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Implementating Multiple Representation-Based Worksheet to Develop Critical Thinking Skills

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ABSTRACT

This study aimed to foster students' critical thinking skills through the use of multiple representation-based worksheet. Through a quasi-experimental research design (non-equivalent control group design), the sample of the study consisted of 74 students drawn from a junior high school in North Lampung. This sample was divided into two groups to assign the experimental and control groups. The experimental group was exposed to multiple representation-based worksheet, while the control group was instructed with conventional worksheet The results of independent samples t-test showed that the experimental group was effective in fostering critical thinking skills (N-Gain = 0,34 --medium category). Furthermore, the study found the following indicators: providing an elementary clarification (N-Gain = 0,51 --medium category), building basic support (N-Gain = 0,39 --medium category), inferring (N-Gain = 0,24 --low category), making advance clarification (N-Gain = 0,46 –medium category), and setting the strategies and tactics (N-Gain = 0,10 --low category).

Keywords: critical thinking skills, multiple representations, student worksheet.

INTRODUCTION

The results of the PISA (Program for International Student Assessment) in 2015 indicated that 40 out of 72 countries had an average science achievement score, which was lower than the international average one (493) (OECD, 2015). Similarly, the results of the TIMSS (Trends in International Mathematics and Science Study) in 2015 revealed that 16 out of 53 countries possessed an average science achievement score, which was lower than the international average one (500) (IEA, 2015). This means that some countries have still possessed some problems in science learning. The results of the last PISA and TIMSS pointed a dramatic rank for Indonesia (i.e., 62nd in the PISA and 50th in the TIMMS) (IEA, 2015; OECD, 2015).

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Because the TIMMS and PISA require high-order thinking skills, such as critical thinking skills, students are expected to make inference properly and provide causal explanations in various ways. Furthermore students consistently demonstrate advanced scientific thinking skills, which require to use abstract models and ideas. Students may also propose experimental designs within the range of personal, local and global contexts (OECD, 2016). Thus, the TIMMS and PISA include the indicators of critical thinking skills suggested by Ennis (1985) and contain an elementary clarification, basic support, inference, advance clarification, strategies and tactics.

Therefore, integrating Higher Order Thinking Skills (HOTS) into learning calls for re-designing science classes. For example; Casagrand and Semsar (2017) reported that students significantly performed better at lower-order cognitive skills (LOCS) than higher-order cognitive skills (HOCS). They showed that a reformed course helped students move from LOCS to HOCS. Hence, their reformist approach sheds more light on retroactively assessing how to impact student learning.

Saido et al. (2015) also suggested that the main component of the present reformation in science education needed to shiftfrom Lower Order Thinking Skills (LOTS) to Higher Order Thinking Skills (HOTS). However, the growth of low-level thinking is still very dominant at Indonesian schools, even though the 21st century educational skills need to realize a shift or change in mindset including such learning processes as virtual/abstract to the real-world context, a single tool to the multimedia tools, and factual to the critical thinking ability (Indonesia Ministry of Education & Culture, 2014: 5).

One way to solve this problem is to implement multiple representation-based-student worksheet. Worksheets are more effective in science teaching than traditional materials (Özmen & Yildirim, 2005). Futhermore, multiple representation enables science educators/teachers to display science concepts via verbal, pictorial, graphic, diagram, table, or mathematical equation simultaneously (Abdurrahman et al., 2011). Thus, students effectively learn in different informative ways. For this reason, students differently understand the same concept (NRC, 1996). Atila et al. (2010) addressed that students, who used a certain mode of representation with the text, had higher academic achievement than those with textual mode of representation. They suggested that presenting concepts and interrelationships between them needs to systematically exhibitthem in different forms/modes. For instance; student worksheets impact the delivery of content by actively engaging students in multiple representation and enhancing their learning capacities.

Oz and Memis (2018) showed that the use of the multi-modal representations in ‘writing to learn’ activities improved the students’ scientific critical thinking skills. Students are able to form representations to show their thoughts by writing and using different modes, i.e., diagrams, pictures and images (Hoban & Nielsen, 2012). Representations contain the interpretation and explanation of a scientific idea or concept by using such modes as analogies, verbal statements, written texts, diagrams, graphics and simulations (Tang, Delgado & Moje, 2014). Using multiple representations to display science concepts will make them more comprehensible. The outputs of science learning require a number of representations, verbal, images and varied representations, called multiple representations (Ismet, 2013). Through multiple representations, a common concept or process can be presented in various forms (i.e., verbal, graphical, and numerical and simultaneous forms) (Waldrip & Prain, 2013). Structuring the knowledge through multiple representations will foster student learning (Prain & Waldrip, 2010). Multiple representations facilitate to understand science and make students aware of their own understanding (Tolppanen et al., 2013). Multiple representations are an important part of scientific language (Tang, Delgado & Moje, 2013). Students are required to develop their description abilities in specializing or learning scientific subjects (Ainsworth, Prain & Tytler, 2011).

