers to the theory of Borg and Gall with 9 steps of development. Small-scale test subjects were conducted on 21 students and a large-scale test was conducted on 90 grade X students of MIPA SMA N 1 Pringgasela. The content validity in this study used the Aiken's V formula and the Ebel formula to look for reliability. Whereas the construct validation with the Confirmatory Factor Analysis (CFA) model used the AMOS 24 application. The results showed that: (1) the validity of the contents of the instrument, from the aspects of construction, language, and material got the score > 0.3, which means that the instrument was stated to be very valid in content, and very reliable in values > 0.5; (2) contract validity, loading factor per item > 0.3 means that the instrument was valid in contract, the RMSEA value = 0.023 < 0.06, and the GFI value = 0.932 > 0.9, which means that the model developed was very suitable; (3) validation of the items showed that items 5 and 11 were accepted with a slight revision because d < 0.4 and the remaining 10 items were received without revision with d > 0.4, for Alpha Crombach values = 0, 783> 0.5 (very reliable instruments); (4) practicality test used all math teachers (5 teachers), with an average score of 85.6 means that the instrument was very practical. In conclusion, the instruments developed were very valid, very reliable and very practical. The benefits of the development results were, there were guidelines in carrying out assessment of students' critical thinking skills.

✉Correspondence Address
Kampus Pascasarjana UNNES
Jalan Kelud Utara III Semarang 50237, Indonesia
E-mail: ikhwan.mat01@gmail.com

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INTRODUCTION

The development of an assessment instrument of critical thinking ability is an effort to meet the needs of teachers in conducting assessments of critical thinking skills towards students, on mathematics subjects, development efforts are also carried out, given the need for critical thinking skills themselves. Critical thinking is very necessary, where everyday individuals face unlimited information, complex problems, rapid technological and social changes (Vong & Kaewura, 2017:92).

Critical thinking ability is the basic provision of life, so teachers need to train and develop students' critical thinking skills (Fuadi, Hamdu & Natalina, 2016). Mellanie L. Buffington in the research journal Susilowati et al., (2016) concluded that students 'critical thinking skills can develop if teachers in teaching and learning activities periodically display critical thinking skills in each step of learning that is useful as a provision for students' lives. Students need critical thinking skills in the 21st century, but the facts that occur show that critical thinking skills have not been a special concern for teachers in the field, most teachers are still reluctant to conduct an assessment of students' critical thinking skills (Mabruroh & Suhandi, 2017).

The teacher never assesses students' critical thinking skills, most teachers assess mastery of the concept of students using test questions that refer to the tests in the National Examination (Mabruroh & Suhandi, 2017). The teacher has not succeeded in assessing students' critical thinking skills, and the teacher prefers to teach learning material as usual (Ismail, Suwarsono & Lukito, 2017). In line with what was revealed, Sugiarti, Kaniawati, & Aviyanti (2017) stated that critical thinking skills included in one of the higher-order thinking skills were not really noticed by the teachers, because the teacher only referred to the material in the National Examination.

Teacher's obstacle in assessing students' critical thinking skills due to the absence of quality instruments possessed by teachers, even though the instruments of critical thinking ability are not only useful for testing students' mastery, but also can improve students' critical thinking skills (Sugiarti, Kaniawati, & Aviyanti, 2017). The teacher in conducting assessment of critical thinking skills in students is constrained by the absence of instruments and competencies to develop assessment instruments for critical thinking skills (Mabruroh & Suhandi, 2017), The teacher should need to make an evaluation tool to record the abilities displayed by each student (Ashari, Lestari & Hidayah, 2016).

Assessment of critical thinking skills should be done well. If it done properly and correctly can produce accurate data and information (Fuadi, Sumaryanto & Lestari, 2015:92). Assessment of school mathematics learning is an important thing to do in order to obtain information about student learning success (Hidayad, Masrukan & Kartono, 2017: 31). Assessment of critical thinking skills is said to be good, if the instrument used is also good (valid, reliable and practical). The assessment carried out by most teachers, only as a school assignment, is limited to giving material without any serious meaning (Lusiana & Lestari, 2013).

