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THE USE OF MULTIMODAL REPRESENTATION IN THE PHYSICS LEARNING MATERIAL DEVELOPMENT TO PROMOTE STUDENTS' COGNITIVE AND CRITICAL THINKING COMPETENCES

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ABSTRACT

The research was aimed to develop physics learning material by infusing multimodal representation to promote students' cognitive and critical thinking competences. Additionally, the developed learning material would be compared with the physics textbook used by many schools. The study employed Research and Development as the research method. The samples were 54 students of grade XI from one of senior high schools in Bandung; 28 students in experiment group and 26 students in control group. The instruments were cognitive competence and critical thinking tests. The collected data were analyzed by measuring the normalized average gain percentage and Cohen's d. The results of cognitive and critical thinking competences showed that Cohen's d value were 1.66 and 1.63 which were classified as high categories. From the study it could be concluded that design of physics learning material by involving the multimodal representation was more effective to promote students' cognitive and critical thinking competences than the physics text book used in the school.

KEYWORDS: Learning Material, Multimodal Representation, Cognitive Competence, Critical Thinking Competence

INTRODUCTION

In order to compete in this 21st century, the competences needed by human resources are critical thinking, complex problem solving, creative thinking, collaborative communication, and innovation making by using technology (Kay& Greenhill 2011). Critical thinking is a competence in depth and logic thinking by evaluating facts with systematic stages (Lloyd and Bahr, 2010:26). Ennis (2011:70) in the book entitled 'Goals for a Critical Thinking Curriculum and Its Assessment, 3rd Edition' stated that a critical thinker should have competences which include (1) arranging problems, (2) analyzing arguments, (3) delivering and answering questions, (4) finding accurate and reliable information, (5) conducting observation and making report, (6) deducting, (7) inducting, (8) making and measuring decision, (9) defining and giving terms, and (10) identifying assumption.

The government of Indonesia has been preparing its human resources to be able to compete in the 21st century as stated in the Decree of Minister of National Education and Culture No. 144 Year 2014 about the Standard of Graduate Competency for Primary and Secondary School, and also the Decree of Minister of National Education and Culture No. 104 Year 2014 about the Assessment of Critical Thinking Competence that should be comprehended through: a)

developing, using and applying information about surrounding environment with logic, critics, and creative, b) showing the critical thinking ability with logic, critics, creative and innovative, c) showing high curiosity and realizing potential, d) showing problem solving competence, e) showing the ability to recognize the nature and social signs in surrounding environment, f) showing the ability to learn autonomously within their own potential.

The study conducted in one of private senior high schools in Bandung, Indonesia shown that the percentage of students' cognitive competence and critical thinking with logic strategy as its indicator was only 12% categorized as very low. The indicator of logic strategy using based on critical thinking framework of Ennis was included in sub-aspect: deciding an action. The result was similar to the research done by Golding (2011). The research depicted that critical thinking competence should be improved in terms of "decided" aspect which was a part of strategy and tactic.

The main reasons why many students have a low critical thinking competence are due to the learning materials used in the school. Based on the three text books used in the school, the result of analysis showed that the three books were not eligible in including the sub aspects of critical thinking such as asking and answering classification and challenging questions, observing and considering the result of observation; making and measuring induction, making and measuring the value of decision, identifying assumption, taking an action, and interacting with others. There should be a solution to solve the students' low critical thinking competence. There were many researches that had been done to improve students' critical thinking competence. Hartati (2010) stated that the use of effective learning aids in friction with the inquiry-based can promote critical thinking competence. Thomas (2011) conveyed that critical thinking was identified as the main competence of univesity graduates. Students should be given motivation to think, time to develop ideas and collaboration, and support from teach community which can provide them information, feedback, and motivation. Meanwhile, many research in learning model such as PBL or inquiry-based which were able to improve students' critical thinking competence had been done by Schultz (2011) and Nezami (2013). In addition, the study in the use of strategy, approach, and learning model by some researchers (Afiatun and Putra, 2015; Mandaekisdkk. 2014; Simon, 2015; Thomas, 2011). The development of learning instrument by Arifiyanti (2015). Besides, Asmawati (2015) had developed student workbook in improving students' critical thinking competences.

However, based on the results of the mentioned previous studies, there was no any research which tried to explore the students' critical thinking competence through developing the learning materials that could be used by students. Nwike (2013) described that students who were given learning materials would perform better than those who were not. Learning material is used by teachers or students to make learning easier and to promote knowledge and experience as well. Textbook shows the whole competency that should be mastered by the students along the learning process. A good learning material has a better effect in improving students' academic achievement than a good teacher (Chingos&Whitehurst, 2012).