Haglund, Jeppsson and Andersson (2012) found that young children's drawings affected their reasoning abilities. Children make drawings to figure out related representations of ideas, reflections, and judgements. Drawings may be seen as a tool to promote reasoning and communication skills (Haglund, Jeppsson & Andersson, 2012). Reasoning explains the concepts with models and relationships, makes predictions or draws outcomes supported by the data (So, 2016). Embedding model representations within 'writing to learn' activities affords students to establish a connection between daily language and science language and link individual reasoning with construction of scientific knowledge (Günel & Yesildag-Hasançebi, 2016). Reasoning is one of the most significant components incritical thinking (Oz & Memis, 2018). In view of Kabatas Memis (2015), knowing and systematically using multiple representations allow students to learn science. Moreover, Demirbag and Günel (2014) depicted that students, who studied with multiple representations, had higher science successes, argumentation skills and writing skills in comparison to the control group. The effective use of multiple representations provides invaluable resources in thinking and learning processes as well as promoting cognitive diversty (Günel & Yesildag-Hasançebi, 2016).

Energy, which is widely seen as a cross-cutting core concept, has enormous political, scientific, societal and practical meanings. Because it plays a central role in everyday life situations, it provides a powerful tool to model, analyze or predict phenomena in all science disciplines (Podschuweit & Bernholt, 2017). Thus, energy is a cross-cutting core concept within each science discipline (Chen et al., 2014). A conserved quantity makes energy an important concept. Being a basic mathematical principle (as a numerical quantity) does not change what happens. Hence, different attempts (e.g., proposing to differentiate forms, transfer/transformation, degradation and conservation) need to describe the characteristics of the 'energy' concept in order to make it less abstrac (Podschuweit & Bernholt, 2017). Energy, as one of the major scientific concepts, has influenced research and policy documents, although they have possessed different extension and emphasis (National Research Council, 2011). Conceptual change studies have extensively concentrated on students' conceptions of energy. Lancor (2014) qualitatively analyzed student-generated analogies using the metaphor theory to gain how students conceptualized energy in different contexts. Lee and Liu (2010) re-analyzed the TIMSS items and used the results to postulate five conceptual understanding levels of energy: activity and work, forms and sources, transition and transformation, dissipation and conservation. Neumann et al. (2013) who, tried to assess grades 6, 8 and 10 students' understanding of energy in a cross-sectional study in, reported that only some of them achieved a deeper understanding of energy conservation. The concept of energy, which reflects the different characteristics of specifically energy-related phenomena, provides a specific conceptual framework to interpret, understand and predict these phenomena from a scientific perspective. In addition, numerous studies revealed that students used different scaffolds to make sense of these phenomena (Podschuweit & Bernholt, 2017).

Energy is possibly the most important and dominant issue in today's world. Problems regarding resources and energy depletion have environmental consequences and affect the global, local, political and economic issues as well as our consuming choices, the health and welfare of humanity and the natural world (De Waters et al., 201. The use of energy, as a global environmental issue, results in global warming through CO_2 emission, and such other environmental problems as air pollution, ozone depletion, excessive utilization of forests and forest destruction, and emission of radioactive substances. These issues call for a sustainable energy future with minimal environmental impacts. Earlier researches have shown that if humans continue degrading the environment, the future will negatively be affected. Increases inglobalized population and economic development will globally trigger the demand(s) for energy services and natural resources. In this direction, one solution to impede energy shortage is to use renewable energy sources (Omer, 2007).

The renewable energy sources are extremely attractive for European and international educational systems (Anwar, Favier & Rasolomampionona, 2012). Education for energy issues should help students cope with the energy needs fort he present and future, which have social, economic and environmental dimensions. Adapting renewable energy advancements into secondary education systemshas been of interest in the USA (Champion et al., 2014), Northern Europe (Kandpal & Broman, 2014), Central Europe (Stebila et al., 2014), South-Eastern Europe (Balouktsis & Kekkeris, 2013) and Asia (Ibrahim & Hilme, 2007) since the last 15 years.

Environmental education for energy is a dominant parameter to establish a sustainable society. This education should be based on technological innovations and social improvements (Ntona et al., 2015). The advent of modern civilization and continuously growing human population constantly increase the energy demand(s) for livelihood and recreational purpose (Singh et al., 2013). The educational process has attempted to realize how to accomplish a more sensible use of energy. Students' knowledge and comprehension of the 'energy' concept allow them to convey their knowledge to their family in order to achieve energy conservation and saving in their daily lives. An educational approach on energy issues will enable students to obtain a profound view of the problem. Consequently, students will act as the agents to encourage all members in society to participate in societal decision-making procedures (Dias, Mattos & Balestieri, 2004).

