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Fostering Critical Thinking Skill through Optimizing Science Process Skills in Physics Learning

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***Abstract**: Low science process skills is along with low students' critical thinking skill. The result of this research indicated that there was an increase of the score in critical thinking skill before and after learning process by optimizing the science process skill. Even the correlation inferential analysis showed that any change score of science process skill could cause the change of the score of critical thinking skill as much as 0.02 in the same direction. The result of this analysis indicated that there was a relationship between critical thinking skill and science process skill. When the science process skill increased, the critical thinking skill of students also increased. In other words, if the science process skill was optimized in learning process, the critical thinking skill developed too.*

***Keywords:** critical thinking skill, science process skills.*

I. Introduction

The problem of students' science process skill in fact not only happens in Indonesia but also happens in other countries. The research result of Akinyemi and Folashade showed that the analysis of the exam practice result of the science- physics process skill organized by *the West African Senior Secondary School Certificate* in Nigeria in the 10 years (1998-2007) was still low. It was seen in the acquisition score percentage of science process skill how students manipulated (17,20%), calculated (14.20%), recorded or noted (13.60%), observed (12.00%) and communicated (11, 40%) [1]. Low science process skills is actually along with students' low critical thinking skill. It was proved by the result of the preliminary study on six high schools in Makassar with 200 students. Instrument used in the preliminary study was test of the critical thinking skill that could also measure students' science process skill. This refers to the opinion of Collis & Davey, which states that the assessment of critical thinking skill can be used together to measure the science process skill. The result of preliminary study showed that the mean score of students' skill to interpret was 1.53, to analyze was 1.15, and to draw an inference was 1.52. This result also happened to students' critical thinking skill which was still low. Therefore, of the 108 students who took the test, the average interpreting skill was 1.46, analyzing was 1.46, and drawing inference was 1.79 [2]. It indicated that there was a relationship between critical thinking skill and science process skill, and both were still relatively low, compared with the maximum possible score that could be achieved by the students, namely 10.00. Yet according to Michael Scriven, the main task of education is to train students and or university students to think critically because of the demands of work in the global economy, the democratic survival and personal decisions as well as decisions in an increasingly complex society that requires people who can think well and make good judgments [3]. Therefore, critical thinking is an important thing that should be taught to students and or university students to be successful in an increasingly complex world. Paul believes that critical thinking is an important basis for education to adapt to the demands of the 21st century, both personally and socially. In a view of the rapidly changing world and global reality there is a critical need for individuals to develop the skills and abilities that enable them to adapt the changes and to respond the demands of the 21st century.

II. Science Process Skills

Science education experts see that science not only consists of facts, concepts, and theories that can be memorized, but also consists of the activities or active process using the mind and scientific attitude in learning natural phenomena that have not been explained. Broadly speaking, science can be defined on three components, namely (1) scientific attitude, (2) scientific process, and (3) scientific product. So the process or process skill or scientific method is a part of science studies, including the subject material that must be learned by the students. Teaching the subject areas of science in the form of a product or facts, concepts and theories is not complete because it is only teaching one component. Components of scientific attitude that need to be nurtured are being responsible, curios, honest, open minded, objective, creative, tolerance, careful, self confident, positive self-concept, knowing the relationship between society and science, having attention to fellow beings, realizing that scientific advance is obtained from a joint venture, and interpreting natural

phenomena in terms of scientific principles. In other words, science education also aims to develop the personality of students.

The process can be defined as a complex skill device used by the scientists in conducting scientific investigations. The process or scientific method is a great concept that can be broken down into a number of components that must be mastered if the person is going to do research and development in the field. Scientist develop theories through science process skill [4]. Abruscato [5], classifies science process skill into two parts, namely *Basic Processes* and *Integrated Processes*. *Basic Processes* are observation, the use of numbers, classifying, measuring, communicating, forecasting, inferring, while the *Integrated Processes* are controlling variables, data interpretation, hypothesis formulation, defining operationally, conducting experiments. In order to make students to have these skills, they must be trained to perform activities relating to the skills. Provision of direct learning experiences in science learning is emphasized through the use and development of process skill and the scientific attitude in order to understand the concepts and be able to solve the problem. Science process skills that are used in high school (SMA) and Madrasah Aliyah (MA) in Competency Based Curriculum (CBC) are: observing, measuring, classifying, asking questions, drawing up hypotheses, planning experiments, identifying variables, determining the pace of work, performing experiments, creating and interpreting information/graphics, applying concepts, inferring, communicating both verbally and nonverbally [6]. Karamustafaoglu [7], says that the development of science process skill enables students to construct, solve problems and think critically. This possibility can occur because the components of critical thinking are largely the components of science process skill such as *designing experiments, testing hypotheses*, *hypothesizing, predicting, inferring, classifying, measuring, observing* [8]. Thus, if the students' science process skill develops, their critical thinking skills will also develop.

