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The Development of Critical Thinking Skills in Vocational High School Students in Indonesia

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This research was conducted at a vocational high school in the City of Bandung, Indonesia. It involved 68 students aged 15 to 17 years old, 27 of whom were female and 42 were male. The purpose of this research was to measure the critical thinking skills of vocational high school students. Critical thinking skills were measured by a Physics test concerning the kinematics concept in the form of a 5- (five) answer-option multiple-choice test. The results showed that the critical thinking skills of the vocational high school students applying the multiple representations approach in their Physics learning are better than those using the conventional approach. The critical thinking skill aspects investigated included elementary clarification, basic support, inference, advanced clarification, and strategies and tactics. The critical thinking skills of the vocational high school students engaged in the Physics learning activity applying the multiple representations approach indicate that this approach to Physics learning is able to improve higher-order thinking skills.

Key words: *Critical thinking skills, multiple representations, Physics learning.*

Introduction

Physics studies have multifarious natural phenomena as well as their causes, consequences, and applications. Findings in Physics lay a foundation for modern industries and technologies. Some examples are the computer, transportation, communication, and health technologies, and many more (Tipler, 2007). Physics is a quantitative science that uses mathematics to convey ideas (Alonso & Finn, 1992). As a basic science it is used to gain understanding of applied sciences that underlie technological advances. As a component of a curriculum, Physics has a significant impact on intellectual, attitude, interest, skill, creativity, and critical thinking ability development.

To have a mastery of Physics as a subject, it requires student understanding and ability of various ways of representation for the concept learnt. However, their inability to use multiple representations in understanding Physics concepts seems to pose a hindrance to their understanding (Gunel, Hand, and Gunduz, 2006). In line with that, Waldrip (2008) states that the ability to master concepts of Physics is closely related to how various languages of science in Physics learning are used. For example, words (oral and writing), visuals (pictures, graphs, simulation), symbols and equations, body gestures, role-playing, and presentation, will allow students to learn Physics through the development of mental ability in thinking. This is what is referred to as the multiple representations approach.

Multiple representations serve three primary functions: contemporary roles, constraining interpretation, and constructing a deeper understanding (Ainswort, 1999). Multiple representations serve as a complementary role in students' thinking and cognitive process in understanding a concept in a more holistic way. Multiple representations can also be used to constrain possible misinterpretations of a concept, a principle, and a law of Physics. The last function of multiple representations is to encourage students to construct a deeper understanding of a situation.

According to Angell et al. (2007), multiple representations are models that represent one common concept in different formats. Rosengrant et al. (2007) defines representation as something that symbolises or stands in for objects or processes. They, then, added that representations in Physics can take the form of words, pictures, diagrams, graphs, computer simulations, and mathematical equations.

Angel et al. (2007) furthermore argue that the multiple representations method must serve as the main strategy in Physics learning. This is based on two underlying arguments. First, the Physics learning at school should reflect the learning model that is directed to knowledge seeking and knowledge product introduction processes. Second, a variety of approaches must always be in place in Physics learning. Many researchers have attempted to employ the multiple representations method to elaborate on physical phenomena.

Representation is a process of formation, abstraction, and demonstration of physical knowledge. Representation of concepts, principles, and contextual problems are issues arising in the Physics learning and assessment. The representation model used as an assessment can help with understanding and is related to one's readiness. Aside from helping with understanding, one's multiple representation assessment indicates his or her problem-solving ability in Physics. A problem deemed complicated and complex can be made simpler if Physics strategies and representations are used in finding the solution to such problems.

Studies on multiple representations in Physics have been carried out by some researchers. Hubber et al. (2010) inferred that learning with multiple representations can help students overcome difficulties in understanding Physics concepts and in constructing understandings on a concept based on how representations are used. Kohl and Noah (2005) found that students' success in solving a Physics problem is influenced by the format in which the problem is represented; a particular form of representation sometimes makes it easier for students to understand a Physics concept.