In addition, energy education should have impacts on attitudes, values, decisions and actions. The cognitive level and educational information we receive affect our actions and abilities to process this kind of information. In particular, education for renewable energy resources should globally educate people. That is, education should intend to: (a) make students awareness of energy crises and their reasons, (b) inform them about different types of renewable energy resources, their potential sources and relevant technologies, (c) undertake an action to suggest solutions and alternative strategies for resolving future energy crises, and (d) develop positive attitudes and values toward energy resources (Karatepe et al., 2012). The level of education, energy practices, behavior, and individual responsibility are related to decisions and choices of renewable or non-renewable energy recourses and directly impact the environmen (Olugbenga, 2010).

Students should be equipped with critical thinking skills, which are indispensable to compete in 21st century life. Because nowadays people easily access to any information through the internet, critical thinking skills make people good decision makers. For this reason, these skills are very important to succeed in the 21st century (Susilowati, Sajidan, & Ramli, 2017). The ability to evaluate and decide any information requires critical thinking skills (Potter, 2010).

Kurnaz and Arslan (2014) implied that the use of the multiple representations effectively improved students' understanding of the concept of energy. Further, Astuti (2013) suggested that the use of materials with multiple representations effectively developed students' understanding of concepts and problem solving skills in learning physics. Abdurrahman (2010), who portrayed quantum physics learning through multiple representations, stated that physics student teachers significantly acquired the mastery of concepts, generic science skills, and disposition of critical thinking.

This study aimed to implement multiple representations-embedded within student worksheet to foster their critical thinking skills of the theme 'role of energy in life.' Researcher chose the theme because students have difficulties in comprehending the 'energy' concept (Hirça et al., 2008). Even though the 'energy' concept is taught at primary and secondary schools, students often have deficiencies at building a scientific understanding of the concept (Won et al., 2017). Since the term ‘energy’ is frequently used in everyday language, such as “saving energy” or “losing energy” or “feeling energetic,” students hold various intuitive conceptions that may or may not be aligned with the scientific understanding of the concept. Duit (2014) reported that students tended to use everyday language to explain their understanding of energy instead of scientific terms or definitions. Further, he reported that although they usually did not grasp scientifically the concept, only a small number of high school students understood the concepts of energy conservation and energy degradation. There are various approaches to teach the ‘energy’ concept, such as the ability to do work or causal changes, or a substance-like quantity. Duit (2014) concluded that educators and education researchers needed to systematically unfold and differentiate students’ ideas to build a better understanding of the concept.

Unfortunately, Çakirlar and Turan (2014) found that renewable energy sources were not integrated into the curricula and syllabi of various educational institutions from primary school to higher education. On the other hand, students, who want to study in a renewable energy department, do not need literature-mathematics scores, but they need mathematics-science scores in the university entrance exam. Since mathematics-science courses in secondary schools will increase these students’ awareness of the renewable energy sources, renewable energy courses play a significant role in students’ job choices (Çakirlar & Turan, 2017).

In particular, education for renewable energy at earlier ages will contribute to raise experts, who know the advantages and disadvantages of the use of natural resources. Hence, these experts will make a contribution to the economy of the country (Emodi & Ebele, 2016). European countries, where renewable energy sources are commonly used, pay more attention to education for renewable energy sources. For example; even though the curricula in Germany change from one state to another, all curricula cover the ‘renewable energy sources’ topic starting from primary school (Çakirlar & Turan, 2014). Starting education for the renewable energy in early grades will not only contribute to raise the number of students, who want to be experts in the future, but also enhances conscious consumers, who have a positive attitude towards the subject and contribute to the developments in the field. For example, Curry et al. (2005), who studied with 1,000 English participants, identified that the participants with a high level of knowledge about renewable energy had a positive attitude towards the environment.

Çakirlar and Turan (2014), who investigated relevant curricula in various class levels and lessons in terms of renewable energy sources, found them inadequate. In addition, because Turkey, which has a rich potential in terms of renewable energy sources, development and enrichment of undergraduate and postgraduate programs, further research and development should be undertaken (Çakirlar & Turan, 2017: 17).

Energy and its usage constitute one of the most important environmental issues nowadays that substantially affect economic, and social development as well as qualified life in all countries. The risks of climate change and environmental degradation are real with the globalized developmental process and human intervention(s) in dictating the nature of environmental problems. Education for energy issues should help students cope with the present and future energy needs by adopting appropriate attitudes, lifestyle practices and behaviors into science classe (Ntona et al., 2015).

Because environmental problems are associated with energy-related factors, energy and environment are interrelated concepts. Education plays an important role in understanding the relationship between these concepts (Ntona et al., 2015).

