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Assessment of Critical Thinking Skills in STEM-Based Science Learning Through Project Assignments

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ABSTRACT
Critical thinking skills are one of the 21st century learning skills that students must have, considering that the rapid development of science and technology causes more problems that arise in everyday life. Critical thinking skills are related to skills in using various reasons in various situations, thinking systematically, and being able to make decisions and solve problems. The development of these skills can be done through STEM-based science learning. To find out how far the students' critical thinking skills are, it is necessary to assess them. Assessing these skills can be done through the project assignment method. Project-based learning can encourage students to explore their abilities and potential, conduct experiments, think rationally and logically, solve problems during the project, and discover new knowledge or verify existing concepts. The results of this study indicate that the assessment of critical thinking skills in STEM-based science learning through project assignments is valid (with AVI (Aiken's Validity Index) of 0.958) and reliable (Cronbach Alpha test with a value of 0.717> r table). The average value of critical thinking skills of students after being measured using the assessment instrument was 69/100 (good category).

Keywords: *Assessment, Critical thinking, STEM, Science learning, Project*

1. INTRODUCTION

In addition to providing positive benefits for human life, the increasingly rapid development of science and technology in this era of globalization has indirectly led to various new problems that arise in everyday life. This shows that the next generation will face quite tough challenges. To overcome this, it is necessary to have a revolution in the education system that is able to realize an increase in the quality of human resources. One of the characteristics of quality human resources is being able to manage, use and develop thinking skills [1]. Schools as educational institutions have the responsibility to develop thinking skills through learning activities.

Thinking skills can be said to be the main skills that must be possessed by students so that they can support the entire continuity of the learning process. Of the many types of thinking skills, critical thinking skills are one type of thinking skills that are relevant to addressing the challenges of problems in this era of globalization. Critical thinking is an organized process that allows students to evaluate evidence, assumptions, logic, and the language that underlies the thinking of others [2]. Critical thinking skills are a complex process based on consistency and objective standards, in this case, making judgments using objective criteria and expressing opinions based on logical reasons [3]. These critical thinking skills can be developed through the learning process, one of which is in science learning.

Science explains the phenomena, matter, and life that exist in the universe. Science can also be said to be knowledge obtained through data collection through experimental activities, observation, and deduction in producing an explanation of a reliable symptom [4]. Based on these facts, science learning can actually be carried out with various strategies and learning approaches those not only prioritize the final result but also the process. If it is related to the effort to develop students' critical thinking skills, learning science with the STEM (Science, Technology,

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Engineering, and Mathematics) approach can be an alternative answer. STEM is a learning approach that integrates more than one scientific field so that it can create problem-based learning in everyday life [5]. In addition, STEM involves four 21st century learning skills (4C's) in its curriculum [5]. One of the 21st century learning skills is critical thinking skills.

Science learning is said to be effective if learning is able to empower the potential of students and refers to the achievement of the competence of each student. One of the competencies of students that need to be achieved is critical thinking skills. One of the factors that affect students' scientific literacy skills is critical thinking skills. In other words, an increase in critical thinking skills is expected to increase students' scientific literacy [6]. However, it seems that this hope is not in accordance with the reality that is happening on the ground. Based on data from the results of the Indonesian Student Competency Assessment (AKSI), there are 73.61% of Indonesian students' scientific literacy in the low category, 25.38% in the middle category, and the rest in the high category [8]. Likewise with the results of a survey conducted by PISA (Program for International Student Assessment) in 2015 which stated that the average score of Indonesian scientific literacy was 403 from the average score of scientific literacy in all OECD countries of 495 [8]. Moreover, achievements of IPA based on a survey Trends in Mathematics and Science Study (TIMSS) by the International Association for the Evaluation of Educational Achievement (IEA) in 2015 Indonesia's position shows the ranking 44th out of 47 countries with the average value of 397 [9]. This reality shows that increasing scientific literacy needs to be improved, one of which is by increasing the critical thinking skills of students through science learning that is in accordance with the achievement of these competencies.

Critical thinking ability is one such enduring skill, that it is a central element in lifelong learning [10]. Therefore, this skill is important to be trained and developed in each individual student. To achieve this, learning activities must be designed in such a way as to stimulate critical thinking skills of students. Learning activities must be able to encourage students to identify problems, find problem solving strategies, verify basic concepts, to be able to construct new knowledge. One of the learning activities in accordance with these objectives is project-based learning. Project-based learning is learning that involves students in the transfer of knowledge and skills through a discovery process with a series of questions arranged in a task or project [11]. Through project-based learning, students are encouraged to find out or explore information in a structured manner so that they are able to solve problems faced by developing a learning process that is in accordance with scientific procedures.