Students' ability to use representations in understanding Physics sets a barrier to their understanding (Gunel, Hand, and Gunduz, 2006). Students' competence in varying representation formats has become a popular topic in science education and modern mathematics. Representation formats refer to the many ways in which certain concepts or problems are expressed (Kohl P. & Noah D. F., 2007). To have mastery of Physics as a subject, it takes student understanding and ability of various ways of representation for the concept.

The results of some studies show that multiple representations may serve as a means of facilitation for students' various learning ways and characteristics in understanding Physics concepts. The results of the present research suggest that multiple representations are needed in Physics learning to help students learn Physics concepts.

One of the reform efforts that can be made in the field of education and learning at all educational levels is to develop higher-order thinking skills needed for navigating through life and winning the competition in the globalisation era. To win the competition and to succeed in life, one must have higher-order thinking skills. Meanwhile, to improve the quality of education, the learning applied should be focused on higher-order thinking skills (Zoller, 2000). This is aimed to enhance the logical, rational, and reflective thinking skills.

Thinking is a cognitive process—a mental activity to obtain knowledge. Thinking processes are classified into basic thinking (rational thinking) and complex thinking (higher-order thinking). Basic thinking includes memorising, imagining, classifying, generalising, comparing, evaluating, analysing, synthesising, deducting, and inferring. On the other hand, complex thinking includes four kinds of thinking, namely problem-solving, decision-making, critical thinking, and creative thinking (Costa, 1985). The higher-order thinking skills underlying all higher-order thinking skills are critical thinking skills. According to Ennis (1985), critical thinking is a reflective and reasonable thinking that is focused on deciding what to believe or do.

Critical thinking is a process that enables students to gain new knowledge through problem-solving and collaboration. Critical thinking involves various activities such as analysing,

synthesising, making consideration, creating, and applying new knowledge in a real-world situation. Critical thinking is important in a learning process as it presents an opportunity for students to learn by finding. When students think critically, they are actively responsible for their learning (Walker, 1998).

Critical thinking is a life skill students must have to live their lives in their families, schools, or communities. Students with critical thinking skills will be adept at making systematic plans and solving problems. Critical thinking is widely known as a valuable skill in everyday life (Verlinden, 2005). Critical thinking is to a great extent needed in today's science and technology development era as science and technology outcomes come with problems for humans and the environment.

A study reveals that critical thinking skills do not develop unless efforts are made explicitly or they are instilled purposefully in their development (Zohar, 1994). A student will not develop good critical thinking skills if he or she is not challenged to practice them in the learning. A student born without critical thinking skills will be unable to develop thinking ability naturally to live. Critical thinking is a learnable ability, making it a must to teach it. Most individuals seldom learn it, however.

Understanding of Physics concepts, which involves solving Physics problems, requires thinking and reasoning. It will take basic (Novak & Gowin, 1985) and complex (higher-order) thinking skills, including critical thinking (Costa, 1985), to master Physics content. Critical thinking is logical and reflective thinking focused on deciding what to believe or do (Ennis, 1985).

A learning-teaching process should be undertaken in a variety of ways according to students' learning styles and the ongoing conditions or situations so as to achieve the desired learning goals. According to Treagust et al. (2003), teachers often assume that students can transfer their knowledge from one understanding level to another easily. In fact, as Russel et al. (1997) state, novices usually form one type of representation and scarcely do they transfer their knowledge into another form as easily as experts would do. Meanwhile, Waldrip (2008) states that students' experience and knowledge will depend on the language, device, and schemes at hand to represent such experience and knowledge. Dynamic Physics thinking and learning requirements such as reasoning, communication, and connection need a communication mode verbally or in writing, stated in a representation form. One may use it to express his or her ideas or communicate them with others, verbally or in writing, through graphs, tables, pictures, equations, to name but few.

Methodology of Research

General Background of Research

The research method used was the quasi-experimental method. This method was used to obtain a picture of the improvement in the vocational high school students' critical thinking skills as a result of the application of the multiple representations approach in Physics learning. The research design used was the randomised pre-test-post-test control groups design (Fraenkel and Wallen, 2009). Firstly, a control group and an experimental group were selected randomly. A preliminary test was then administered to both groups, followed by the implementation of different treatments to either groups. Lastly, a final test was given using the same instrument.