METHODS

a) Research Design

This research used a quasi-experimental research method with nonequivalent control groupdesign, which involves the use of an intervention without randomly assigning participants to experimental and control groups (Cresswell, 2008).

b) Sample

The population of this research were 7^{th} grade students in Junior High School 7 Kotabumi, North of Lampung, Indonesia at the spring semester of the 2016-2017 academic year. The sample of the current study was selected from 7^{th} grade students using cluster random sampling technique.

c) Instrument

A 20-item critical thinking skills instrument was developed to measure students' critical thinking skills (i.e., providing an elementary clarification, building basic support, inferring, making advance clarification, and setting the strategies and tactics). The researchers developed the critical thinking skills instrument given the aforementioned indicators, and related studies. An expert checked the content validity of the instrument and ensured that only 17 of them was valid and feasible items. The instrument was administered as a pretest before the teaching intervention. The same instrument was re-administered as a post test after the teaching intervention. To determine its validity and reliability, the instrument was pilot-tested with 30 grade 8 students in Junior High School 7 Kotabumi, who had studied the topic 'role of energy in life.'

A Pearson correlation test was tested to find how each item is related to with a total of the instrument score. Using SPSS 17.0^{TM}, valid correlation coefficient was looked for each item> 0.30 (Sugiyono, 2010). The results indicated that 15 items in the instrument had a higher correlation coefficient validity (Corrected Item-Total Correlation) than 0.30. Also, 2 of them showed a lower correlation coefficient than 0.30. Thus, this means that 15 validated items could be used to measure students' critical thinking skills. Then, the researchers tested the reliability of validated items.

Using SPSS 17.0^{TM} in view of Arikunto's criteria (2009), the results revealed that Cronbach Alpha value was found to be 0.745, meaning a high reliability of the instrument. Overall, this instrument was reliable and valid to test students' critical thinking skills.

d) Developing and Piloting Student Worksheet

The researchers developed the student worksheet through storyboard. In designing the draft student worksheet, the researchers involved such components as: core competence, basic competence, competency achievement indicator, workmanship manual, supporting information, and activity step. The student worksheet was related to the subjects "energy concepts and forms of energy," "the transformation of energy and energy resources," "energy from food and the transformation of energy in the process of digesting food," "transformation of energy during respiration," and "transformation of energy during photosynthesis." An expert validated the design of the student worksheet (see Tables 1-2). Afterwards, the student worksheet was pilot-studied.

The expert ensured that the student worksheet was valid, but needed some improvements (i.e., adding the type of representation) to conform its design to multiple representation. After the foregoing validation process, the student worksheet was pilot-tested with a small sample through a pre-experimental research design with one-shot case study. That is, the effect of an independent variable on a dependent variable was investigated with only an experimental group (Sugiyono, 2010). The used research design is as follows:

X 0

Figure 1. The Experiment Design with One-Shot Case Study

Information: :

X = Treatment (independent variable)

O = Observation (dependent variable)

Table 1. The Results of Content Validity

Rated aspect	The number of experts	% Achievements	Information
Conformity of material content with core competency-basic competence (max score = 4)	4	100	Very valid
Conformity of material content with multiple representation approach (max score = 5)	4	80	Valid
Conformity of content with critical thinking skills (max score = 3)	3	100	Very valid
Total	11	91,67	Very valid

Table 2. The Result of Construct Validity

Rated aspect	The number of experts	% Achievements	Information
Construction according to ideal worksheet format (max score = 11)	10	90,90	Very valid
Construction of worksheet contents (max score = 5)	5	100	Very valid
Construction according to multiple representation approach (max score = 4)	4	100	Very valid
Total	19	95	Very valid

The pilot study was selected from a Junior High School in Lampung Province, Indonesia via cluster random sampling technique. That is, one (30 students) of six classes was randomly involved in the current study. The results of the pilot study suggested some revisions for the draft student worksheet. The pilot study pointed that learning syntax, social systems, principle of reaction and student response had a high degree at the implementation of the current study. The observation indicated that the implementation of learning syntax was time-consuming because the students did not focus on a predetermined learning plan. Furthermore, the sample of the current study was randomly selected without grouping them with their own learning desires.

e) Procedure

Through cluster random sampling, this study selected the sample from two classes in Junior High School, North of Lampung, Indonesia at the spring semester of the 2016/2017 academic year. The population of this research were 7th grade students. The sample of the study was selected two of six classes (each class included 37 students). One of the classes was assigned to an experimental class (7th grade A), while the other was devoted to the control class (7th grade B). The experiment group was instructed with multiple representations-based-student worksheet, whilst the control group was taught with a conventional worksheet. Treatments lasting three weeks were carried out by two similar experienced teachers. Within a quasi experimental research method with non-equivalent control group design, two groups took pretest before the treatment, and then were exposed to the treatment. After the treatment, the posttest was re-administered to comparethe experimental and control groups' results with each other (Sugiyono, 2010). The experimental research design used is as follows:

O1	X	O2
O3		O4

Figure 2. The Experiment Research Design

Information :
O1 = Pretest for experimental class
O2 = Pretest for control class
X = Treatment (independent variables)
O3 = Postest for experimental class
O4 = Postest for control class

f) Data analysis

Test of gain normalized (N-gain) (see the following formula) was used to determine any improvement in the students' critical thinking skills before and after the treatment (Hake, 2002).