Based on the teacher needs and the problems found in the field, the research is aimed at developing practical critical thinking skills assessment manuals so that they can provide benefits as follows: (1) theoretically, this study contributes to the theory of the steps in developing instruments and forms of assessment of critical thinking skills in mathematics subjects (2) practically, the guidelines developed, became the guideline in the assessment of critical thinking skills in mathematical subjects, especially trigonometric material.

METHOD

The method used is R & D, by adopting the design proposed by Borg and Gall which defines that "Educational research and development is a process used to develop and validate educational products" (Wulandari, Mardiyana & Kumayadi, 2015:36). The stages of development are used as follows: (1) preliminary studies, (2) drafting of products, (3) design validation, (4) design revisions, (5) limited trials, (6) revised results of limited trials, (7) wider

trials, (8) product revisions, (9) practicality tests (Borg and Gall (2003: 570). The subjects used in this study were class X students of SMA N 1 Pringgasela in the academic years 2018/2019 which numbered 3 classes with details of the number of students per class as follows:

Table 1. Details of The Number of Research Subjects

Class	Number of Students
X MIPA 1	30
X MIPA 2	30
X MIPA 3	30
Total	90

RESULTS AND DISCUSSION

Content Validation

Content validation using Aiken's V formula, it was found that 12 assessment instruments of students' critical thinking skills in mathematics subjects were stated to be very valid from the aspects of instrument construction, material and instrument language, this can be seen from the results of V values which are greater than 0,3.

After testing the validity of the results of the assessment of experts related to the content of the assessment instrument of students' critical thinking skills on mathematics subjects, then the reliability analysis was carried out from the calculation of experts. For the calculation of the reliability of the content of the assessment instrument the students' critical thinking skills on mathematics subjects used variance analysis with two-factor ANOVA which is seconded to the SPSS 24 software, and then calculated with the Ebel formula (Azwar, 2018:89).

The results of the reliability calculations between the three rater show that the reliability of the assessment instruments of students' critical thinking skills in mathematics is stated to be reliable both in terms of construction, material and language, it is known from the calculation of r_{xx} values that are greater than 0.3 (Wahyuni, Kartono & Susiloningsih, 2018:150). The value of r_{xx} for the construction aspect = 0.6758, for the material aspect = 0.935, and the r_{xx} value for the language aspect = 0.973.

The conclusions that can be drawn from the results of the calculation of validity and reliability from the experts' assessment of the assessment instruments of students' critical thinking skills in mathematics showed that all instruments were accepted from all aspects, both aspects of construction, material, and language, so that 12 items of assessment instruments Students' critical thinking skills in mathematics subjects can be continued in the field trials.

Small Sample Field Test

The small sample field testing phase, using a sample of 21 students taken from class X MIPA consisting of 3 classes, each class was taken 7 people to be held the first trial on the assessment instrument of students' critical thinking skills on mathematics subjects. The results of limited trials are known: (1) the level of difficulty of each question, (2) lack of tests before being tested on a large scale test. The following are the results of the analysis of the difficulty level of the questions in the small sample trial:

Table 2. The Results of The Calculation Of The Questions Difficulty Level

No	Mean	Maximum Score	Difficulty level	Category
1	1	4	0.25	Difficult
2	1.6667	4	0.41667	Medium
3	2.428	4	0.6	Medium
4	2.714	4	0.6786	Medium
5	2.9	4	0.7	Easy
6	2.095	4	0.52	Medium
7	1.190	4	0.2976	Difficult
8	1.952	4	0.488	Medium
9	2.428	4	0.6	Medium
10	2.76	4	0.69	Medium
11	3.238	4	0.8	Easy
12	2.238	4	0.5595	Medium

Table 2. shows that 12 instruments are divided into 3 categories, difficult, medium and easy items, there are 2 items in difficult categorized instruments; items 1 and 7, two items easily categorized; 6 and 11, the remaining items are medium categorized; points 2, 3,4, 5, 8, 9, 10, 11.

The small scale test found several points, it needs to be improved from the assessment instrument of students' critical thinking skills in mathematics subjects, especially in the assessment rubric, where many criteria for correct answers are revised due to the discovery of other alternative answers, or students using their own ways to find answers and ways used correctly, so that the correct answer criteria are designed to be more open, to accommodate students' answers that are not in accordance with the steps in the answers to the questions, but according to the mathematical method, especially in trigonometry material.