Sample of Research

The population in this research was the tenth graders of the Technical Drawings program (TGB) of a vocational high school in the City of Bandung, Indonesia, from 6 classes, with a total number of 204. Research samples of two classes was taken randomly by lottery. From the sampling process, Class X TGB-1 was selected as the experimental class, while Class X TGB-4 the control class. Each class had 34 students. Hence, the sample consisted of 68 students in total, 27 of whom were female while the remaining 41 were male. They were 15–17 years of age. The present study was conducted in the odd semester of the academic year 2017/2018.

Instrument and Procedures

There have been many studies examining critical thinking skills. Such studies would need a test for measuring critical thinking skills accurately. One's critical thinking skills can be measured by a two-tier multiple-choice test, skill test, and essay test (Ennis, 1985). In this research, the preferred test for measuring critical thinking skills of vocational high school students was a multiple-choice test.

This research aimed at measuring the critical thinking skills of vocational high school students. The instrument used was the Physics Critical Thinking Skill Test relating to kinematics concepts. The test developed for measuring students' critical thinking skills was restricted to the aspects stated by Ennis (Costa, 1985), namely 1) elementary clarification, 2) basic support, 3) inference, 4) advanced clarification, and 5) strategies and tactics. With two question items for each indicator, there were a total of 10 question items in the instrument. The instrument used was previously subject to validity and reliability testing through expert judgment and limited tryout.

The present research was conducted in three stages, namely planning stage, implementation stage, and final stage.

1. Planning stage

The activities performed in the planning stage are as follows:

a. Conduct a preliminary study in the form of a literature study concerning Physics learning with multiple representations approach, critical thinking skill indicators, curriculum analysis, and Physics content for vocational high school grade ten.
b. Determine the learning content to be developed, namely particle kinematics.
c. Develop a Physics learning plan applying the multiple representations approach.
d. Develop a research instrument, namely the critical thinking skill test.
e. Conduct validity testing on the research instrument.
f. Revise the research instrument.

2. Implementation stage

The activities performed in the implementation stage are as follows:

a. Introduce a Physics learning activity under the multiple representations approach and train the vocational high school Physics teacher who was to conduct the learning process.
b. Administer a pre-test in the experimental class and the control class to find out about the students' initial critical thinking skills for the particle kinematics concept.
c. Conduct Physics learning under the multiple representations approach in the experimental class and conventional approach in the control class.
d. Observe how the Physics learning under the multiple representations approach were unfolding.
e. Administer a post-test in the experimental class and the control class to find out about the students' critical thinking skills after they received the treatment.

3. Final stage

The activities performed in the final stage include the following:

a. Process the research result data.
b. Analyse and discuss the research findings.
c. Draw conclusions.

Data Analysis

The improvement in the critical thinking skills gained by the vocational high school students after the learning activity was conducted and measured by normalised gain.

$$< g >= \frac{\% < G >}{\% < G >_{\max}}$$

$$< g >= \frac{(\% < S_f > - \% < S_i >)}{(\% < S_m > - \% < S_i >)} \qquad \text{(Hake, 1998)}$$

where

<g> denotes the normalised gain,
S_f denotes the post-test average score,
S_i denotes the pre-test average score, and
S_m denotes the maximum score.

Normalised gain <g> is an appropriate method for analysing pre- and post-test results (Hake, 1999). It is also a better indicator of the effectiveness of a treatment based on the post-test scores obtained (Hake, 1999). There are three categories of normalised gain:

High gain : (<g>) > 0.7
Medium gain : 0.7 ≥ (<g>) ≥ 0.3
Low gain : (<g>) < 0.3 (Hake, 1998)

The results of the comparison between the experimental class and the control class were counted using t-test for normally distributed data and Mann-Whitney test for non-normally distributed data. Normality testing was conducted using Kolmogorov-Smirnov test, and statistical data processing was conducted using SPSS Version 16.0.