$$\langle g \rangle = \frac{(\%\langle posttest \rangle - \%\langle pretest \rangle)}{(100 - \%\langle pretest \rangle)}$$

Information:
<g> = *average normalized gain*
% <posttest> = *posttest class percentage averages*
%<pretest> = *pretest class percentage averages*

Table 3. Criteria for N-gain values

N-gain	Criteria
$g \leq 0{,}3$	Low
$0{,}7 \geq g > 0{,}3$	Medium
$g > 0{,}7$	High

Hypothesis was tested throughout mean difference between the experimental and control groups after normality and equality tests of two variance (homogeneity) were conducted with SPSS 17.0TM. The normality test serves to determine normality of the data and decide further tests/statistics (i.e., parametric or non-parametric statistics). The data normality test was performed on pretest, posttest, and N-gain data of the experimental and control classes using Kolmogorov-Smirnov (K-S) test (see Table 4).

Table 4. The Results of Normality Test

Groups	*Asymp. Sig. (2-tailed)* N=37		
	Pretes	Postes	N-gain
Experimental group	0,263	0,091	0,645
Control group	0,357	0,189	0,344

The results of Kolmogorov-Smirnov (K-S) test indicated a normal distribution for the current study at .05 (2-tailed significance). Then, homogeneity tests were performed to obtain the assumption that the study sample originated from the same or homogeneous conditions. Homogeneity tests were implemented with Levene's test at .05 (2-tailed significance) (see Table 5).

Table 5. The Results of Homogeneity Test

Data	Levene's Statistics	df1	df2	Sig.
Pretest	0,135	1	72	0,715
Posttesd	0,896	1	72	0,347
N-Gain	2,952	1	72	0,090

This result indicated that there was no difference in variance between the experimental and control classes. Thus, the results of the normality and homogeneity tests pointed that an independent samples t-test was appropriate for the current study. Using SPSS 17.0TM, the independent samples t-test determined how the treatment was effective at evolving students' critical thinking skills and whether there was any significant difference between the experimental and control classes' N-Gain values.

FINDINGS

The result showed that there was no significant difference between the experimental and control groups' critical thinking skills ($p = 0{,}090$). After the treatment, the results of N-Gain values showed significantly difference between the groups ($p = 0{,}015$). Thus, the experimental group's growth of critical thinking skills was higher than that of the control group. As seen from Table 6, the N-gain value of the experimental class had an average of 0,34, indicating significant differences between students' critical thinking skills from the pretest to the posttest with medium criteria.

Table 6. Independent Samples T-test Results for N-gain values

	Pretest $\bar{x} \pm$ SD	Posttest $\bar{x} \pm$ SD	N-gain $\bar{x} \pm$ SD	Criteria	Sig. (2-tailed)
Experiment	18,74 ± 11,63	51,17 ± 19,07	0,34 ± 0,18	Medium	0,015
Control	20,90 ± 11,67	33,96 ± 10,42	0,15 ± 0,13	Low	

Also, the N-gain value of the control class had an average of 0,15, showing an increase in the critical thinking skills. However, the control class' critical thinking skills were lower than those of the the experimental class. The results revealed a significant difference between the experimental (multiple representation-based-student worksheet) and control (conventional student worksheet) groups' N-gain values of the critical thinking skills (see Figure 3).

As observed in Figure 3, the elementary clarification, as an indicator of the critical thinking skills, was the highest N-gain value for both the experimental and control classes. While the 'strategies and tactics' indicator of the critical thinking skills was the lowest N-gain value for the experimental class, the control class did the lowest one in the 'inferring' indicator.