To find out the extent of students' critical thinking skills, it is necessary to conduct an assessment. With assessment activities, the success of students in mastering competencies or learning materials can be measured. Assessment as a systematic process and includes activities to collect, analyse, and interpret information to determine how far a person or group of students reaches predetermined learning goals, both aspects of knowledge, attitudes, and skills [12]. Through project-based learning activities, critical thinking skills can be assessed through project appraisal techniques. Project appraisal is usually based on meetings and discussions between the teacher and students during the semester, observations of student work in class, group and portfolio reports, personal reflective reports, and classroom exhibits [13]. Through project appraisal, teachers can find out the ability of students to understand, apply, investigate, and clearly communicate their findings. Project appraisal is a form of authentic assessment, where the assessment measures all aspects of learning, namely performance and product results. In project appraisal, assignments given to students must be contextual with the daily lives of students.

Based on the description of the research background above, there are several things that will be discussed in this paper, namely 1) the method of assessing students 'critical thinking skills through project assignments in STEM-based science learning and 2) the results of assessing students' critical thinking skills in STEM-based science learning.

2. METHODS

This research is an R&D research which aims to determine the results of the assessment of students' critical thinking skills in STEM-based science learning through project assignments. The instrument for assessing critical thinking skills has gone through several stages of 3D development (adaptation of the 4D development stage, because the dissemination stage was not carried out), namely: 1) the defining stage or a preliminary study, which consists of concept analysis, task analysis, and material analysis, 2) stages a design consisting of the preparation of an instrument for assessing critical thinking skills in project learning, and 3) a development stage

consisting of testing instruments: expert validation, reliability testing, and limited class trials.

The validity of the instrument of critical thinking skills in STEM-based science learning through project assignments was carried out by expert validation tests conducted by two validators. The validator provides an assessment regarding the content of the instrument with a rating scale of 1-3 on each assessment indicator. The validity of the content of the critical thinking skills instrument in STEM-based science learning is represented by the Aiken's Validity Index (AVI). Aiken's Validity Index is a content validity coefficient based on the results of the assessment of n experts on an item in terms of the extent to which the item represents the measured construct [14]. The AVI coefficient values range from 0 - 1. The formulas used to calculate the AVI coefficient are:

$$V = \frac{\sum s}{[n\,(c-1)]} \quad (1)$$

$$s = r - l_0 \quad (2)$$

where V is the item validity index; s is the score determined by each level minus the lowest score in the category used (s = r - lo, where r = the scoring category selection score and lo is the lowest score in the category score); n is the number of experts; and c is the number of categories that can be selected by the expert [15].

The assessment instrument is not sufficient to just be valid; therefore it is necessary to test the reliability. The reliability of the instrument for assessing critical thinking skills in STEM-based science learning through project assignments was carried out through the Cronbach Alpha test with SPSS. The value of r Alpha will later be compared with the r table which will show whether the assessment instrument is reliable or not.

Assessment of critical thinking skills through this project assignment was carried out on the material "Heat and Its Transfer". The subjects of the assessment in this study were 26 grade VII junior high school students. The data obtained were the scores obtained by students on each indicator of critical thinking skills. The scores obtained by students on each indicator will be collected and then analysed based on how many students get a certain score (3, 2, or 1) in the form of a percentage. In addition, data processing is also carried out by determining the average value of critical thinking skills using a scale of 100. The average value of students' critical thinking skills will later be adjusted for categories based on the conditions listed in table 1 below.

Table 1. Interpretation of skills

Value Percentage of	Criteria
81-100	Very Good
61-80	Good
41-60	Good Enough
21-40	Less
0-20	Very Less

3. RESULTS AND DISCUSSION

3.1. Instruments for Assessing Critical Thinking Skills through Project Assignments on STEM-Based Science Learning

In this study, the assessment of critical thinking skills was carried out through project appraisal. Project appraisal is carried out by giving a number of tasks related to the learning material and in accordance with the competency achievements of students. There are three main aspects that are assessed in project appraisal, namely management, relevance and authenticity [19]. Management ability is related to the ability of students to choose topics, find information, manage data collection time, and write reports. Relevance relates to the suitability of the tasks given to students with the material, the school environment, and the characteristics of students. And finally, the aspect of authenticity is related to the originality of the work of students.