III. The Concept of Critical Thinking Skill

According to Mainali [9], thinking is a mental activity that is aware of the purpose, while critical thinking refers to the process and methodology by using rationality, insight, awareness, imagination and sensibility to criticize and evaluate an object. However, the phrase 'critical' is often interpreted as a negative thing, but critical thinking is a procedure for analyzing and evaluating a knowledge [9]. Further Mainali says that critical thinking can enhance students' understanding, ability to solve problems, think creatively and communicate their ideas clearly and effectively. In other words, critical thinking can improve the quality of education. This is reinforced by research done by Clifton [10], which concludes that the critical thinking in learning provides an opportunity for teachers to know how far their students' ability to ask and reason in the academic context, so that students' meta-cognitive skills and learning can be improved.

Some opinions of experts on the concept of critical thinking skill are proposed by Facione [11] who argues that *"Critical thinking in terms of cognitive skills in interpretation, analysis, evaluation, inference, explanation and self regulation."* Critical thinking is a term to interpret, analyze, evaluate, infer, explain and self-regulation. This is in line with Dewey that gives an opinion *"Critical thinking is an attitude of being disposed to consider in a thoughtful way the problems and subjects that come within the range of one's experience, knowledge of the methods of logical inquiry and reasoning, and some skills in applying those methods* [12]." The core, according to Dewey, critical thinking is an act that follows the scientific method to know and understand something. This opinion is reinforced by Damirchi Dewey, et al. [13] who say that critical thinking is a thinking process to know and decide the truth.

Angelo finds that *"Critical thinking as the intentional application of rational, higher order thinking skills, such as analysis, synthesis, problem recognition and problem solving, inference, and evaluation* [14]." Critical thinking is as a rational application designed as such, critical thinking is a high-level thinking skill such as analyzing, synthesizing, understanding and solving problems, inferring, and evaluating. According to Beyer [15], critical thinking is a way of thinking used by someone to evaluate the validity of statements, ideas, arguments, and research. Michael Scriven and Richard Paul see that *"Critical thinking is the intellectually disciplined process of Actively and skillfully conceptualizing, applying, analyzing, synthesizing, and / or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action* [16]." It means critical thinking as an intelligent process of conceptualization, implementation, analysis, synthesis and active evaluation and critical skill is resulted from a collection of observation, experience, reflection, reasoning, or communication as a guide to the belief and action. Meanwhile, according to Woolfolk, *et al.* [17]*"Critical thinking is the evaluating conclusions by logically and systematically examining the problem, the evidence, and the solution."*

Rudinow and Barry [18] argue that *"Critical thinking as a set of conceptual tools associated with the intellectual skills and strategies useful for making reasonable decisions about what to do or believe.*" Critical thinking is a process that emphasizes a base logical and rational belief and provides a set of standard procedures to analyze, test and evaluate. According to Ennis [19] Critical thinking is a deep process by expressing a purpose completed with firm reason of a belief and the activities that have been done. Basically critical thinking

skill according to Ennis [19]is developed into indicators of critical thinking skill that consist of five major groups, namely: (i) giving a simple explanation (*elementary clarification*), (ii) building the basic skill (*basic support*), (iii) concluding (*interference*), (iv) providing further explanation (*advanced clarification*), (v) setting the strategy and tactics (*strategy and tactics*). McPeck [20] states that the main work of critical thinking is solving problems in finding a context.

Kurfiss believes that critical thinking is a form of problem solving, but the main difference is that critical thinking involves *open-ended* reasoning or *ill structured problems*, while the study of problem solving is usually more superficial. Further Kurfiss views that critical thinking is more than an argument analysis. He emphasizes that "finding context" is as a representation of invention and creativity, while critical thinking phase is the representation of "context justification" [21]. Kelly, *et al.* [22] identifies seven key words of critical thinking, namely identifying the problem, (ii) setting out clearly on the issue, (iii) finding the alternative solutions, (iv) identifying the context, (v) showing the fact of identification and evaluation, (vi) making basic assumption implicitly, (vii) making implication assessment and potential conclusion. Borich [23] suggests that critical thinking emphasizes on mental process or students' strategies by using the analysis and evaluation, selection and concept. Burden and Byrd [24] categorize critical thinking as a high level thinking activity that requires a cognitive skill.