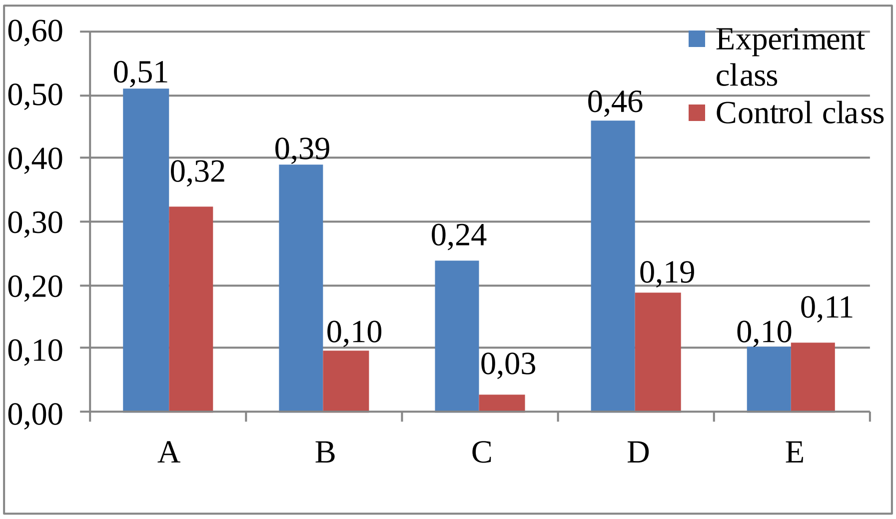
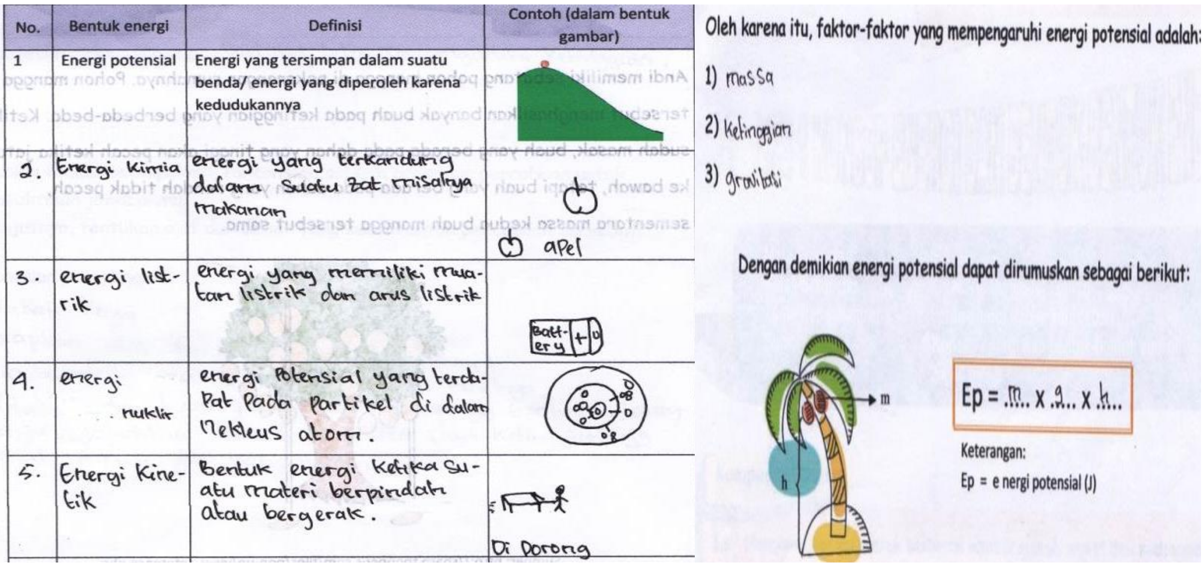


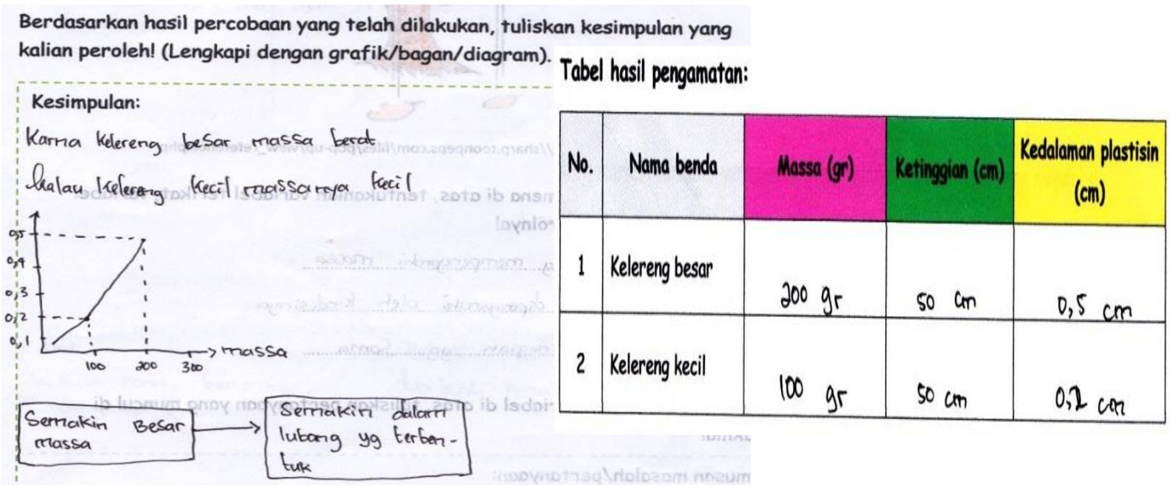
Figure 3. N-gain values of the Experimental and Control Groups' Critical Thinking Skills for Each Indicator

Information:
A = elementary clarification
B = basic support
C = inferring
D = advance clarification
E = strategies and tactics

In the testing phase, the students were very enthusiastic to use the student worksheet. Thereby, their interactions with the student worksheet were good. They were able to change the form ‘verbal representation’ (words to definite) with another representational form ‘visual representation’ (images on worksheet I in Figure 4a). In addition, they were also able to shift the representation numbers or data of the experimental results to graphical representations, words into formulas or formulas (see sample student answers to the student worksheet I in Figure 4b).



