Development of Diagnostic Assessment of Critical Thinking Skills in Four-Level Format on Kinematics Material

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Abstract

The purpose of this study was to develop a valid and reliable four-level critical thinking skills assessment. The assessment was developed based on four factors of critical thinking skills, namely explanation, analysis, conclusion, and evaluation. This research is classified as development research (R&D). The research sample was class XI students of SMA Nahdlatul Ulama Tegal city, totaling 52 students. Data analysis methods include: expert validation, construct validity, and assessment reliability. Expert validation by two lecturers and two physics teachers, construct validity test with factor analysis consisting of: One-Sample K-S Test, KMO MSA test, correlation between variables (Anti-Image Correlation), communality, and Total Variance Explained. The results of the expert test analysis obtained an average questionnaire value of 78.8% with high validity criteria. The results of the One-Sample K-S Test of critical thinking skills assessment are 0.261, so it is concluded that the data is normally distributed. The results of the adequacy test through the KMO MSA value are 0.000, so factor analysis can be done. The results of the Total Variance Explained analysis in the scree plot diagram obtained 4 points where the eigenvalue was greater than 1.00, so that 4 factors were obtained which proved that the assessment had 4 aspects of critical thinking skills components as assessment factors. The assessment reliability test obtained the Cronbach alpha coefficient value of 0.693, so it was found that the diagnostic assessment of critical thinking skills developed was reliable. The developed assessment is not only able to describe students' critical thinking skills, but also able to provide an overview of how each aspect of critical thinking skills supports each other. The developed assessment is feasible to be used as an instrument to measure critical thinking skills and the relationship between each aspect of students' critical thinking skills on kinematics material.

Keywords: *test assessment, critical thinking, four levels, validity, reliability*

Abstrak

Tujuan penelitian ini yaitu untuk mengembangkan asesmen penilaian keterampilan berpikir kritis empat jenjang yang valid dan reliabel. Asesmen dikembangkan berdasarkan empat faktor kemampuan berpikir kritis, yaitu penjelasan, analisis, simpulan, dan evaluasi. Penelitian ini tergolong dalam penelitian pengembangan (R&D). Sampel penelitian yaitu siswa kelas XI SMA Nahdlatul Ulama kota Tegal sejumlah 52 siswa. Metode analisis data meliputi : validasi ahli, validitas konstruk, dan reliabilitas asesmen. Validasi ahli oleh dua dosen dan dua guru fisika, uji validitas konstruk dengan analisis faktor yang terdiri dari : *One-Sample K-S Test*, KMO MSA *test*, korelasi antar variabel (*Anti-Image Correlation*), komunalitas, dan *Total Variance Explained*. Hasil analisis uji ahli diperoleh nilai rata-rata angket 78,8 % dengan kriteria validitas tinggi. Hasil *One-Sample K-S Test* asesmen keterampilan berpikir kritis yaitu 0,261, sehingga disimpulkan data terdistribusi normal. Hasil uji kecukupan melalui nilai KMO MSA yaitu 0,000, sehingga analisis faktor dapat dilakukan. Hasil analisis *Total Variance Explained* dalam diagram *scree plot* diperoleh 4 titik dimana diperoleh nilai eigen lebih besar dari 1,00, sehingga diperoleh 4 faktor dimana membuktikan bahwa asesmen memiliki 4 aspek komponen keterampilan berpikir kritis sebagai faktor asesmen penilaian. Uji reliabilitas asesmen diperoleh nilai koefisien *alpha Cronbach* yaitu 0,693, sehingga diperoleh bahwa asesmen diagnostik keterampilan berpikir kritis yang dikembangkan adalah reliabel. Asesmen yang dikembangkan tidak hanya mampu menggambarkan kemampuan berpikir kritis siswa, tetapi juga mampu memberikan gambaran mengenai bagaimana tiap aspek keterampilan berpikir kritis saling mendukung. Asesmen yang dikembangkan layak digunakan sebagai intrumen untuk mengukur keterampilan berpikir kritis dan keterkaitan tiap aspek keterampilan berpikir kritis siswa pada materi kinematika.

Kata Kunci: *asesmen tes, berpikir kritis, empat jenjang, validitas, reliabilita*

INTRODUCTION

The introduction should contain (in order) the setting Learning is a complex sequence, as many aspects of the human being are involved. An important aspect of learning is the inclusion of mental processes. We often refer to this mental process as the thinking process. Therefore, successful learning is not only seen through observable changes in behavior, but also through the development of thinking skills. This can be interpreted that the purpose of learning is not only to change behavior but also to improve

higher-level thinking skills (Khairani, S. et al, 2020).