The research questions of the study were: 1) how was the developed learning materials involving the multimodal representation compared with the textbook used by the school in promoting the students' cognitive and critical thinking competences?; 2) how was the effectiveness of the developed learning materials involving the multimodal representation compared with the textbook used by the school in promoting the students' cognitive competence?; 3) how was the effectiveness of the developed learning materials involving the multimodal representation compared with the textbook used by the school in promoting the students' critical thinking competence?

In general, the research was aimed to design physics learning material which specifically promoted students' cognitive and critical thinking competences in high school. The research contribution to the development of science was through developing the modelling process of making physics materials for students in high school.

METHODS

The research method used in developing the learning material was Research and Development (Borg and Gall, 1983). After arranging the sub chapters of the learning material, the next stage was to design the learning material. The development of the learning material was adopting the Design Representational Approach Learning to write technique proposed by Sinaga (2014). The developed learning material was validated by experts and some related stake holders, three physics lecturers and ten physics teachers. The learning material was also tried out by some of students of SMA Laboratorium UPI to check the readability of the material. Based on the feedback gained from the stake holders and the result of try-out by the students, the revision had been done towards the feasibility of the content and the appropriateness of diction and terms which were not familiar to students.

The instruments used in the research were a) understanding instrument, b) quality of learning material instrument, c) instrument to measure cognitive and critical thinking competence. The understanding instrument was used to check students' understanding towards the developed learning materials. There were 21 passages in the developed learning materials and had been tried out. The instrument used to measure each passage in every sub topics of developed learning materials. Additionally, the quality of learning material instrument was used to see the quality of physics learning materials using multimodal representation. The instrument used in the process of validation in the form of questionnaire rating scale with interval 1-4. The intervals were classified as very appropriate, appropriate, not quite appropriate, and inappropriate. There were 28 questions and a suggestion column to fill in so the writer could improve the developing learning material. Moreover, the instrument, tests, to measure cognitive and critical thinking competence was developed through the aspects (indicators) in cognitive and critical thinking competences. The tests were conducted two times; in the beginning (pre-test) and at the end (post-test) of the learning process. The pre-test and post-test were given to both experimental group and control group. The technique of the data analysis was measuring the average gain percentage which had been normalized and interpreted with Hake's criteria (1998), measuring Cohen's d and interpreted by Cohen's criteria (Coe, 2000).

The object of the research was physics learning materials in high school with static fluids topic. The subject of the research was XI grade students of high school who studied physics. The learning strategy used was reading to learn. In the first meeting, students were given cognitive and critical thinking pre-tests which were used to measure the basic competences of the students. In the second, third, and forth meeting, students were given the developed learning materials by using reading to learn strategy. Furthermore, the students were obliged to fill in the questions given in learning materials. In the fifth meeting, the students were given a post-test to check the development of their cognitive and critical thinking competences.

RESULTS

The first draft of static fluids learning materials had been validated by three expert lecturers and ten physics teachers in high school. The aim was to grade the quality of the materials and to develop the second draft of the learning materials. The validation was conducted in 28 descriptions which measured the learning materials using likert scale. The

average percentage of first draft components learning material was 83% and was categorized as appropriate.

Draft 1. The material was tested for the readibility, and then it was devided into texts. A text can be understood if it has medium or high in the readibility criteria. If a text has low tendency in these criteria, it then needs to be improved since it will be difficult to be comprehended.

Moreover, from the test, the students could find the main ideas for each given text based on the criteria of the assessment of the main ideas. Therefore, based on the main ideas test, it can be concluded that the materials had 90% for its readibility level.

Additionally, the finding on the effectiveness of the physics materials that had been developed in increasing students' cognitive competence is shown in the following table, Table 1. The finding was from the pretest, posttest and the N-gain calculation on the cognitive competence of the students to both experiment and control groups.

Table 1: The Development of Students' Cognitive Competences

Experiment Group			Control Group		
<Pretest>	<Posttest>	<N-gain>	<Pretest>	<Posttest>	<N-gain>
27.67	76.78	0.67	23.07	60.38	0.48

From the table above it can be concluded that the learning material adapting the multimodal representation could promote the students' cognitive competences compared with the general physics book, although both of them were in the same category, medium. In addition, to investigate the effect size on the use of the developed learning material in promoting students' cognitive competence, the Effect Size test had been done and the result was displayed in Table 2.