Based on some opinions above, the researcher states that critical thinking skill is a thinking skill that involves the high-level cognitive process, namely interpretation, analysis, and inference through scientific procedures in order to solve the problem [24]; [15]; [18]. Based on the definition, the researcher makes it as an indicator that is critical thinking skill is the interpretation, analysis, and inference in this article.

IV. Learning Process and Assessment

To see the growth of critical thinking skill, Critical Thinking Ability Test (CTAT) is used through the physics material. Critical Thinking Skill test includes high-level cognitive process, namely interpretation, analysis, and inference through scientific procedures in order to solve the problem. The scope of this study is Material of Straight motion with constant velocity and acceleration in class X SMA. To see the optimization of science process skill, Science Process Skills test is used. Before the test is done, the learning process is conducted several times by optimizing Science Process Skill by using syntax: (1) Identification of ideas (the teacher asks questions or issues), (ii) Collaboration (the teacher engages students in study groups in order to solve a problem or task together to produce a product.), (iii) authentic investigation: *Science Processes Skills* (the teacher guides and does the analysis, interpretation and inference based on data from group investigation), (iv) Class Discussion and Presentation (the teacher gives students a chance to interpret and infer related to the data results of the group investigation through discussion).

V. Rubrik Penilaian Assessment Rubric/Scoring Rubric

To give a score to the students after taking the test of critical thinking skill, assessment rubric is used. Score item given is 4 if all aspects are done; score 3 is given if the two aspects are done; score 2 is given if only one aspect is done; score 1 is given if aspects are done, but wrong / less precise. After being given a score based on an assessment rubric, then score conversion is done 0 to 100 using the equation = (X / Y) * 100 (X = the score obtained by the students, Y = the maximum score that may be obtained by the students).

VI. Test Result of Science Process Skills

Optimization of students Process Science Skill can be seen from the test results of students' science process skill. The test result of students' science process skill can be seen in Table 1.

Table 1. Test Results of Science Process Skill

*Pretest maximum score that may be obtained by students = **100*** *Posttest maximum score that may be obtained by students = **100*** *Pretest mean score = **46.30*** *Posttest mean score = **90.32***			
Indicator	Score		
	Pretest	Posttest	
Formulating problem	**43.52**	**87.96**	**N-gain = 0.59 (medium)**
Formulating hypotheses	**31.48**	**91.67**	
Identifying variables	**43.52**	**96.30**	
Formulating definition of operational variables	**46.30**	**69.44**	

Experimental procedure	**44.44**	**96.30**	
Creating tables	**44.44**	**96.30**	
Making a chart	**49.07**	**85.19**	
Interpreting graphs	**44.44**	**96.30**	
Analyzing	**54.63**	**86.11**	
Inferring	**43.50**	**91.67**	
Making conclusion	**63.89**	**96.30**	

VII. Test Result of Critical Thinking Skill

The impact of optimizing the science process skill can be seen from the development of students' critical thinking skill. The test result of students' critical thinking skill can be seen in Table 2.

Table 2. Test Result of Critical Thinking Skill

*Pretest maximum score that may be obtained by students = **100***
*Posttest maximum score that may be obtained by students = **100***
*Pretest mean Score = **36.76***
*Posttest mean score = **59.51***

Indicator	Score		
	pretest	posttest	
Interpretation	**32.29**	**63.19**	**N-gain = 0.55 (medium)**
analysis	**36.32**	**57.01**	
inference	**41.67**	**58.33**	

VIII. Result of Inferential Analysis

Analysis of the relationship between science process skill and critical thinking skill is performed using SPSS ***(Statistical Package for Social Science).*** The result of the analysis is as shown in Table 3 below.

Table 3. Analysis Result of Relationship between Critical Thinking Skill and Science Process Skills

Coefficients [a]						
Model		un-standardized Coefficients		standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	78 001	4054		19 243	.000
	Science Process Skills	**.002**	.047	.009	.052	.959

IX. Discussion

The test result of students' critical thinking skill is one of the objectives of physics learning process through the optimization of science process skill. Therefore, to see the development of students' critical thinking skill can be seen from students' ***gain score*** before and after treatment by optimizing the science process skill in learning. Table 1 shows an increase of scores before and after the learning process with the index *gain score* still in the moderate category. This is in line with the test result of critical thinking skill, namely an increase in scores before and after the learning process with the index *gain score* still in the moderate category (Table 2). The result shows that there is a relationship between critical thinking skill and science process skill. Even Table 3 shows if scores of science process skill change, it can be estimated that score of critical thinking skill also changes at **0.02** in the same direction.