When testing a small scale, the scale used in the scoring rubric is from 1 to 4, but because the results of the students' answers to the small-scale test there are unanswered questions, so that the previous scale changes are held, from 1 to 4 to 0 to 4, 0 given to Unanswered questions at all. The answers to the questions in the rubric were also revised because some small errors were found, at the beginning of the examination the results of small-scale tests found students' answers were different from the answers in the rubric, but after a deeper examination it turned out that the error occurred in the rubric's answer, which should be tan $(60 - 45)^0$, but instead becomes tan $(60 - 30)^0$ due to typing error.

Field testing large samples

The wider field testimg in the sample is a final trial with a larger number of samples than limited trials. The number of samples used at this stage amounted to 90 students, taken from the X class MIPA which amounted to 3 classes. In the large-scale trial phase was found several results including: (a) construct validation, (b) different power test / item validity, (c) reliability test item. More details are presented as follows:

a. Construct Validation

The construct validity in this study uses CFA (Confirmatory Factor Analysis) which is seconded to the AMOS 24 program, to test the validity and failure of assessment instruments on students' critical thinking skills in mathematics subjects constructively. The results of the analysis of construct validity assessment instruments for students' critical thinking skills in mathematics through the AMOS program can be seen as follows:

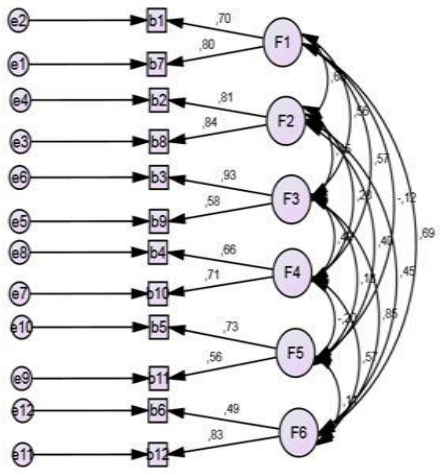

Figure 1. Path Diagram from AMOS Calculation Results

Figure 1 shows the results of the calculation of the Confirmatory Factor Analysis procedure through the AMOS 24 application, which functions to determine the extent of the relationship between items with factors, can be seen from the value of loading factors in the estimate standard. Sitinjak & Sugiarto in Rusilowati (2014: 131) states that the validity of an observed variable can be seen from the factor loading of the variable to its latent variables. Referring to the standard value of loading factors revealed, Bendesa in Mentari & Bendes (2018: 669-670) that the general rule for assessing factor loading is determined by the following criteria: (1) factor loading> ± 0.30 means meeting the minimum level, (2) factor loading> ± 0.40 means more important, (3) factor loading> ± 0.50 means practically significant.

The following is a summary of the results of the calculation of the loading factor of the instrument

assessment of students' critical thinking skills in mathematics subjects which are being developed based on a wide-scale test in the field:

Table 3. Summary of The Estimated Coefficient of Loading Factors

	Indicators	Items	Estimation	Category
Critical Thinking Ability	Interpretation (F1)	Item 1 (b1)	0,702	Significant
		Item 7 (b7)	0,803	Significant
	Analysis (F2)	Item 2 (b2)	0,808	Significant
		Item 8 (b8)	0,840	Significant
	Evaluation (F3)	Item 3 (b3)	0,712	Significant
		Item 9 (b9)	0,580	Significant
	Concluison (F4)	Item 4 (b4)	0,656	Significant
		Item 10 (b10)	0,712	Significant
	Explanation (F5)	Item 5 (b5)	0,727	Significant
		Item 11 (b11)	0,565	Significant
	Self-regulation (F6)	Item 6 (b6)	0,486	Not Significant
		Item 12 (b12)	0,833	Significant

Table 3 shows that the loading factor of each item assessment instrument students' critical thinking skills in mathematics subjects seen in the estimation column states that there are significant and not significant items, significant items including items 1, 2, 3, 4, 5, 7 , 8, 9, 10, 11, 12, because the value of loading factor > 0.5 and non-significant items is item 6 with a loading factor value of < 0.5, but despite that all items are valid in construct or accepted because they have exceeded the minimum value of loading factor > 0.3.