Table 2: The Effect Size on the Development of Students' Cognitive Competence

$M_{Exp.}$	$M_{contr.}$	$SD_{Exp.}$	$SD_{contr.}$	Cohen's d
76,7	60,3	8,7	16,4	1,63

Based on the Table 2, it can be stated that the learning material that developed by involving the multimodal representation gave more effect on the students' cognitive competence than the general physics learning materials. It can be seen from the Cohen's d = 1.63 which was meant that the effect size was categorized as high.

Moreover, the finding on the effectiveness of the physics materials that had been developed in promoting students' critical thinking is shown in Table 3. It was from the pretest, posttest and the N-gain calculation on the students' critical thinking to both experiment and control groups.

Table 3: The Student's Critical Thinking Tests

Experiment Group			Control Group		
<*Pretest*>	<*Posttest*>	<N-*gain*>	<*Pretest*>	<*Posttest*>	<N-*gain*>
37.77	77.4	0.44	49.14	66.0	0.28

From Table 3, it can be stated that the students' critical thinking was developed after the use of the developed learning material in their classroom, with the medium criteria. On the other side, the students' critical thinking of the control group was also develope in the low criteria, though. Furthermore, to investigate the effect size on the use of the developed learning material in promoting students' critical thinking, the Effect Size test had been done and the result was able to be seen in Table 4.

Table 4: The Effect Size on the Development of Students' Cognitive Competences

$M_{Exp.}$	Mcontr.	$SD_{Exp.}$	SDcontr.	Cohen's d
0.794	0.630	0.156	0.071	1.66

From the Table 4, it can be concluded that the learning material that developed by involving the multimodal representation gave more effect on the students' critical thinking competence than the general physics learning materials. It can be seen from the Cohen's d = 1.66 which was meant that the effect size was categorized as high.

DISCUSSIONS

From the quality assessment on the instructional material conducted by the teachers and the lecturers, 83% of them stated that the material was proper. On the other words, the developed learning material could be categorized as very good. Sinaga, et al (2014) claimed that the instructional material that is written should meet the requirements of good learning material; the provided concepts must be described well and in undersandable manner; the description must be in order, whether it is inductively or deductively; the content must be suitable for the students; the verbal and visual representation are intergrated in the content; the order of the multimodal representation is appopriate and is used to make the concept clearer; the materials can motivate the readers to read more about the given information; and the punctuation and the grammar are well-organized. Since the presentage of the quality was high, it can be stated that the learning material was categorized as good and could be more developed as the learning material for senior high school students.

Based on the main ideas test in draft 1, the readability of the learning material was 90% (two texts were categorized as very high in the readibility level and 19 others were classified as high). It means that the draft 1 of the learning material was able to be understood by the students, since 90% was categorized as high. In line with this, Flood (1984) said that the students' understanding was influenced by the readability of the written text. Thus, it can be concluded that the students could comprehend the developed materials, so they could use them in their autonomous learning.

From the tests of readibility and properly, it could be restated that the developed learning material had good quality. Moreover, it allowed students to learn autonomously. In line with it, Nieveen (2006) argued that an instruction material could be considered as having good quality if it met the following aspects: 1) relevance (refering to the content validation), 2) consistence (refering to the the construct validity), 3) practicality, and 4) effectiveness. Furthermore, the validation aspect is related to two things, the appropriateness to the curriculum and the theorical consideration of the proposed model and also there is a consistency among the components. A product can be considered as valid if it meets the content validation and the construct validation. The validation of the developed learning material was done by the validators.

In regards to the effects on the students' cognitive competence, the Cohen's d = 1.63 with large effect criteria. This finding meant that the developed learning material, developed by the multimodal representation, was more effective in promoting students' cognitive and critical thinking competences than the general textbook. One of the causes was the materials were displayed in multimodal representation; so that, their different learning styles were facilitated maximally. This was in line with Ainsworth (1999) who stated that the multimodal representation had the main functions: 1) to represent the complementing information or to complete the cognitive process; 2) one representation could restrict the

misinterpretation of other representations; 3) to motivate the students building their deep understanding about the given situations.

Naturally, students have different characteristics in understanding the information they got. Some of them easily understand the given information by verbal representation, yet some others are good with pictures and equation representations. Hence, in dealing with different learning styles, the media which provides the multimodal representation is needed to facilitate them. Multimodal representation is a way in which a concept is conveyed in various modes, such as by verbal, pictures, graphs, and math equations. Prain dan Waldrip (2006) claimed that the multimodal representation is representing the same concept with various formats, such as verbal item, pictures, graphs, and math equations.