Results of Research

Several prior studies have analysed representation employment for promoting reasoning and representation-making skills. The primary activities in the learning conducted under the multiple representation approach are i) discussions between teacher and students on student-made representations and ii) the making of alternative representations for supporting previously made representations. Previous studies are largely focused on the influence of representation employment on students' concept understanding, reasoning skills, and representation skills. Yet, the study of representation use for improving critical thinking skills is still uncommon. This research studies the effect of a multiple representation approach application in Physics learning at a vocational high school on critical thinking skills.

The results of critical thinking skills testing for the experimental class and the control class are described in the table below.

Table 1: Results of Critical Thinking Skills Test of Vocational High School Students

Aspect	Score
Pre-test average score of experimental class	53.5
Pre-test average score of control class	52.9
Post-test average score of experimental class	81.5
Post-test average score of control class	65.0
n-gain of experimental class	0.60

n-gain of control class	0.26

Based on the data presented in Table 1, the pre-test scores on the experimental class and the control class were 53.5 and 52.9, respectively. From the testing at the 0.05 level, a significance level of 0.845 (> 0.05) was obtained, suggesting that the pre-test average scores of the experimental class and the control class were not significantly different. This means that the critical thinking skills of the vocational high school students prior to the learning activity were of the same category. The post-test scores of the experimental class and the control class were 81.5 and 65.0, respectively. The testing at the 0.05 level yielded a significance level of 0.00 (< 0.05), suggesting that the post-test average scores of the experimental class and the control class were significantly different. This means that the critical thinking skills of the experimental class, where the Physics learning was conducted using the multiple representations approach, were greater than those of the control class, where the conventional approach was applied.

This superiority of multiple representations approach application in the Physics learning in promoting critical thinking skills was supported by the normalised gain data. For the experimental class, where the Physics learning was conducted using the multiple representations approach, the normalised gain obtained was 0.60, which fell into the medium category. As for the control class, with conventional approach being applied in the Physics learning, a low normalised gain of 0.26 was obtained.

The vocational high school students' critical thinking skills in each aspect are described in the table below.

Table 2: Description of Vocational High School Students' Critical Thinking Skills in Each Aspect

No	Critical Thinking Skill Aspect	Pre-E	Pre-K	Post-E	Post-K	Ng-E	Ng-K
1	elementary clarification	11.8	12.9	17.4	17.1	0.70	0.60
2	basic support	8.8	10.9	17.1	12.1	0.70	0.10
3	inference	11.2	10.9	16.8	14.4	0.60	0.40
4	advanced clarification	9.4	7.6	14.1	9.4	0.40	0.10
5	strategies and tactics	11.5	10.3	15.9	12.6	0.50	0.20

Description:
Maximum score for each indicator = 20
Pre-E = pre-test score of the experimental class
Pre-K = pre-test score of the control class
Post-E = post-test score of the experimental class
Post-K = post-test score of the control class

Ng-E = normalised gain of the experimental class
Ng-K = normalised gain of the control class

Based on the data presented in Table 2, the pre-test scores in the elementary clarification aspect of the experimental class and the control class were 11.8 and 12.9, respectively. From the testing at the 0.05 level, a significance level of 0.458 (> 0.05) was obtained, suggesting that the pre-test average scores of the experimental class and the control class were not significantly different. This means that in the elementary clarification aspect prior to the learning activity, the two classes were of the same category. The post-test score of the experimental class was 17.4, while the control class was 17.1. From the testing at the 0.05 level, a significance level of 0.768 (> 0.05) was obtained, suggesting that the post-test average scores of the experimental class and the control class were not significantly different. This means that in the elementary clarification aspect, the experimental class, where the Physics learning was conducted by applying the multiple representations approach, was of the same category with the control class, in which the conventional approach was applied. Both classes were able to make an improvement in the elementary clarification aspect within the high category, that was, at 80% of the maximum score. With respect to score increase, the experimental class had a normalised gain of 0.70, while the control class 0.60. The improvement made by the vocational high school students in both classes in the elementary clarification aspect was of medium category.