Technically, the project appraisal instrument consists of several appraisal parts, namely 1) project planning, 2) project implementation, 3) project reports, 4) project presentations, and 5) project products. For indicators of critical thinking skills, assessment activities are focused on assessing reports and presentation of project results. The assessment report is focused on assessing the skills of students in reporting all activities carried out and the findings during the project activities in the form of a written report, while the assessment of project presentations is focused on assessing the skills of students in presenting project results directly to the teacher.

There are several indicators of critical thinking skills, including: a) conclusion drawing, namely distinguishing between the degree of truth and error of a conclusion drawn based on the data provided, b) assumptions, namely being aware of the unwritten allegations or prejudices of the statements or premises given, c) deduction, namely deciding whether certain conclusions must follow the data from the statements or premises that has been given,

and d) interpreting information, this is measuring evidence and determining whether generalizations or conclusions are based on correct data [17].

The indicators of critical thinking skills above are often used in educational research, especially those related to critical thinking assessments in secondary schools and are known as WGCTA. Watson-Glaser Critical Thinking Appraisal (WGCTA) is a test that is used specifically for measuring critical. The aspects of critical thinking skills as measured by WGCTA, consist of the ability to (a) define the problem; (b) select information relevant to the solution of the problem; (c) recognizes both stated and unstated assumptions; (d) formulating and selecting relevant and promising hypotheses; and (e) draw valid conclusions and assess the validity of conclusions [18]. Based on this description, the researcher adapted the two opinions regarding the classification of critical thinking skills to compile the following assessment indicators:

a. Recognition of assumption: In this aspect, the assessment indicators are to write down the reasons following the problems encountered in everyday life that are the background for the implementation of the project.

b. Inference: Inference is related to the ability of students to identify and select the elements needed to form reasonable conclusions. In this aspect, the assessment indicators are writing theories that are relevant to the project undertaken and sourced from trusted literature such as books and the internet, as well as writing hypotheses related to experiments carried out in the form of logical propositions.

c. Interpretation: In this aspect, the assessment indicators are: 1) writing the results of the data analysis in the form of tables / graphs / propositions of the relationships between variables completely and clearly so that it is easy to generalize / conclude and 2) demonstrating the product results of the project supported by the delivery of material / basics theory relevant to the experiment.

d. Deduction: In this aspect, the assessment indicators are writing conclusions based on observations and supported by relevant and reliable references such as books and the internet, so that they are able to answer the initial assumptions and objectives of the project.

e. Evaluation of arguments: In this aspect, the assessment indicators are answering audience and teacher questions according to the topic and supported by a strong theoretical basis.

Instrument for project assessment of critical thinking skills through project assignments consists of several components including the following:

a. Identity contains information about the object of assessment. This section consists of the name of the school, learning materials / activities, class / semester, project title, and group.

b. Assessment instructions, containing instructions for the use of assessment instruments, such as how to score with a check mark (√) and the meaning of the number for each score, 1 means less, 2 means sufficient and 3 means good.

c. Learning competencies, containing core competencies and basic competences for learning.

d. The assessment table contains rows and columns that contain aspects and indicators of observed critical thinking skills, scores, and information. The assessment table is a core part of the assessment instrument. All the results of the assessment are in this table.

e. The formulation of the assessment score contains a formula for obtaining the final score of student observation skills.

f. Assessment rubric contains a description of the scoring criteria 1, 2, 3 on each assessment indicator. The assessment rubric used in this assessment uses an analytic rubric which explains the scoring guidelines for each indicator of critical thinking skills more specifically. The rubric is used as a reference in providing a score for each measured indicator. With a rubric, the subjectivity of the assessment can be minimized so that the results of the assessment will also be more accurate and objective.

The way to assess critical thinking skills using the project appraisal instrument is to assess the project reports one by one in the project reports that have been compiled by students and observe presentations made by students. The value of students' critical thinking skills is obtained by adding up the overall score obtained for each aspect then divided by the maximum score and multiplied by 100.

The essence of science learning basically contains four things, namely products, processes, attitudes, and technology [16]. Seeing these characteristics, it can be said that science learning should ideally not only focus on products, but also on aspects of

processes, attitudes, and technology so that students can fully understand science [16].