In other words, if the science process skill is optimized in learning process, critical thinking skill also develops. According to Michael Scriven, the main task of education is to train students in facing the global economy, the survival democratically and personal decision as well as decisions in a society because the more complex society requires people who can think well and make good judgments [3]. Therefore, critical thinking is an important thing that must be developed by the students or university students to be successful in an increasingly complex world. Paul believes that critical thinking an important basis for education for

adaptation to the demand of the 21st century both personally and socially. In view of a rapidly changing world and global reality there is an important need for individuals to develop skill and ability which allow them to adapt to change and respond to the demands of the 21st century. Therefore, training students to think critically must be the main objective of an educational institution, as though the students have the knowledge, but they are not taught how to think analytically, they are susceptible to do wrong reasoning. Therefore, the main task of educators is to promote learning how to solve not only the problem of school, but also the problems of everyday life. Brookfield, *et al.* [25] conclude that without ability to think and act critically, then it will never be attempted to change social structure or could push social action collectively. Even Sternberg [26] argues that the future of a nation lies in the ability to think of its citizens.

According to Perkins, Jay, & Tishman [27], Halpern [28], Samani, M. [29], learning critical thinking requires a lot of practices and critical thinking skills that must be used as a "culture of thinking". Critical thinking skill should be taught continuously [30]. Therefore, to develop students' skill cognitive aspect including critical thinking skill is not an easy job. It needs a long time to build and develop the skill [31]. So students should be more involved with the concrete objects. Students are active to act and act as scientists. Thus, students will be accustomed and trained as well as having direct experience. An increasing after following learning by optimizing the science process skill indicates that social learning theory of Bandura as one of the supporting theories in the learning process is to confirm that individual behavior is formed through imitation toward the behavior in the environment. Learning is a process of how to make imitation as well as possible, so that it is suitable with the condition and goal. This theory emphasizes the cognitive component of mind, understanding and evaluation [32]. Vygotsky in Woolfolk, et al. [17], states that social interaction is an important thing in learning because it functions high-level mental such as reasoning, comprehension and critical thinking that comes from social interaction, which it is further internalized by individuals. Moreover, it also indicates the constructivism learning theory is confirmed that it can foster critical thinking skill. In constructivist theory, Lunenburg [33] assumes that students must build their own knowledge individually and collectively. Each student has a conception and skill to build knowledge in order to solve real problems. Therefore, if students do not have experiences in the field, then the teacher is responsible for guiding students' activities, behavior modeling, and providing examples through group discussions to be meaningful communication about the subject matter.

In this study, the teacher had been able to manage learning based on social learning theory and constructivism as a model supporting theory. It was because the teacher had organized the students into some learning groups and shared worksheet of student (LKS) where each group consisted of 2-3 students and each student got one LKS. Thus, students learned in a working group with LKS through interaction with friends. Students are involved in groups in doing LKS based authentic investigation, conducted experiments as listed on LKS in groups, presented the results of the experiment/observation, and gave a rational explanation to enhance the answer of other groups. The high activities of students were because (i) students could identify as many as possible the issues which were relevant with the material, so they could pick one issue and formulate it in hypothetical form (temporary answer to the question), (ii) the students did the interpretation and inference related to the result data of the investigation group, so there was an increase of skill in interpreting and inferring students based on data and developing self-confidence. The reasons stated above were in accordance with the opinion of Kincaid [34] stating that the critical thinking skill can be developed through the development of science process skill. According to Karamustafaoglu [7], the development of science process skill enables students to construct and solve problems and think critically. This possibility can occur because the components of critical thinking is largely a component of science process skill such as *designing experiments*, *testing hypotheses*, *hypothesizing*, *predicting*, *inferring*, *classifying*, *measuring*, *observing* [8]. Thus, if the students develop science process skill, then allegedly their critical thinking skills will develop. It is supported by the result research of Liliasari [35] that states that the critical thinking skills can be developed through the development of science process skills.

X. Conclusion

After the learning process by optimizing the science process skill is done, there is an increase in score of critical thinking skill, along with the scores increase of science process skill. It means that the result shows there is a relationship between critical thinking skill and science process skill. In other words, critical thinking skill can be developed through the optimization of science process skill development in learning physics.

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