Based on the data presented in Table 2, the pre-test scores in the basic support aspect of the experimental class and the control class were 8.8 and 10.9, respectively. From the testing at the 0.05 level, a significance level of 0.182 (> 0.05) was obtained, suggesting that the pre-test average scores of the experimental class and the control class were not significantly different. This means that in the basic support aspect prior to the learning activity, the two classes were of the same category. The post-test score of the experimental class was 17.1, while the control class 12.1. From the testing at the 0.05 level, a significance level of 0.004 (< 0.05) was obtained, suggesting that the post-test average scores of the experimental class and the control class were significantly different. This means that in the basic support aspect, the experimental class, where the Physics learning was conducted using the multiple representation approach, had a greater score than the control class, in which the conventional approach was applied. With respect to score increase, the experimental class had a normalised gain of 0.70, while the control class had 0.10. The vocational high school students in the class applying the multiple representations approach in the Physics learning made an improvement in the basic support in the medium category, while the control class made an improvement in the low category.

Based on the data presented in Table 2, the pre-test scores in the inference aspect of the experimental class and the control class were 11.2 and 10.9, respectively. From the testing at

the 0.05 level, a significance level of 0.845 (> 0.05) was obtained, suggesting that the pre-test average scores of the experimental class and the control class were not significantly different. This means that in the inference aspect prior to the learning activity, both classes were of the same category. The post-test score of the experimental class was 16.8, while the control class 14.4. From the testing at the 0.05 level, a significance level of 0.058 (> 0.05) was obtained, suggesting that the post-test average scores of the experimental class and the control class were not significantly different. This means that in the inference aspect, the experimental class, where the Physics learning was conducted using the multiple representation approach, was of the same category with the control class, in which the conventional approach was applied. With respect to the score increase, the experimental class had a normalised gain of 0.60, while the control class 0.40. Both classes made an improvement in the medium category.

Based on the data presented in Table 2, the pre-test scores in the advanced clarification of the experimental class and the control class were 9.4 and 7.6, respectively. From the testing at the 0.05 level, a significance level of 0.245 (> 0.05) was obtained, suggesting that the pre-test average scores of the experimental class and the control class were not significantly different. This means that in the advanced clarification aspect prior to the learning activity, both classes were of the same category. The post-test score of the experimental class was 14.1, while the control class was 9.4. From the testing at the 0.05 level, a significance level of 0.007 (< 0.05) was obtained, meaning that the post-test average scores of the experimental class and the control class were significantly different. This means that in the advanced clarification aspect, the experimental class, where the Physics learning was conducted using the multiple representations approach, had a greater score than the control class, in which the conventional approach was applied. With respect to score increase, the experimental class had a normalised gain of 0.40, while the control class 0.10. The vocational high school students in the class applying the multiple representations in the Physics learning made an improvement in the advanced clarification in the medium category, while the control class made an improvement in the low category.

Based on the data presented in Table 2, the pre-test scores in the strategies and tactics aspect of the experimental class and the control class were 11.5 and 10.3, respectively. From the testing at the 0.05 level, a significance level of 0.353 (> 0.05) was obtained, suggesting that the pre-test average scores of the experimental class and the control class were not significantly different. This means that in the strategies and tactics aspect prior to the learning activity, both classes were of the same category. The post-test score of the experimental class was 15.9, while the control class 12.6. From the testing at the 0.05 level, a significance level of 0.006 (< 0.05) was obtained, suggesting that the post-test average scores of the experimental class and the control class were significantly different. This means that in the strategies and tactics aspect, the experimental class, where the Physics learning was

conducted using the multiple representations approach, had a greater score than the control class, in which the conventional approach was applied. With respect to score increase, the experimental class had a normalised gain of 0.50, while the control class 0.20. The class applying the multiple representations approach in the Physics learning made an improvement in the strategies and tactics aspect in the meadium category, while the control class made an improvement in the low category.