STEM (Science, Technology, Engineering, and Mathematics) is a learning approach in describing two or more STEM subjects with practical activities so as to motivate learners' learning. In its implementation, it is advisable not to integrate all fields of science in STEM because it will make it difficult for educators. There are at least two fields of STEM science that are integrated into one particular subject [5]. In this study, STEM-based science learning carried out through project appraisal was carried out through the assignment of making simple tools such as simple flasks, cooler pots, and eco-coolers. These simple tools are several forms of simple technology that apply the concept of science, especially in the material "Heat and Its Transfer". Of course, the integration of scientific fields is not carried out as a whole. For example is in making a simple thermos. In the manufacturing process, in "science" students are expected to be able to understand how the heat transfer process can take place so that they can keep the water in the bottle warm and in a "technological" way, students are also required to be able to choose materials that can be used to withstand the hot water stored in bottles.

3.2. Validity and Reliability of Assessment of Critical Thinking Skills through Project Assignments on STEM-Based Science Learning

The validity of the instrument for assessing critical thinking skills in STEM-based science learning through project assignments is measured through expert validation tests conducted by two expert validators. The aspects of assessing the validity of the instrument include the following aspects: 1) format, which consists of spatial arrangements, assessment instructions, and score processing guidelines, 2) content, which consists of conformance to basic competences, conformance with STEM, suitability with critical thinking skills, and defining the indicators of critical thinking skills itself, and 3) language, which consists of grammar and sentences. Based on the results of calculations using the AVI formulation, the average AVI coefficient for all aspects and indicators is 0.958, where this score is in the range 0 to 1.00. This shows that the validity of the device being developed has a fairly high coefficient.

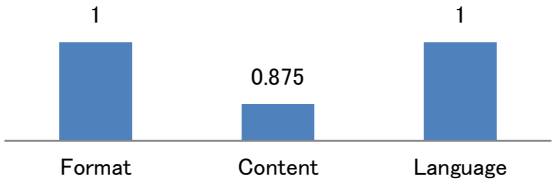

Figure 1 The results of the aiken's validity index test on the instrument for assessing critical thinking skills in STEM-based science learning through project assignments.

In Figure 1, the AVI coefficient on the format and language aspects has high validity (score 1), and the content aspect is still interpreted in the high validity category (score 0.875). Of the three aspects, the content aspect has the lowest AVI coefficient among other assessment aspects. There are 2 indicators that need to be observed in the content aspect, namely: 1) conformity of the assessment with STEM and 2) indicators of critical thinking skills that are set operationally. However, overall the assessment instrument is very comprehensive and STEM appears in various aspects. Therefore, based on the results of the above assessment, it can be concluded that the instrument for assessing critical thinking skills in STEM learning through this project assignment is valid.

In addition to the validity test, it is also necessary to do a reliability test to determine whether the assessment instrument is reliable or not. The reliability test was carried out through the Cronbach Alpha test by using SPSS 18 for *Windows* with the following results.

Table 2.a Result of reliability test using Alpha Cronbach Test per item

Item-Total Statistics				
	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Item_1	10.69	1.262	.698	.582
Item_2	10.15	2.135	.258	.726
Item_3	9.58	1.214	.788	.542
Item_4	10.42	1.534	.567	.639
Item_5	9.92	1.754	.303	.730
Item_6	10.19	2.322	.000	.747

Table 2.b Result of reliability test using Alpha Cronbach Test for all items

Reliability Statistics	
Cronbach's Alpha	N of Items
.717	6

Based on table 2.a, it can be seen that for each item or indicator it has an r alpha value between 0.542 to 0.747. When compared with the r table (with a total sample size (n) of 26 people) which is 0.388, then the r alpha value for each assessment indicator is greater than the r table. Likewise, the r alpha value for all indicators based on table 2.b is 0.717 which is greater than the value of r table. This shows that the instrument for assessing critical thinking skills in STEM-based science learning through project appraisal is reliable.

3.3. Results of the Assessment of Critical Thinking Skills through Project Assignments on STEM-Based Science Learning

Instrument for assessing critical thinking skills through this project assignment was tested on 26 grade VII junior high school students. The results of the assessment instrument trial were analysed for each indicator to determine how well the instrument was used to measure students' critical thinking skills. The results of the analysis are presented in the following graph.