(a)

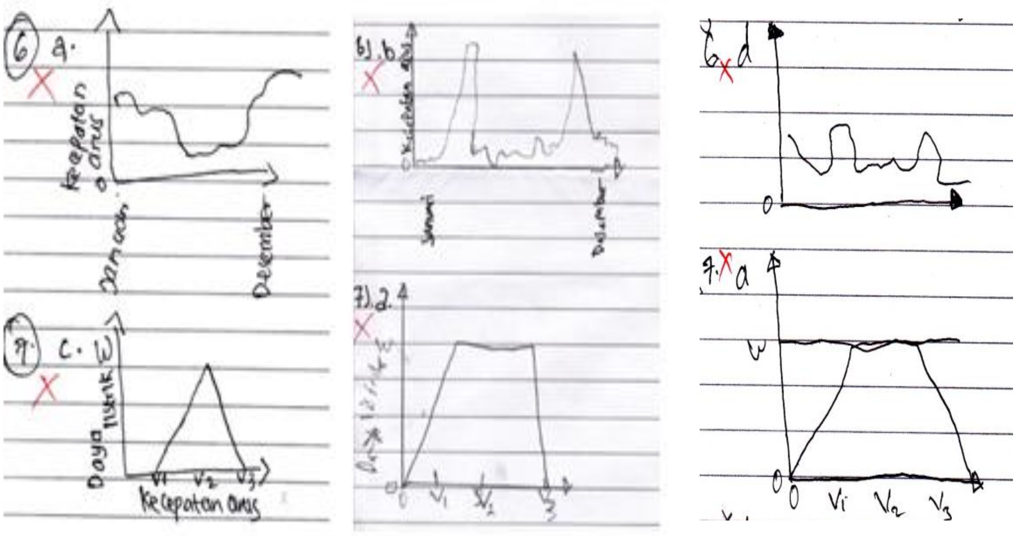


(b)

Figure 4. Sample student answers to the student woorksheet I

The results of the observationsshowed that the students started to adapt to the use of multiple representation-based-student worksheet at the beginning of the first learning meeting. While the implementation of the second learning meeting run more conducive, the implementation level of overall learning at multiple representation-based-student worksheet was 93,33%, which fell into a very high category (Table 7). Moreover, as seen in Table 8, more than 90% of students positively responded to the multiple representation-based-student worksheet.

After the treatment in the experimental class, six students with different N-gain values (high, medium, and low) were selected for interviews. The results of the students with high N-gain value indicated that the use of the multiple representation-based-student worksheet was very helpful for them in science learning, especially on the role of energy in life. The student worksheet with various representations facilitated their understanding and visualization of the learning materials. In addition, the use of the student worksheet made student learning more interesting and funny.



High N-gain Medium N-gain Low N-gain

Figure 5. Some examples for the Student Answers with Graphical Representation

The results of the student with medium N-gain value showed that the use of the multiple representation-based-student worksheet helped their understanding of the learning materials involving many practical questions and experiments. In addition, they expressed that they preferred learning with various representations to only textual learning. Hence, learning with various representations would not be boring and simplify their learning. The results of the students with low N-gain value pointed that the use of the multiple representation-based student worksheet helped to student learning. Otherwise, the others stated that they found the use of graphs, diagrams, and images in the student worksheet difficult to understand. Furthermore, the results of the students' responses to the critical thinking skills test and interviews showed that many students had difficulties in answering the graphical representation questions. Some of them are presented in Figure 5.

DISCUSSION and CONCLUSION

As seen in Table 6, the experimental group (multiple representation-based-student worksheet) performed better at critical thinking skills than the control group (conventional worksheet) (p = 0,015). This may result from the structures of multiple representation-based-student worksheet at the experimental group and the conventional textual worksheet at the control group. This result is in a parallel with Ainsworth and Labeke’s (2008) view depicting that learning through multiple representations potentially empower students’ understanding over the years. Combining several different forms of representation within different properties increases students’ learning capacities without limiting a particular representation (Ainsworth, 2008). Therefore, science teachers have used different representational techniques (e.g., voice, text, and gesture) in their classrooms (Tsui & Treagust, 2003). Thus, it can be concluded that the use of multiple representation-based-student worksheet effectively improved the students' critical thinking skills and had a potential to meet the HOTS questions in the TIMSS and PISA. This resultis in a harmony with Treagust's (2010) statement showing that students need to develop a strong understanding of different representational forms about how to use and represent the concept of science. This has implications for students to understand or explain science concepts via their cognitive and representational resources (Prain & Tytler, 2013).

As seen inFigure 3, the experimental group showed the highest achievement for the indicator "elementary clarification" of the critical thinking skills. This may come from the use of certain symbols or representations into the student worksheet, which helped the students give a simple explanation of the energy concept clearly. This is consistent with the results of Prain and Tytler (2012) addressing that the use of materials and specific symbolic tools provide special abilities for students (i.e., building representations, and making claims about science topics or processes). Similarly, *macroscopic–submicroscopic–symbolic forms of* multiple representation method enhance students' mental models and effectively facilitated their learning of chemical reactions (Sunyono, 2015).