Discussion

Physics is a branch of science that studies natural phenomena. Natural phenomena are formed by the interaction between physical magnitudes. In forming one natural phenomenon or more physical magnitudes connect and interact with each other. In order to make it easy for analysing and shedding light upon such natural phenomena, physicists typically use various forms of representations. In a natural phenomenon, the functional relationships arising between physical magnitudes are normally expressed in simple mathematical formulae and then visualised in the form of graphs. The interactions taking place between physical magnitudes are usually illustrated in the form of interaction diagrams.
Representations may function as a thinking tool for predicting, understanding, and making claims (Waldrip et al., 2010). Multiple representations refer to re-representation of the same concept in different formats (verbal, picture, graph, mathematical) (Waldrip et al., 2013). In thinking and acting scientifically, students must know how to integrate representations for a reasoning process, recording the results of a scientific inquiry, constructing knowledge, and clarifying claims and evidence.

Physics learning agrees with its essence as a science in the form of product, process, and attitude. How a scientific process unfolds is affected by scientific attitudes, supported by interactions with the environment and others. Shakirova (2007) states that critical thinking skills allow a student to effectively deal with social, scientific, and practical problems.

The results of the present research suggest that the critical thinking skills of vocational high school students in the experimental class, in which the multiple representations approach was applied in the Physics learning, achieved better than those of the control class, which applied the conventional approach. The advantage of applying the multiple representations approach in Physics learning in promoting critical thinking skills was supported by the normalised gains. The vocational high school students participating in the Physics learning used the multiple representations approach and had a normalised gain of 0.60, which fell into the medium category. Meanwhile, those who participated in the Physics learning that used the conventional approach had a normalised gain of 0.26, which fell into the low category.

These results show that multiple representations could train students into problem-solving associated with critical thinking skills. As Rosengrant et al. (2007) stated, "Students use representations to help them understand the problem situation and to evaluate the results. Representations other than verbal in problem statements can have different effects on student performance and on their choice to use other representations".

The better critical thinking skills of vocational high school students of a class in which the multiple representations approach was implemented serve as a basis that the implementation of this approach in Physics learning can improve higher-order thinking skills. Using multiple representations in instilling a concept is predicted to be able to help students gain an understanding of such concept. This is based on the fact that every student is better at one specific skill than others. While some students are better at their verbal skill than the spatial or quantitative one, some others are just the contrary.

All physical processes can be explained through a number of laws of nature. To gain an understanding of such processes, however, it takes abstract knowledge of the processes in question and reasoning (theoretical) ordered in their basic components in a structured way to allow for their formulation and processing. Quantitative formulation in mathematical models is of huge importance. Mathematical formulation enables students to have a deep range of analysis of the problems studied and gives them the ability to predict (forecast).

Wavering (Nasution, 2000) states that graphs are aids used in science to expose data and help with the analysis of relationships between variables. Soedarso (1999) adds that graphs allow for the delivery of complex ideas in a simpler manner as well as abstraction of information. In other words, graphs can be used to summarise the materials presented without omitting some of the learning content prepared.

Critical thinking skills are an indispensable requirement in today's learning. Concerns now are directed to critical thinking skills thanks to their influence in today's rapidly developing science and technology era (Luthvitasari et al., 2012). These skills become all the more critical as they influence one's success and professionalism to a great extent (Quitadamo et al., 2008). Research by Frijters, Dam, & Rijlaarsdam (2008) states that if one has lacking critical thinking skills, he or she will find difficulties in competing globally. But with good critical thinking skills, one will be able make a contribution as a scientific consumer (National Research Council, 2012). With that in mind, it is important to continuously develop critical thinking skills in Physics learning. Such development can be performed in many ways, one of which is by applying the multiple representations approach.

The advantages of using the multiple representations approach in Physics learning are pointed out by Angell et al. (2007) in their journal *Multiple Representations as a Framework for a*

Modelling Approach to Physics Education. They argued that the multiple representations method should be used as the main strategy in Physics learning. This is based on two arguments. First, Physics learning at school should reflect a learning model that is directed toward knowledge seeking and knowledge product introduction processes. Second, varied approaches must always be in place in Physics learning. Researchers have attempted to use the multiple representations method to elaborate on physical phenomena. In their research, they developed a test where students' mathematical empirical modelling skills were operationalised as an ability to interpret physical phenomena. It took three years to complete the research, involving 4 researchers, 13 teachers, and 250 students. It was carried out in advanced physics classes. Students used multiple representations to understand physical phenomena, formulate hypotheses and specify reasons for an experiment, make mathematical modelling, and validate it. In an additional study, questionnaires were administered to students to find out about the relationship between learning and awareness of multiple representations in Physics, their epistemological views, and learning strategies.