Thinking skills are very important for students, because problems in the future masses are increasingly complex. The Partnership for 21st Century Skills (2015) states that the critical thinking skills of creative thinking fans are indispensable in facing the 21st century. Critical thinking processes must be owned by students, because of the 21st century challenges related to increasingly complex skill needs. Students at all levels of education and professional levels really need critical thinking skills (Van Laar, E. et al, 2020, Fuad, et al, 2017, Khairani, S. et al, 2020).

Critical thinking skills are classified as high-level thinking skills consisting of the ability to reason and think reflectively in order to obtain conclusions that must be done (Ennis et al, 2011, Alsaleh, N. J., 2020, Ahmad, S. et al, 2017). Critical thinking skills cannot be observed directly from a person. This is because the critical thinking process occurs in the human mind or brain which is directly unobservable. Measuring aspects of students' critical thinking is needed to measure the achievement of students' critical thinking skills, thus, an assessment that is able to explore students' critical thinking skills is needed.

The process of learning physics is not only memorizing formulas, but it is necessary to understand the existing concepts, and be able to interconnect between concepts in the mind for problem solving. Related to this, students need to have the ability to analyze and evaluate, which is the ability of higher order thinking skills (Karthwohl and Anderson, 2010). This shows that learning physics requires higher-order thinking skills, and problems in physics require students to hone skills in higher-order thinking, which here are specifically critical thinking skills.

Assessment of critical thinking skills is one of the elements used to determine the extent of the achievement of students' critical thinking skills during the learning process as one of the benchmarks for achieving learning objectives. Students' critical thinking skills can be trained through learning by giving questions that contain critical thinking categories. The quality of learning is determined by the quality of the assessment carried out by the teacher in the learning process (Hulinggi, S. A, 2023, Wangsa, G. N. A. S, 2021, Amalia, N. F., 2014).

Critical thinking components include: interpretation, analysis, evaluation, inference, explanation, and self-control. The components of these skills work continuously or separately (Facione, 2011, Marfu'i, L. N. R. et al, 2018, Firdaus, F. et al, 2015) The development of critical thinking skills assessment assessments that have been developed are the Californis Critical Thinking Dispositions Inventory (CCTDI), Californis Critical Thinking Skills Test (CCTST), and Watson-Glaser Critical Thinking Appraisal (WGCTA). The development of critical thinking skills assessments was also carried out by Shaw (2020), Liu (2018), de Bie (2015), Heinrich (2015), Nawawi (2018), Dharmawati (2016), Sudrajat (2018), Miftahussa'adiah (2020), Febriana (2015) and Putriadi (2020). The assessments developed have shortcomings, namely the separate measurement of each aspect of thinking skills (Haynes, 2016).

Kinematics material is material that is considered quite difficult for students to understand. This is because motion kinematics material is dominated by concepts and principles. Kinematics material describes the movement of objects without linking what causes the object to move. Kinematics quantities for particles include: mass m, position r, velocity v, and acceleration a. In order for students to understand the principles in the material, critical thinking skills are needed. This supports the importance of developing an assessment of students' critical thinking skills in kinematics material (Rahayu, C., 2019, Mas'ula, N., 2020, Rahayu, C, 2019).

The importance of developing an assessment of students' critical thinking skills in science learning, especially physics, is needed because students must be skilled in formulating problems, asking and answering questions, solving problems, and concluding in every lesson both during discussions, practicums, and solving physics problems, especially in kinematics material (Muna, N., 2018, Syafitri, et al, 2021, Agustiani, N., 2022).

The assessment developed is only able to measure the achievement of students' critical

thinking skills, but has not been able to provide information about the relationship between aspects of critical thinking skills. This certainly cannot provide complete information about students' critical thinking skills. Based on this, it is very necessary to develop a critical thinking skills assessment that is not only able to measure the achievement of students' critical thinking skills, but also able to provide information on how each aspect of critical thinking is interrelated, so the researchers conducted research on the Development of a Diagnostic Assessment of Four-Level Critical Thinking Skills on Kinematics Material.

METHODS

This research was conducted at NU High School in Tegal city. The study population consisted of all ninth grade students of SMA NU Tegal city in the academic year 2023/2024 which amounted to 105 students. The sample in the feasibility test of the assessment was students of class XI IPA 1 and XI IPA 2 with a total of 52 students. Sampling using *purposive sampling* method. The variables studied include the validity and reliability of the diagnostic assessment of four-level critical thinking skills on kinematics material. This research is classified as development research or *Research & Development* (R & D). Development is guided by the R & D research steps according to Sugiyono (2007) in Table 1.