The indicator "advanced clarification" was also a very influential factor in increasing N-gain after providing the indicator "a simple explanation." This may result from integrating multiple representations (images, words, and charts) into the student worksheet. This supports Ismet's (2013) statement claiming that using various representations (multiple representations) to describe a science concept makes science learning clearer.

The use of the student worksheet with various representations (especially, drawings, graphs, and diagrams) not only built the students' basic skills in understanding, creating, and using such representations and increased N-gain values in the indicators. Morrison and Watson (2010) explain that such representations as graphs, diagrams, and animations, have the ability to reinforce students' understanding of sciences. Further, they not only represent an abstract science concept but also play a significant role in their memories.

The results of the study showed a lower N-gain value for the indicator "make inference (inferring)" than previous indicators. This may stem from students' difficulties in determining representation-based-generalizations, especially graphical representations and diagrams. Therefore, the students may have developed a strong understanding of how to use and represent the science conceptsinstead of relying on particular representations on a topic (Tytler et al., 2007).

The indicator "set the strategies and tactics" had the lowest N-gain value. However, Dahar (1986), who included seventh grade junior high school students , depicted that the students in the formal operational stage were able to formulate many alternative hypotheses in responding the problem, but they did not have the ability to accept or reject the hypothesis. Thus, the students at this stage may still have difficulty in selecting the criteria to make a decision for the solution. Therefore, an increase in the indicator "set strategy and tactics" of the critical thinking skills showed good results. This advocates Ristiasari's (2012) result reporting that the ability to provide an elementary clarification had the highest percentage for the experimental class (exposed to mind mapping) before and after the treatment. However, their abilities of the "set strategies and tactics" indicator were the lowest percentages for the experimental and control groups.

As can be seen from Figure 4, the picture (a) showed that the students started to learn the use of multiple representation, although some of them sawthe package book as a changing representation form from words to image. The picture (b) indicated that the students began to confuse how to change the form of data representation into a graph. After the treatment, the students tried to make a graph corresponding to the obtained data, but some of students were unable to create a graph matching the expected one. The Figure (c) showed that the students were able to change the form of representational words into formulas given the teacher's directions.

The results of the interviews also revealed that the use of the multiple representations greatly helped the students to visualize abstract material(s). This supports Eilam and Poyas' (2010) result stating that science educators recognize the visualization and learning with representation as a meaning to improve the understanding of science. Thus, the findings show that teachers' approaches to choose, use and perform multiple representation(s) act as a key to develop students' representational competencies and conceptual understanding of complex scientific concepts (Hilton & Nichols, 2011).

The results of the interviews pointed that all students (with high, medium, and low N-gain values) preferred the representations of images and words, and viewed a mixture of words and images as a simultaneously reading without boring. They also expressed that using pictorial representations accompanied by an explanation was more funny, because such a procedure made problem-solving easier. Mayer (2003) addresses that by merging the pictures with words, teachers can foster students' deeper learning. Indeed, this is normal since scientific ideas cannot be separated from their representations (Tytler et al., 2006).

The results of the current study showed that many students had difficulties answering the questions with the graphical representation. This supports the results of Meltzer (2005) providing four questions in four representational forms (i.e., verbal, diagrams, mathematical/symbolic, and graphics). The results showed that the students had slightly higher error rates in the graphical questions than the other representations. As observed in Figure 5, three students with different N-gain values were unable to determine the appropriate graph. Further, their answers were quite different from the charts requested on the matter. This means that the students had difficulties in using the graphical representation(s).

The results of the interviews also indicated that the students were unfamiliar with the graphical representation as compared with the other representations. This is in accordance with Ainsworth and Labeke's (2004) statement depicting that the familiar concrete representations (i.e., simple animations,I and simulations) support the interpretation of complex and unfamiliar graphical representations. Most of the students stated that they did not understand about the graphical representation, but they liked the experimental and practical activities. This is in a parallel with Ainsworth et al.'s (2002) explanation about the role of the simulation environment on the concrete representation. Hence, the simulation environment helps students interpret unfamiliar or abstract representations (Ainsworth et al., 2002).

This study showed that student active engagement with multiple representation-based-student worksheet positively improved their learning performances of the 'energy' concept. Exploring various representational modes in the student worksheet not only enabled the students to experience a meaningful learning and understanding of the 'energy' concept and energy-related concepts, but also resulted in significant conceptual changes. In light of the results, it can be concluded that the multiple representation-based-student worksheet effectively improved their critical thinking skills of the theme "the role of energy in life". Furthermore, it can be deduced that the students were good at the indicator "an elementary clarification" and bad at the indicator "managing strategies and tactics". Moreover, the students tended to consider a combination of images and words as an easy representational form, although they were less familiar with the graphical representation.

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