Profile of students’ critical thinking ability in project based learning integrated science technology engineering and mathematics

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Abstract. The aim of this research is to obtain a profile of students’ critical thinking ability in project based learning (PjBL) integrated STEM (Science Technology Engineering and Mathematics). The research method used is quantitative descriptive. The subjects in this research were students of 8th grade in one of Junior High School Bandung with a total of 34 students taken by purposive sampling. Students’ critical thinking ability is measured on aspects of interpretation, analysis, explanation, inference and evaluation using task and rubric instruments also peer assessment. The analysis of critical thinking ability uses the Item Response Theory Graded Response Model. The results showed that the profile of critical thinking ability was 25% in the low category, 34% in the medium category and 41% in the high category. This result is supported by the results of peer assessment which showed that 12% in the low category, 41% in the medium category and 47% in the high category. Based on the results of the research, it can be concluded that a profile of students’ critical thinking ability in PjBL-STEM learning is high category.

1. Introduction
The 21st century is an era of globalization where in this century there have been changes in all aspects of life, both in the economic, social, political, scientific and technology. The rapid of science and technology development in the 21st century must be able to be anticipated by the education world to prepare students who are ready and adaptive in an all-digital era. The learning process as one part of education must be able to train various skills in the 21st century skills consisting of life and career skills, learning and innovation skills, and information media and technology skills [1]. Learning and innovation skills as a part of 21st century learning consists of critical thinking, creativity, communication and collaboration. Critical thinking as one of the skills of the 21st century is one aspect of ability that is essential and functions effectively in all aspects of life, so critical thinking ability must be instilled and trained from an early age. Critical thinking is a process of thinking that has a purpose, both proving intentions, interpreting an intention, interpreting the meaning of something, and solving problems. People who have critical thinking ability not only recognize an answer to a question or problem but also will try to develop the possibility of other answers based on analysis and information that has been obtained from a problem. There are several aspects that can demonstrate
students' critical thinking ability including interpretation, analysis, evaluation, explanation, inference and self-regulation [2].

The results of several previous studies show that students' critical thinking ability are still in the low category [3-5]. The low level of critical thinking ability of students is caused by the learning that is applied in schools is still dominated by the teacher so that it does not train students' critical thinking ability [5]. According to [6] the learning process that is centered on students has the potential to train and develop critical thinking skills, because students are given the freedom to build their own knowledge, discuss with friends, freely submit opinions, be able to accept or reject peer opinions and with the guidance of the teacher can formulate conclusions. One of learning model is the project based learning (PjBL) model which is integrated with STEM (Science, Technology, Engineering, and Mathematics). PjBL is an innovative learning practice that builds learning based on task challenges or problems that guide students to investigate, make decisions, design and finally conclude with a product [7]. STEM is an approach to learning that integrates science, technology, engineering and mathematics. In PjBL-STEM learning using projects becomes the core of activities that are integrated with engineering design processes. Implementation of PjBL-STEM in the learning process is carried out through 5 stages of learning, namely reflection, research, discovery, application and communication [8].

The purpose of this research is to describe students' critical thinking ability in project based learning integrated STEM using authentic assessment. With this research, it is expected to be able to provide information and description to the teacher about students' critical thinking ability so that the teacher can design learning activities that can invite students to train and develop their critical thinking ability.

2. Methods

This research is a descriptive research using quantitative approach. Descriptive research is a quantitative research method that attempts to collect quantifiable information to be used for statistical analysis of the population sample and describes what it is about variable, symptoms or condition [9]. The subjects in this research were 34 8th grade students in one of Junior High School Bandung selected through purposive sampling technique. The instrument used to collect data in this research is authentic assessment namely task and rubric also peer assessment. Task adjusted to the stages in PjBL STEM and assessed according to the assessment rubric that contains aspects of critical thinking. Peer assessment contains statements about critical thinking ability in the form of a rating scale consisting of four alternative answers. In this research the aspects of critical skills measured consisted of five aspects, there are interpretation, analysis, evaluation, explanation, and inference [2].

Critical thinking ability data were obtained from task and rubric also peer assessment were analyzed using the Item Response Theory (IRT) Graded Response Model (GRM). The GRM is a polytomous IRT model developed for item responses which are characterized by ordered categories [10]. GRM is used with the aim of displaying item parameter estimates and students' abilities obtained through the test characteristic curve. Based on the test characteristic curve, critical thinking skills (latent variable estimation) can be grouped into low, medium, and high with descriptions as in table 1 [11].

| Latent Variable Estimates | Category |
|---------------------------|----------|
| $\theta \leq b - 0.5$    | Low      |
| $b - 0.5 < \theta < b + 0.5$ | Middle   |
| $\theta \geq b + 0.5$    | High     |

3. Result and Discussion

3.1. Result
Critical thinking ability data in this research were obtained through task scoring contained in student worksheets in accordance with the rubrics that have been prepared. The scores obtained are then analyzed using the IRT GRM through the samejima’s graded models. The results of data analysis using the GRT IRT produce a total characteristic curve of critical thinking ability shown in Figure 1.

Based on the characteristic curve in figure 1, the parameter-b value is 0.1. The parameter-b value classifies students according to the latent variable estimates obtained in the three categories [11] shown in Table 2.

| Latent Variable Estimate | Category | Percentage (%) |
|-------------------------|----------|----------------|
| $\theta \leq -0.4$     | Low      | 25             |
| $-0.4 < \theta < 0.6$ | Middle   | 34             |
| $\theta \geq 0.6$      | High     | 41             |

In this research to measure students’ critical thinking ability not only using task and rubric but also using peer assessment. Scores obtained based on the results of peer assessment are then analyzed using the IRT GRM through the samejima’s graded models. The results of data analysis using the IRT GRM produce a characteristic curve of critical thinking ability shown in Figure 2.
Based on the characteristic curve in figure 2, the parameter-b value is -0.3. The parameter-b value classifies students according to the latent variable estimates obtained in the three categories [11] shown in table 3.