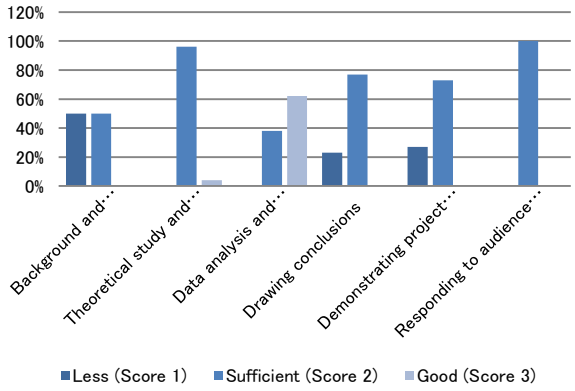

Figure 2 Percentage of students who scored 1, 2, and 3 on each of the critical thinking assessment indicators in project appraisal.

Figure 1 shows the percentage of students in obtaining scores for each indicator of critical thinking skills. When viewed as a whole, it appears that a score of 2 is the average score obtained by students in almost all indicators. Score 1 is quite a lot seen in the percentage of the aspect recognition of assumption which is shown through background writing activities and problem formulation. The difficulty of students in determining the background to the problem is shown from several things such as unclear discussion directions, too many copies from internet sources, and more explaining things that are general in nature and do not emphasize the basic things that want to be studied. This can be caused by students who do not decide for themselves what projects to work on, but are only given a number of choices by the teacher. The same thing also happened to the deductive aspect which was shown by drawing conclusions. Based on Figure 1, the percentage of students who get a score of 1 in this aspect is 23%. The average error in writing conclusions is shown through the contents of the conclusions which tend to summarize existing information but do not answer the problem formulation. In the interpretation aspect shown through the demonstration of the project results, the score of 1 shown in Figure 1 also shows a significant number, namely 27%. The deficiencies found when students present the results of their projects are the lack of understanding of students in linking the results of their experiments with relevant theories. Lack of literacy and writing skills can also be the cause of this problem. Therefore, it is necessary at least the teacher to guide students to make preliminary observations or preliminary studies related to what material will be discussed in the project, so that students have an overview and sufficient insight to analyse problems encountered in everyday life.

In addition to the shortcomings previously mentioned, the acquisition of the "good" category mostly appeared in the interpretation aspect shown through data analysis and discussion activities. In this section, most of the students seemed to be able to write down the results of their observations and measurements in a clear and coherent form and analyse them according to the data obtained. This shows that project appraisal is able to encourage students to issue more ideas and ideas either through data or other findings obtained while carrying out these project activities.

Based on the results of the assessment that has been carried out, the average value of critical thinking skills of students obtained through project assignments on STEM-based science learning is 69 which is in the good category, with an average value of critical thinking skills through report assessment of 66 (good) and through a presentation assessment of 71 (good). The results of this assessment are of course not a perfect assessment result and certainly

still need to be reviewed in depth through limited trials in class or other learning materials.

In its implementation, the assessment of critical thinking skills through project assignments in STEM-based science learning is inseparable from a number of advantages and disadvantages. The advantages of conducting project-based assessments in measuring students' critical thinking skills are 1) students are given space to convey as many ideas as possible but still have to be based on a logical and scientific theoretical basis and 2) foster a sense of responsibility for students, both in work on assignments and in conveying the reasons for the results obtained in the project activity. The drawbacks of this project appraisal are 1) project assignment design activities are difficult for the teacher to monitor, because most projects are carried out at home, and 2) the time required to carry out this assessment is relatively longer.

4. CONCLUSION

The conclusions that can be drawn from this study are as follows:

a. Assessment of critical thinking skills in science learning through STEM can be done through project assignments, especially at the reporting and presentation stages of project results. Project assignments are adjusted to the nature of STEM where the project at least integrates more than one field of science listed in STEM. Measurable aspects of critical thinking skills include recognition of assumptions, inference, interpretation, deduction, and evaluation of arguments. All indicators are then broken down into indicators that can be observed operationally and in accordance with the components in the reporting and presentation of project results. The assessment is carried out with a rating scale of 1-3 which is then converted into a scale of 100.

b. Assessment of critical thinking skills in STEM-based science learning through project assignments is tested for validity and reliability which shows that the instrument is valid and reliable so that it is suitable for use in learning activities.

c. Assessment through project assignments gave results of 69 (good category) for the average score of critical thinking skills as a whole. This value is not the maximum value that can be obtained, but needs to be tried again in class or other learning materials

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