Table 1 Stages of Researcher Activities

Stages	Researcher Activities
The stage of reviewing potential and problems	Researchers Review that the development of assessments to measure students' higher order thinking skills is needed. This is related to the results of journal studies related to the importance of higher order thinking skills. Researchers also found that critical thinking assessments that have been developed have not been able to provide information on how each aspect of critical thinking is interrelated.
Literature review and information gathering stage	Researchers collect references in the form of books and journals, both national and international, related to the development of critical thinking skills assessments and make a critical thinking skills assessment.
Product design stage	The researcher designed a four-level critical thinking assessment product that is not only able to measure the achievement of students' critical thinking skills, but also provides information on how each aspect of critical thinking is interrelated.
Product validation stage	Validating the assessment to expert validators, namely two lecturers and two physics teachers.
Product revision stage	Revise the product according to the expert validator's suggestions and inputs.
Product trial stage	Tested the assessment with 52 students of class XI of SMA NU Tegal to obtain the validity and reliability of the assessment.
Product improvement stage after trial	Improve the assessment product from the validity and reliability test results.

The research instruments included: expert validation sheet and written test. The expert validation sheet was given to two lecturers and two physics teachers. The written test was conducted by 52 XI grade students with a diagnostic assessment of four-level critical thinking skills. Instrument data were analyzed using expert validation and construct validity. Expert validation was carried out by giving expert test questionnaires to two lecturers and two

physics teachers. Expert validation analysis with the following equation.

$$N = \frac{Skor\ total\ penilaian}{Total\ skor} \times 100\ \% \qquad (1)$$

The results of expert validation are then categorized according to the validity value adapted from Arikunto (2013):

Table 2 Criteria for expert validation results

Percentage Score	Validity Criteria	Description
81-100	Very High	Can be used without revision
61-80	High	Usable with minor revisions
41-60	Simply	Can be used with many revisions
21-40	Low	Extensive revision and revalidation
0-20	Very Low	Extensive revision and revalidation

Construct validity by analyzing the results of the assessment trial to students. Test validity with factor analysis of each aspect of critical thinking skills (Hartanto, 2021). The tests carried out were confirmatory factor analysis with the *One-Sample Kolmogrov-Smirnov Test*, KMO assumption test, *Anti-Image Correlation*, communality, and *Total Variance Explained*. The test used SPSS *software*. The assessment reliability test is used to determine whether the assessment is suitable for use. Reliability test with *Cronbach's Alpha* formula using SPSS *software*. The results of the validity and reliability tests were used to determine the feasibility of the developed assessments.

RESULTS AND DISCUSSION

This study produced a set of four-level critical thinking skills assessment assessments consisting of: diagnostic assessment grids, four-level critical thinking skills diagnostic assessments, and diagnostic assessment rubrics. The material used in the developed assessment is motion kinematics material. The developed critical thinking skills assessment assessment was then tested for validity and reliability.

The four-level critical thinking skills diagnostic assessment grid contains six sections. The first section consists of the identity of the grid, namely grade level, subject, and semester level. The second section contains the basic competencies of physics lessons. The third section contains a description of physics material from basic competencies. The fourth section is a description of the questions according to the competency indicators. The fifth part is the indicator of critical thinking skills developed from aspects of critical thinking skills, namely explanation, analysis, conclusion, and evaluation (Facione, 2011, Marfu'i, L. N. R. et al, 2018, Firdaus, F. et al, 2015). The sixth section is the question numbers.

The stage of designing the developed assessment product includes:

1. Define Objectives

   The purpose of instrument development is to get a benchmark for writing questions to measure the level of students' critical thinking skills and as an instrument that can describe the relationship between one aspect of critical thinking and other aspects.
2. Product Development

   The test questions developed are based on indicators of critical thinking skills. Indicators of test questions are developed in accordance with the basic competencies (KD) for physics subjects in kinematics material. In addition, the use of tests needs to be equipped with grids and scoring guidelines.
3. Design validation stage

   The validation of the assessment instrument developed meets the criteria of valid or feasible to use. Validity is reviewed from three aspects, namely: material, question construction, and language.
4. Design revision stage

The results of validation by validators that have been obtained are used to improve the question items to be developed. The question items that have been improved are then made into test instruments for further testing.

