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Development of critical thinking instrument of electricity for senior high school students

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Abstract. Teaching and learning in 21st Century is recommended to achieve higher order thinking skills (HOTS), such as critical thinking skills. However, the availability of instruments of critical thinking skills at senior high school level is very limited. This paper discusses the development of a critical thinking skills instrument on the topic of electricity, dynamic electricity and static electricity for senior high school students. The development procedure consisted of seven stages. The subjects in present study consisted of three experts for content, construct, and language assessment, three students for readability test, and 70 high school students for validity and reliability tests. From the results of Pearson correlation coefficient and Cronbach alpha value, there were 4 indicators (out of 6 indicators) with 32 items were valid and reliable. Thus, the critical thinking instrument of electricity topic may be used to measure students' critical thinking skills at senior high school level.

1. Introduction

In the teaching and learning of 21st century, training higher order thinking skills (HOTS) to students is very crucial. Educators have to encourage their students to gain the skills, one of which is the critical thinking skills [1,2]. It is believed that critical thinking skills play an important role in logical thinking, making decisions, and solving problems [3]. This skills are essential for academic and career success [4] and have a significant role in all aspects of life [5], along with the progress of science and technology that change the structure of society [6].

Teachers often assume that critical thinking skills are necessarily taught to learners, but most of them have difficulty how to teach it effectively [7]. Generally, they teach critical thinking skills to their students only through asking questions about phenomena but never measure their students' critical thinking skills in physics subject [8]. As a consequence, the learning process that takes place today tends to get stuck at a lower order thinking skills. It can be seen from the results of PISA test, Indonesia is ranked 64 out of 65 countries [9].

One of the subjects that are considered difficult for students of senior high school is physics, in particular, electricity topics. Many research on students' learning difficulties were about electricity topics [10,11]. In addition, from the results of a preliminary study conducted at several senior high schools in Bandar Lampung showed that there were many students who had difficulties to understand electricity, dynamic electricity and static electricity topics. Although recent physics education curriculum has been focused on development and improvement of critical thinking skills, the assessment instruments to measure students' critical thinking skills are still very limited [12]. The



efforts to foster the success of educators in teaching critical thinking skills must be supported by its measuring instrument. In fact, the assessment instruments of physics at senior high schools measured only the low level of thinking abilities of students [8].

Availability of test instruments to be used as a guide in determining the level of students' critical thinking skills, especially in physics is still very limited, while the tests are needed to develop critical thinking skills in all topics of physics [13]. Thinking skills must be taught to students so that its implementation needs to be evaluated using the appropriate instrument [14] and this development of critical thinking instruments may provide an alternative instrument to the existing problems. This research, therefore, was conducted to develop a valid and reliable critical thinking instrument in dynamic and static electricity topics for senior high school.

2. Method

This study was a research and development study. The design of research and development employed in this study was based on [1]. Along with developing the instrument, there were seven stages that had been done, namely: 1) define the construct and formulate goals, 2) determine the format of items, 3) determine the construction items, 4) define guidelines for the assessment, 5) expert testing and readability test, 6) field testing, and 7) revision of the item. In the expert assessment, the critical thinking instrument had been examined by three experts to assess the validity of content, construct and language aspect of the instrument. Content aspect was related to the suitability of the content in the instrument, construct was related to the suitability of the indicator, the answer choices, and the level of student cognition. The language aspect, on the other hand, dealt with the accuracy, relevance, and clarity of the language used. Furthermore, readability test was conducted by three students to get prior insight to the clarity of each item from students' point of view.

The development of critical thinking instrument initially consisted of 40 multiple choice questions with five possible answers referred to Ennis [15]. They were 1) focus on the question, 2) analyze arguments, 3) consider whether the source is reliable or not, 4) induces and consider the results of induction, 5) identify assumptions, and 6) take actions. Before compiling and testing the instrument, a review of relevant research and preliminary study to collect data regarding the instruments used in schools, infrastructure, educational system, the potential to allow for the development of test instruments critical thinking had been done firstly. Thus, developing critical thinking test instrument can address the potential problems in the field. The field test was conducted at one of senior high schools in Bandar Lampung with a sample of 70 third-grade students who had studied dynamic and static electricity topics in their previous semester. The validity of instrument was analyzed by Pearson correlation product moment. The reliability, on the other hand, was analyzed with *Cronbach alpha*. Level of difficulty and discrimination power of all of the item of the instrument were also tested as well.

3. Result and discussion

3.1. Expert and readability test

The critical thinking instrument that had been designed was then given to three experts in the field of physics education and physics learning evaluation to assess the content, construct, and language aspects of the instrument. Expert tests were performed to check the suitability between the questions and the purpose of the test [16]. Based on the assessment of experts, the instrument was declared worthy of use. The result of the assessment on the language aspect was 77% in the valid category with minor revisions, the construct aspect of 80% in the valid category with minor revisions, and the content aspect of 87.5% with high valid. In general, the revision of the item lies in the grammar, the suitability of the indicator with the items, the cognitive domain of the content, the conformity of the image and graph. Overall, the validity of the instrument were at 81.5% and could be further tested to three students for readability test and a small number of samples for validity and reliability test.