Aspects of Critical Thinking Skills

Ennis (1996) defined critical thinking as a reasonable and reflective thinking focused on what to believe and do. Reflective thinking refers to active, persistent, and careful consideration on all alternatives prior to decision making. In the education domain, critical thinking proves able to prepare students to think in various disciplines toward independent fulfilment of intellectual needs and to develop them into potential individuals (Fisher, 2009). The aspects of critical thinking skills investigated included elementary clarification, basic support, interference, advanced clarification, and strategy and tactics. Each aspect is elaborated further below.

First aspect: elementary clarification

The critical thinking skill aspect *elementary clarification* was measured using the following indicators: 1) focus on a question and 2) ask and answer clarifying and challenging questions. There were two question items used to measure this aspect: interpretation and explanation of the distance and displacement concept and the free fall concept. Most of the vocational high school students were able to give answers to the questions in the *elementary clarification* aspect.

The research results show that in the *elementary clarification* aspect, the critical thinking skills of the vocational high school students in the experimental class, where the multiple representations approach to Physics learning was applied, had equal score to that of students in the control class, where the conventional approach was applied. Both classes had been able to make an improvement in the *elementary clarification* aspect in the high category (80% of

the maximum score). With respect to the score increase, the experimental class had a normalised gain of 0.70, while the control class had 0.60. The vocational high school students of both classes experienced an improvement in the *elementary clarification* aspect in the medium category.

The vocational high school students who were taking part in the Physics learning using the multiple representations approach and those using the conventional one had the same critical thinking skills in the *elementary clarification* aspect. This is in line with Bloom's statement (Filsaime, 2008) that critical thinking starts from a simple aspect all the way to the complex one. One will acquire a thinking level before acquiring a higher one. It can be said that critical thinking is synonymous with the cognitive domain at the knowledge, understanding, application, and analysis levels. Leiceseter and Taylor (2010) state that students learn critical thinking gradually through trained habits like problem-solving and answering questions that need explanation.

Second aspect: basic support

The critical thinking skill aspect *basic support* was measured with the following indicators: 1) judge credibility (criteria for sources) and 2) observe and judge observation results. There were two question items for measuring this aspect: the ability to use the procedure for calculating average speed from the experiment data recorded along a ticker tape and the ability to provide reasons when interpreting experimental results.

The research results show that in the critical thinking skill aspect *basic support*, the vocational high school students in the experimental class, in which the multiple representation approach to Physics learning was applied, had a greater score than those in the control class, in which the conventional approach was applied. With respect to score increase, the experimental class had a normalised gain of 0.70, while the control class had 0.10. The vocational high school students in the experimental class that applied the multiple representation approach made an improvement in the *basic support* aspect in the medium category, while those in the control class made an improvement in the low category.

The vocational high school students who were taking part in the Physics learning using the multiple representations approach had a better improvement in the critical thinking skill aspect *basic support.* This is in line with the results of Wahyuni's research (2015), suggesting that the critical thinking skills in the *basic support* aspect had a fairly high average score. The advantage of the multiple representations approach application in Physics learning was also observed by Kohl et al. (2007), who state that the multiple representations approach can be considered to be a key to Physics learning. Physics learning using multiple representations can boost critical thinking skills as Physics is a science that presents natural phenomena in

the forms of pictures and mathematical equations and is concerned with relationships between physical variables.

Third aspect: inference

The critical thinking skill aspect *inference* was measured with the following indicators: 1) deduce and judge deduction and 2) make and judge decision value. There were two question items used to measure this aspect: the ability to draw inference based on graph data for universal linear motion and for non-universal linear motion.