Table 3. Categories and Percentage of students’ critical thinking ability based on peer assessment

| Latent Variable Estimate | Category | Percentage (%) |
|-------------------------|----------|----------------|
| $\phi \leq -1.2$         | Low      | 12             |
| $-1.2 < \phi < -0.2$    | Middle   | 41             |
| $\phi \geq -0.2$        | High     | 47             |

Based on table 2 and table 3 it can be seen that the number of students who have the highest category of critical thinking ability has the highest number. These results indicate students’ critical thinking ability in PjBL-STEM learning are in the high category.

3.2. Discussion

Based on the results of data analysis shows that the critical thinking ability of students in the PjBL-STEM are in the high category. One of the factor that causes this is because the stages in the PjBL-STEM starting from the stages of reflection, research, discovery, application and communication are closely related to aspects of critical thinking ability. In the reflection stage, the teacher gives an ill-defined problem in the form of problems presented in the form of text containing stories contained in the student worksheet. The problems presented in the form of stories are intended to help students translate tasks, arouse curiosity and imagination of students [12,13]. At this stage, students are trained to focus and identify the problems presented by the teacher (aspect of analysis). At the research stage students are required to conduct research that will direct them in finding solutions to the problems they have identified previously. At this stage, students are guided to study science material (sound waves). Learning at this stage is presented through observation of images, demonstrations and videos. Students are trained to interpret the results of their observations in the form of questions (aspect of interpretations), and make answers to the questions they ask. In addition, students are trained to be able to give strong reasons for the answers or opinions they convey in accordance with the concepts being studied (aspect of explanation). The final activity of this stage students are trained to make conclusions related to learning outcomes (aspect of inference). At the discovery stage students collaborate to complete project tasks as a solution to the problem using the knowledge they have acquired [8] starting from expressing the problem solution, exchanging solutions to the problem (aspect of analysis), determining one problem solution and present it into a drawing or designing engineering, and manufacturing of products. At the end of this stage students explain the various obstacles encountered in making the project (aspect of explanation). At the application stage the students test the products that have been made. Based on the results of trials students can analyze the weaknesses of the products they make, improve products based on the results of re-engineering design, conduct final product testing and evaluate products that have been made (aspect of analysis and evaluation). At the communication stage students present the products they have made. Based on this explanation, in general the stages of PjBL-STEM are able to train critical thinking ability.

The second factor that causes high-level critical thinking ability in this research is the engineering design process that is applied in the PjBL-STEM. The application of engineering design process activities in PjBL-STEM make meaningful learning and students are accustomed to thinking critically in exploring their projects, and actively participating in learning. When students are actively involved in learning, they will become more motivated, more comfortable to ask questions, to brainstorm ideas and suggest steps to solve a problem [Tawfik et al. in 14]. This emerge students to think critically, creatively, analytically, and improve higher order thinking skills [15]. Based on that learning that
stimulates and facilitates students to explore, build and accustom critical thinking and make students actively participate is very important to train and improve critical thinking ability [16]. Besides that, in PjBL-STEM students apply abstract concepts of science and mathematics to the technical context using technology, so students have the opportunity to communicate and collaborate with peers or teachers in small groups when working on the project [17]. Based on the explanation, design engineering process in the PjBL-STEM can train students' critical thinking ability.

Another factor influencing critical thinking ability in this research is the use of authentic assessments. In this research the authentic assessment used is task and rubric as well as peer assessment. The task provides a guide for students to learn the material or knowledge learned and apply that knowledge in solving problems through project activities. Based on the results of the analysis of the student worksheets, overall students can do the job performance well. The filling of performance tasks automatically becomes a stimulus for students to practice their critical thinking ability. These results are in line with [18] which shows that using authentic assessments with performance appraisal, portfolio, project, product and attitude assessment techniques contribute to increasing 97.4% critical thinking ability in global warming learning. The results of other studies state that authentic assessment can improve cognitive abilities, critical thinking skills, creative thinking skills while still paying attention to the character of students [19]. Another authentic assessment used in this study is peer assessment. The application of peer assessments in PjBL-STEM is an important element because the teacher is not always with all students at all times in the project work process, and peer assessment will make it easier to assess individual students in a group. Through peer assessment students are given the opportunity as assessors in the learning process not only as an object of assessment. Assessments given by peer assessment will motivate each student to change if the assessment of his friend has a negative connotation or persists if the assessment result of his friend has positive connotation. This is in line with what was stated by Kartono [20] that peer assessment is considered to have power in forming positive personal character in addition to students having knowledge and skill competencies. Through peer assessment students become more critical of their peers' performance and strive to provide mutual feedback. The resulting consequences will make students more active in the learning process, so that they are able to exchange opinions regarding solutions to problems they have to solve and develop their thinking ability.

4. Conclusion
The results showed that the profile of critical thinking ability was 25 % in the low category, 34 % in the medium category and 41 % in the high category. This result is supported by the results of peer assessment which showed that 12 % in the low category, 41 % in the medium category and 47 % in the high category. Based on the results of the research, it can be concluded that a profile of students' critical thinking ability in PjBL-STEM learning is high category.

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