Meanwhile, the readability test of the instrument was guided by a questionnaire which aimed to reveal the students' understanding of the questions related to the clarity of language, letters, numbers, images, symbols, and graphs. All of three students stated that the languages of instrument test were clear, understandable and did not lead to multiple interpretations. The letters, numbers, images, symbols, and graphs contained in each item could also be seen clearly. Therefore, the critical thinking instruments could then be tested to a small number of samples.

3.2. Validity, reliability, level of difficulty, and discrimination power

The test was conducted in one of senior high schools in Bandar Lampung with the sample of 70 students. Data analysis of critical thinking test instrument was processed by using SPSS 21.0 data obtained were then processed and analyzed to obtain the validity for each item. The results of the Pearson correlation demonstrated that all item of the instrument were valid. Meanwhile, reliability, level of difficulty, discrimination power, and level of students' critical thinking skills can be seen in Table 1, Table 2, Table 3, and Table 4.

Table 1. Cronbach's alpha value of instrument per each indicator.

Indicators of critical thinking	Cronbach's alpha	Number of items
Focusing question	0.738	8
Analyzing arguments	0.668	8
Considering reliability of information sources	0.218	4
Inducing and considering the results of the induction	0.663	8
Identifying assumptions	0.265	4
Determining an action	0.674	8

The value of *Cronbach alpha* for overall 40 items amounted to 0.907 indicates that the test instrument has high reliability. However, the values of *Cronbach alpha* for each indicator were lower than the overall value. The reliability value for each indicator of critical thinking instrument can be seen in Table 1. Indicators of "considering reliability of information sources" and "identifying assumptions" had very low values of Cronbach alpha, they were only 0.213 and 0.265, respectively. The indicators then were considered not reliable. Therefore, in this study, there were only four valid and reliable indicators consisting of 32 items. However, the overall reliability value for 32 items was only 0.893 which was lower than initial value of 40 items.

Table 2. Distribution of difficulty level.

Category of difficulty level	Number of items
High (0.00 to 0.29)	4
Moderate (0.30 to 0.69)	24
Low (0.70 to 1.00)	4

Table 2 shows the level of difficulty which was ranging from 0.23 to 0.74. From the all of the 32 items, 4 items were at low difficulty level, 24 items were at moderate difficulty level, and 4 items were at the high level of difficulty.

Table 3. Distribution of discrimination power.

Category of discrimination power	Number of items
Lack (0.00 to 0.19)	-
Sufficient (0.20 to 0.39)	8
Good (0.40 to 0.69)	18
Very Good (0.70 to 1.00)	6

Table 3 is the distribution of discrimination power of all items and the results has a range of 0.277 to 0.845. Results of the analysis showed that discrimination power of 8 items with sufficient category, 18 items have good category, 6 items with very good category.

Table 4. Students' distribution of critical thinking skills.

Category	Value	Number of students
Very high	80.1-100	-
High	60.1 to 80	9
Average	40.1 to 60	38
Low	20.1 to 40	13
Very Low	0.0-20	10

Table 4 showed the result of students' level of critical thinking skills that ranged from 5.0 to 87.5 out of 100. It is found that there were no students with very high level of critical thinking skills, nine students with high critical thinking skills, 38 students had medium level of critical thinking skills, 13 students with low critical thinking skills, and 10 students who had very low critical thinking skills. From the data analysis, the average value of critical thinking for 70 samples was 62.41, a high critical thinking ability.

Based on the validity, reliability, level of difficulty, and discrimination power analysis, it was revealed that this present instrument has good criterion as the standard instrument for measuring students' critical thinking. As shown in Table 1, reliability gained 0.893 value which indicates that the test instrument has high reliability, and test also obtained items range from 0.23 to 0.74 of level difficulty which means that the items have good distribution. Moreover, discrimination power index showed that there are 6 items with the very good category, 18 items have good category, and 8 items sufficient discrimination power. Therefore, it can be concluded that this instrument is can be used as a tool to assess critical thinking skill of electricity topics at senior high school level.

The result of the present study is in line with previous study [17] which was about the evaluation techniques at high-level thinking skills of students. It showed that by using both multiple choice test or essay types of HOTS assessment can enhance students' thinking skills. Another study [18] on the development of assessment instruments physics HOTS also obtained the same results that by using HOTS assessments of multiple choice test or essay format can enhance students' thinking skills. The other relevant research [19] was also found the similar result with this study. They investigated the use of the assessment tool in the learning required to develop students' thinking skills. Moreover, Klenowski had showed that assessment for learning is proven to help develop students' thinking skills [20]. Thus, the development of critical thinking test instruments in electrical materials can be used as an alternative instrument to train and develop students' critical thinking skills in teaching and learning of electricity materials.

4. Conclusion

It has been developed an instrument to measure students' critical thinking skills in electricity topics (dynamic and static electricity) for senior high school level. The instrument initially consisted of 40 multiple choice questions with five possible answers. All of 40 items were valid based on the test to 70 students. However, from six indicators of critical thinking initially developed, it appeared that the *Cronbach alpha* of two indicators, i.e “considering reliability of information sources” and “identifying assumptions”, were very low. As a result, there were only four reliable indicators with 32 items in total. Results of the Pearson correlation coefficient indicates that all of 32 items were valid. Meanwhile, the value of Cronbach alpha of 0.893 for overall items indicates that the instrument has high reliability. Therefore, this instrument can be used as an alternative instrument to measure students' critical thinking skills of dynamic and static electricity topics. Further tests for the instrument need to conduct in a broader scale to test the consistency.

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