The research results show that in the *inference* aspect, the critical thinking skills of the vocational high school students in the experimental class, where the multiple representations approach to Physics learning was applied, had an equal score as that of the students in the control class, where the conventional approach was applied. Both classes had been able to make an improvement in the *inference* aspect in the high category (80% of the maximum score). With respect to score increase, the experimental class had a normalised gain of 0.60, while the control class 0.40. The vocational high school students of both classes experienced an improvement in the *inference* aspect in the medium category.

To draw an inference means to identify the elements needed to draw an inference from data, reports, principles, assessments, beliefs, or opinions. Inference drawing practice is a requirement in practically all Physics learning models. The National Research Council (2003) reveals that previously teacher-centered learning activities now tend to turn into student-centered through the employment of scientific methods in solving problems, thereby improving participation and piquing curiosity in learning, improving understanding and mindset, and helping students enhance their critical thinking skills (Howard and Miskowski, 2005).

Fourth aspect: advanced clarification

The critical thinking skill aspect *advanced clarification* was measured with the following indicators: 1) define terms, 2) judge definitions, and 3) identify assumptions. Two question items were used to measure this aspect: reasoning in creating graphs for vertically moving objects and strategies needed for converting one graph to another.

The research results show that in the critical thinking skill aspect *advanced clarification*, the vocational high school students in the experimental class, in which the multiple representation approach to Physics learning was applied, had a greater score than those in the control class, in which the conventional approach was applied. With respect to score increase, the experimental class had a normalised gain of 0.40, while the control class had 0.10. The

vocational high school students in the experimental class that applied the multiple representation approach made an improvement in the *advanced clarification* aspect in the medium category, while those in the control class mad an improvement in the low category.

The research results show that in the critical thinking skill aspect *advanced clarification*, the vocational high school students in the experimental class, in which the multiple representations approach to Physics learning was applied, achieved 71% of the maximum score and fell into the medium category. To improve the critical thinking skills in the *advanced clarification* aspect, emphasis should be placed on the thinking skills that are related to reasoning. Reasoning is done through an analysis of facts and principles coupled with memory, presented based on combined observations and tested to see which conclusions might be depicted or drawn into generalisation.

Fifth aspect: strategies and tactics

The critical thinking skill aspect *strategies and tactics* was measured with the indicator decide on a measure through a criteria selection process to formulate a solution. Two question items were used to measure this aspect: determine the highest acceleration from a graph and determine the graph of an object free falling in a vacuum.

The research results show that in the critical thinking skills aspect *strategies and tactics*, the vocational high school students in the experimental class, in which the multiple representation approach to Physics learning was applied, had a greater score than those in the control class, in which the conventional approach was applied. With respect to score increase, the experimental class had a normalised gain of 0.50, while the control class 0.20. The vocational high school students in the experimental class that applied the multiple representation approach made an improvement in the *strategies and tactics* aspect in the medium category, while those in the control class made an improvement in the low category.

The vocational high school students who learnt Physics using the multiple representations approach had better critical thinking skills in the *strategies and tactics* aspect. Physics learning using multiple representations can boost critical thinking skills as Physics is a science that presents natural phenomena in the forms of pictures and mathematical equations and is concerned with relationships between physical variables. To gain access, it takes characteristics compatible with Physics. One way to gain access is using representations. The use of multiple representations makes it easy for students to identify, understand, analyse, evaluate, and construct arguments, solve problems, and face various challenges to finally make decisions. These activities are part of critical thinking skills.

Conclusions

It is expected that vocational high school students gain critical thinking skills from the learning activities they are engaged in. It is essential for them to have critical thinking skills to continue their education and enter the world of labor. Nobody is born with these skills inherent in them, but he or she can be trained in these skills through learning processes. Learning Physics using the multiple representations approach may help promote the critical thinking skills of vocational high school students. The results of the present research support this, showing that the critical thinking skills of vocational high school students who were engaged in Physics learning using the multiple representations approach achieved better than those using the conventional approach. This is a better achievement of vocational high school students who used the multiple representations approach in Physics learning serves as a basis that this approach is capable of improving higher-order thinking skills.

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