After construct validation based on the value of the loading factor, then the next look at the constants match the instruments of assessment of students' critical thinking skills on mathematics subjects with the model developed. Model compatibility can basically be seen generally from the chi-square value, but the chi-square value is very sensitive to the number of samples, if a large sample has a significant estimation tendency, so the model becomes not fit or not suitable, if so the suitability of the model can be seen from the score, CMIN/DF, Probability, GFI, AGFI, TLI, dan CFI (Akhtar, 2017). The score of Cut off value CMIN/DF ≤ 2,00 (Insane, Hoyyi, & Rahmawati, 2014:544). The score Cut off value GFI, AGFI, TLI, CFI ≥ 0,90 and Probability ≥ 0,05 (Effendi & Purnomo, 2012:110). The score of Cut off value RMSEA < 0,06 Azwar (2018:129). The following is summarized the value of Cut-off value used to estimate the goodness of fit index as follows:

Table 4. Estimation Goodness of Fit

Goodness of fit index	Cut off value
χ 2 - Chi square	-
CMIN/DF	≤ 2.00
Probability	≥ 0.05
RMSEA	≤ 0.06
GFI	≥ 0.90
AGFI	≥ 0.90
TLI	≥ 0.90
CFI	≥ 0.90

As it is known that construct validation with the CFA model is nothing but to test the suitability of the model that has been used, whether or not the model used depends on the output of the goodness of fit statistics, which is known through the results of the analysis using the AMOS 24 program. The following can be summarized the value of the goodness of fit construct of assessment instruments for critical thinking skills in mathematics subjects from a broad-scale test:

Table 5. Goodness of Fit Indicators of Critical Thinking Skills

Goodness of fit index	Cut off value	Model results	Category
χ 2 - Chi square	-	40.844	*Diharuskan Kesil*
Probability	≥ 0.05	0.389	Good fit (*Baik*)
RMSEA	≤ .,06	0.023	Good fit (*Baik*)
GFI	≥ 0.90	0.932	Good fit (*Baik*)
AGFI	≥ 0.90	0.863	Marginal fit (*Kurang Baik*)
TLI	≥ 0.90	0.990	Good fit (*Baik*)
CFI	≥ 0.90	0.994	Good fit (*Baik*)

In table 5. there is a GFI value of 0.932 > 0.9 and the RMSEA value of 0.023 < 0.06 as a whole. It can be concluded that the contract assessment instrument for students' critical thinking skills in mathematics subjects matches the model used, This is assumed from the opinion of Azwar (2018: 129) that to see the suitability of a model it can see the value of GFI and the value of RMSEA, if the value of RMSEA is smaller then the model match is better, or in the sense that the RMSEA value is < 0.06, the model is accepted. and for the GFI value, the closer to number 1, the better the model is. Another opinion says that the RMSEA value is < 0.08 (Effendi & Purnomo, 2012: 110). Although the AGFI value in table 4.11 is 0.863, the AGFI value is classified as marginal because it is still less than 0.9.

Seguro in Fitriyana, Mustafid & Suparti (2013: 104) explains that marginal value is the condition of the suitability of the measurement model below the absolute fit and incremental fit criteria, but can still be continued on further analysis because it is close to the criteria of good fit. The suitability of the model is not only seen from AGFI, but can still be estimated from the values of TLI, CFI, and GFI which are average > 0.9, can be seen in table 4.10 and classified as good fit. Seeing the suitability of a model does not have to be all the categories fulfilled significantly, if two to three of the categories are significant, then the model developed matches the data (Hadi in Rusilowati, 2014: 134).

b. Test of Differences / Validity of Items

Different power tests on the instruments developed are calculated through the SPSS 24 program. Different power calculations are carried out from the results of field tests, namely large-scale tests. The results of the different grain power calculations are then estimated through the different power classifications proposed by Crocker and Algina. The results of the calculation of different power assessment instruments of students' critical thinking skills in mathematics subjects can be seen as follows:

Table 6. The Results of The Calculation of Different Instruments

No	r- items	Conclusion
Item 1	0.640	Question is accepted
Item 2	0.641	Question is accepted
Item 3	0.714	Question is accepted
Item 4	0.463	Question is accepted
Item 5	0.317	Question is accepted with revision
Item 6	0.557	Question is accepted
Item 7	0.617	Question is accepted
Item 8	0.666	Question is accepted
Item 9	0.605	Question is accepted
Item 10	0.492	Question is accepted
Item 11	0.325	Question is accepted with revision
Item 12	0.669	Question is accepted

Based on Table 6. it can be concluded that the different power classifications of the assessment instruments of students' critical thinking abilities in mathematics subjects indicate that the total number of items is 12, two of which are accepted with revisions; points 5 and 11, the rest of the questions are accepted without revisions with different powers > 0.4, as a whole the problem is accepted considering the correlation (rxy > 0.20) is accepted as the final instrument item, conversely if rxy ≤ 0.20 then the item is rejected (Ambarsari, Bharati & Rusilowati, 2017:15).

c. Reliability Test of Item

Reliability of an instrument is the consistency of an instrument in measuring subjects or objects at different times. The reliability of the instrument is shown by a reliability coefficient. Instruments that are valid need to be tested for internal consistency. The following are the results of the reliability analysis of the assessment instruments of students' critical thinking skills on mathematics subjects, from the results of testing instruments in the field (large-scale testing).

Table 7. The Calculation Results of Instrument Reliability

Reliability Statistics	
Cronbach's Alpha	N of Items
,783	12

From the reliability statistics table above, Cronbach's Alpha reliability coefficient is obtained at 0.783 > 0.5, so it can be concluded that the item assessment instrument for students' critical thinking skills in mathematics learning is acceptable.

After the validity and reliability of the items are known and then the items are then processed by selecting and sorting which instruments are used to be instruments for assessment of students' critical thinking skills on mathematics subjects that can be used by the teacher. The selection of this instrument is based on different power tests, construct validity and reliability test instruments.

d. Practicality Test

The practicality test in this study was carried out on 5 mathematics subject teachers aimed at knowing that the instruments that had been developed were in accordance with the needs of the teacher and were easy and practical to use, so that they could help the teacher carry out assessment tasks or assessment of critical thinking skills easily. The practicality of assessment instruments for students' critical thinking skills in developed mathematics subjects was obtained through analysis of the practicality questionnaire results, by looking at the actualism score given by five mathematics teachers and comparing it with the practical classifications expressed by Hestari (2016:10).

Tabel 8. Practicality Criteria

Percentage	Category
86% - 100%	Very practical
71% - 85%	practical
56% - 70%	Practical enough
41% - 55%	Less practical
≤25% - 40%	Not practical

From the results of the recapitulation of the rater assessment as obtained by an average score of 85.6 from the results compared with the assessment criteria in Table 4.16, the mean or mean values of the rater assessment on the practicality of students' critical thinking assessment instruments in mathematics subjects are concluded that the assessment instrument of students' critical thinking skills in mathematics subjects is "practical" to use.

CONCLUSION

The product that was developed in the form of an assessment manual for students' critical thinking skills in mathematics subjects was declared valid, relational and practical, it was concluded from the results of discussion that validity and reliability based on expert judgment had a value of > 0.5 which made the instruments developed were very adequate and feasible for use in field tests. Based on the results of the CFA factor analysis, it was concluded that all valid instruments constructively with a load of factor loading greater than the minimum limit => 0.3, and the model accepted, where the GFI value was 0.932 > 0.9 and the RMSEA value was 0.023 < 0.06. Different power test (item validation) all items totaling 12 are accepted without revision with r count > 0.5. The results of the reliability coefficient are 0.783 > 0.5, which means that the instruments developed meet reliable and good conditions that can be trusted to provide information related to students' critical thinking abilities. The instrument was also stated to be practical to use, based on practicality testing to find that the average score was 85.6

(practical). Based on the results of the discussion it can be concluded that the manual book for assessing critical thinking skills that has been developed was valid, reliable and practical.

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