The four-level diagnostic assessment developed consists of : The first level is a multiple choice question with two answer options. In the first level, it is the conclusion aspect that is reviewed. The second level is a multiple choice question with three closed answer options and one open answer option. The aspect measured at the second level is the explanation aspect. The third level is a multiple-choice question with four answer options. The aspect measured at the third level is the evaluation aspect. The fourth level is a description of the stages of problem solving that underlie the answers at levels one to three. The aspect measured at the fourth level is the analysis aspect.

The number of items in the trial assessment was 12 four-level diagnostic items. The results of the validity and reliability tests showed that the assessments developed were suitable for use. The validity test of the critical thinking skills assessment includes expert validation and construct validity. Expert validity was obtained through a validation questionnaire given to four expert validators including two lecturers and two high school physics teachers. The results of the expert validation questionnaire are in Table 3.

Table 3 Expert and Media Validation Results

Validator Code	Score per Category			Value (%)
	Material	Problem Construction	Grammar	
V-01	14	13	11	73
V-02	13	16	12	78,8
V-03	16	16	11	78,8
V-04	16	17	11	84,6

The results of the expert validation scores were then translated into scoring guidelines according to Arikunto (2021), so that the results of expert validation were obtained, for validators 1, 2, and 3, namely high assessment validity criteria. According to these criteria, the developed assessment can be used with minor revisions. The results of expert validation by validator 4, stated that the assessment validity criteria were very high, according to these criteria, the assessments could be used without revision.

The average score of expert validators, obtained a value of 78.8% with high validity criteria, so that the assessment can be used with minor improvements.

The revision suggestions from the four validators are presented in Table 4.

Table 4. Revisions and Suggestions

Component	Revision Suggestion
Material	It is better to ensure that the stem of the question is in accordance with the KD, set a more operational rubric
Problem Construction	The sentences used are made into effective sentences, where the sentences used are not too long.
	The sentence lengths used in the answer choices are not too different.
	The size of images and graphs is adjusted to proportion, i.e. not too large.

After the improvements were made, the assessment was tested to obtain data used for construct validity and reliability.

The results of the assessment trial were then factor analyzed to obtain the construct validity value. Factor analysis includes One-Sample K-S Test, KMO MSA test, correlation between variables (*Anti-Image Correlation*), communality, and *Total Variance Explained*.

Table 5 *One-Sample K-S Test* Results

Criteria	Value
Explanation	0,423
Analysis	0,241
Summary	0,072
Evaluation	0,307
Average	0,261

Table 5 states that all aspects of thinking skills reach a value above 0.05 so that the data is concluded to be normally distributed. This is as according to Hartanto (2021), that in order to carry out factor analysis, the data must be normally distributed.

The next test is KMO MSA testing, as a condition of factor analysis. The KMO MSA test results are presented in Table 6.

Table 6 KMO MSA and Bartlet test

KMO MSA Value	0,699
Bartlett's Test Value	0,000

Based on Table 6, the KMO MSA value is 0.699. The minimum value of KMO MSA so that factor analysis can be carried out is 0.500 (Hartanto, 2021). The *Bartlett* test result is 0.000, so factor analysis can be done. The next step is to see the number of factors formed. The number of factors formed is presented in the *Total Variance Explained* table by reviewing the eigenvalue. Factors are formed if the eigenvalue is above 1.00. The *Total Variance Explained* table is presented in the *scree plot* diagram in Figure 1.

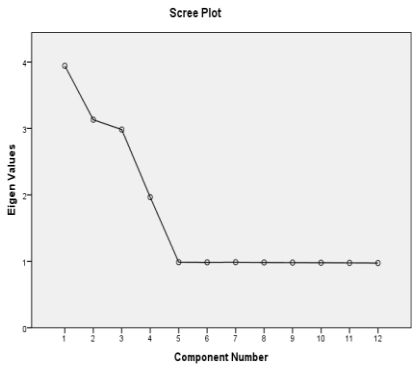

Figure 1 *Scree Plot* Diagram of *Total Variance Explained*

Based on Figure 1. obtained 4 points where the eigenvalue is above 1.00, so that 4 factors are obtained. In line with the theory that the assessment has 4 aspects of critical thinking components in the four-level assessment, so that 12 items are obtained which are declared feasible to use. The next step is to conduct a factor analysis of each aspect of critical thinking. The results of factor analysis on each aspect are presented in Figures 2, 3, 4, and 5.