When some students learn physics, they are demanded to comprehend different representations, for instance experiments, graphs, verbal concepts, formulas, pictures and or diagrams in one time. Moreover, representation is a configuration that can display, represent, or symbolise thing in one way. It also represent, describe, or simbolize an object or a process. Thus, multimodal representaion means representing the same concept with different formats, covering verbal item, pictures, graphs, and math equations. It has three main functions which are complementary, restricting the missinterpretation, and comprehension builder.

Furthermore, according to Lemke (in Hand, Gunel & Ulu, 2008), science cannot be done and communicated only by verbal. He also added that the scientists complement, connect, and intergrate the verbal text with the math equations, quantitative graphs, information box, abstract diagrams, maps, pictures, and some other visual stuff. Therefore, to make the learning material could be comprehended by the students; the multimodal representaion was involved in the developed learning material.

The findings of this study tended to have similar results with some previous studies. Vaughan Prain A. & Bruce Waldrip (2006) claimed that a concept was comprehended better by the students who had good comprehension in multimodal representation than those who did not have this kind of comprehension. It was similar with the previous research conducted by Kok-Sing Tang, Seng Chee Tan and Jennifer Yeo (2011). They believed that the intergration of multimodal themes could promote students' scientific understanding which was congruent with the physics curriculum. Additionally, the difficulty in the multimodal integration came from the slight different in categorization, quantitative, and spatial meaning from the concept of energy that was not usually explicitely explained to the students. Moreover, Sinaga's research in 2014 argued that the lectures program with high criteria could promote the students' conceptual understanding, their competence in making the translation among the representations, their competences in making multi representations in increasing their strategy and self-regulation.

In addition, based on the results of the effects on the students' critical thinking, the value of the Cohen's was 1.66 with large effect criteria. It means that the developed learning material involving multimodal representation could be more promoting the students' critical thinking competence than the general physics materials used by the schools. This was because the developed materials covering all aspects of critical thinking. The use of multimodal representation could also support the students to have some excercises for their critical thinking competences. The difference of the N-gain on the experimental group and the effectiveness of the use of the developed learning materials might be influenced by some following factors. Firstly, the developed materials were developed through the method of Design Representational Approach Learning to Write (DRAWL) that was proposing by Sinaga, Suhandi, and Liliasari (2014). This technique was

effective to promote the quality of the learning materials (Sinaga, Suhandi, and Liliasari, 2015). Moreover, the technique also appropriate for a research with multimodal representation as the tool to promote students' competences in learning Physics.

Learning materials that are developed by DRAWL technique have some strength compared with others. Those materials were tested for their contents, and scaffoled the students to construct their understanding about the materials through the given activities. In addition, the development of these learning materials also considered the use of multimodal representation which could promote the students' critical thinking competences. It is in line with Oliveras, Marquez, and Sanmarti (2011) and O'Halloran ET. al. (2015) who had conducted the research on the multimodal representation. They used the multimodal representation in a narration and it was able to help the students to promote their critical thinking competences.

The instructions in the experimental and control groups used the same teaching method but different learning materials. The developed learning material and the general one were sharing different characteristics. In the developed material, the students' activities were planned to facilitate them to build their comprehension on the fluid static topic. Moreover, the activities were arranged by emphasizing the critical thinking competency. According to Mayer (2008), a student will not be able to develop his/her critical thinking competence if s/he does not get enough exercises on it in their subjects. The provided activities were based on the validation conducted by the profesionals. Meanwhile, the general learning materials that were used by the schools only consisted of the summary of the materials followed by the exercises that only test the surface of their cognitive competences. From the use of multimodal representation, the developed learning material was more planned and complex. The multimodal representation tended to be dominant in text mode, math equations, pictures, tables, and diagrams. Meanwhile, the exist learning material tended to be dominant in the use of text.

CONCLUSIONS

The physics learning material that had been developed using the multimodal representation was more effective in promoting students' cognitive and critical thinking competences than the general physics learning material that were used by many schools. The result also showed that the developed material could be used by the students to learn autonomously.

Furthermore, it is reccomended for the physics teachers, especially in senior high school level, to write their own learning material involving the multimodal representation. Finally, the further study needs to explore the influence of the domains in developing learning material in promoting students' cognitive and critical thinking competences.

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