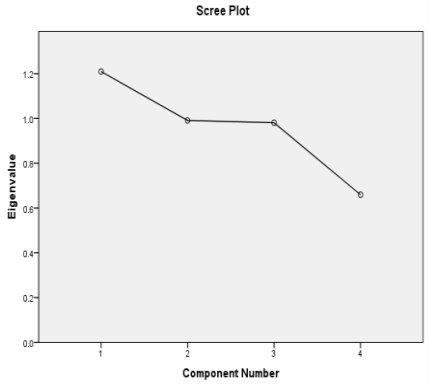

Figure 2 *Scree Plot of* Explanation section

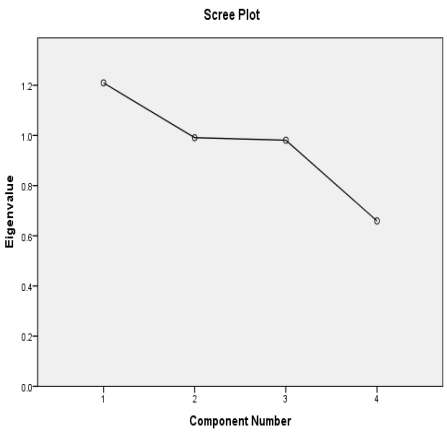

Figure 3 *Scree Plot of* Analysis section

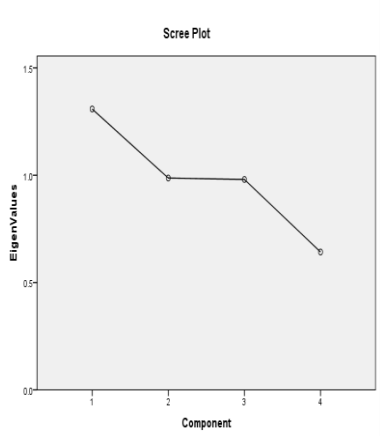

Figure 4 *Scree Plot of* the Conclusion section

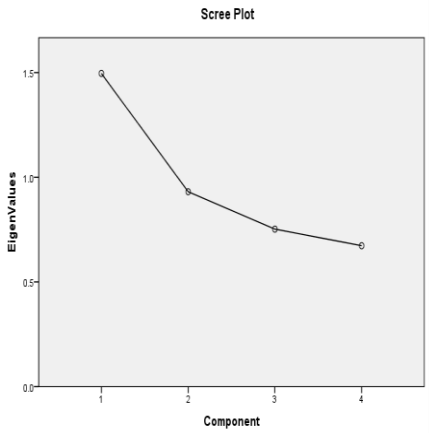

Figure 5 *Scree Plot of* Evaluation section

The assessment reliability test was obtained from the trial data of the critical thinking skills assessment. The results of the reliability test are presented in Table 7.

Table 7. Reliability of Assessments

Cronbach Alpha Value	**Number of Question Items**
0,639	12

The Cronbach's alpha coefficient value is 0.693, so it is found that the diagnostic assessment of critical thinking skills is reliable (Widhiarto, 2016). It can be concluded that the internal consistency category of the diagnostic assessment of critical thinking skills is good, and can be implemented to measure critical thinking skills. As according to Ennis (2011), critical thinking aspects consist of explanation, analysis, evaluation, and conclusion. Critical thinking skills consist of two components, namely reasoning and reflective thinking (Ennis, 2011, Chan, N. M. et al, 2011, Supriyatno, T. et al. 2020).

Inferring and evaluating skills as component aspects of critical thinking skills are representations of reasoning and reflective thinking abilities. Inferring and evaluating skills are continuous and linked by the ability to analyze and explain (Wechsler, S., M., et al, 2018, Heard, J. et al, 2020).

Benyamin (2021) states that the disconnection between aspects of critical thinking will make someone fail in solving problems. Changwong (2018) states that analytical skills and creative thinking are the main keys to critical thinking skills. The analysis aspect as a foundation and the conclusion aspect and evaluation aspect as a peak are mutually sustainable in producing a solution. So it can be concluded that there is an influence and role of each aspect of critical thinking in achieving problem solving.

CONCLUSIONS

The assessment developed is a four-level critical thinking skills diagnostic assessment device which includes: assessment grids, assessments and four-level diagnostic assessment scoring rubrics. The developed assessment covers motion kinematics material. The diagnostic assessment developed is composed of 12 four-level assessment items.

The feasibility test of the assessment found that the assessment developed was feasible to use. The content validity test value reached 78.8%, with minor improvements in technical writing and question material. The results of the construct validity test produced four factors in the assessment which are in accordance with the theory. The results of the assessment reliability test resulted in a *Cronbach Alpha* coefficient value of 0.639 so that the assessment was categorized as reliable.

The developed assessment is not only able to describe students' critical thinking skills, but also

able to provide an overview of how each aspect of critical thinking skills supports each other....

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