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ENHANCING MASTERY OF EARTH SCIENCE CONCEPT OF PROSPECTIVE PHYSICS TEACHERS THROUGH INTERACTIVE CONCEPTUAL INSTRUCTION SUPPORTED BY VISUALIZATION AND GRADS

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ABSTRACT

Most all of earth and space science concepts are unobservable and require reasoning. Unobservable concepts have made prospective physics teachers found it hard to understand the concepts correctly. It needs visualization to help understand the concepts easily. The aim of this study was to enhance the mastery concept of earth science topic especially the earth atmosphere using interactive conceptual with visualizations and authentic data analysis with GrADS (Grid Analysis Display System). There were 23 prospective physics teachers in Bengkulu, Indonesia participated in this study. A convenience sampling technique was employed in this study. This study used pre-experimental, one group pretest-posttest design. The data were collected using pretest and posttest, questionnaires, and observation sheets. The pretest and posttest were analyzed quantitatively, while the questionnaires were analyzed qualitatively. The results showed that the prospective physics teachers' concept mastery improved from no mastery to compete with the average normalized gain of 0.64 (medium category). 30.44% of the prospective physics teachers obtained the N-gain score in the high category and 69.56% obtained the N-gain score in the moderate category. This compilation gave them experience about the real condition of solar radiation in Indonesian atmosphere during their learning activity. It concluded that the earth science learning using interactive conceptual instruction supported by visualization and GrADS could enhance the students' concept mastery.

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Keywords: earth science, mastery concept, visualization

INTRODUCTION

Utmost of earth atmosphere phenomena are indirectly observable which require favorable reasoning to understand. Therefore, media assistance are needed to explain the earth atmosphere concepts due to visualize the imaginary, abstract

*Correspondence Address E-mail: hennyjohan88@gmail.com concepts (Bilici et al., 2011; Park, 2013; Sunderlin, 2009). It was also reinforced by the previous investigation that about 78% of the future science teachers considered that geoscience materials were fairly convoluted and abstract which therefore made them difficult to understand (Rosnita, 2016; Miller & Brewer, 2010). Hence, a neatlyconstructed learning on earth atmosphere should be designed in order to assist future science teachers to improve their concept mastery (Jolley et al., 2012). A research carried out in Bengkulu using the Search, Solve, Create, and Share (SSCS) learning model indicated a slight enhancement of mastery concept having the N-Gain score of 0.49 and belonged to the 'moderate' category (Johan et al., 2018a). The Interactive Conceptual Interaction (ICI) applied in this research focused on evocative learning aiming at improving the future science teachers' mastery of earth and space concepts. Moreover, this study provided the established ICI model supported by authentic data of atmospheric phenomena as the main materials.

One of the ways to advance the concept mastery is by using a scientific model to aid learners in comprehending the concepts (King, 2010; Park, 2013; Sibley, 2009; Saribas et al., 2016). According to Bloom, notion mastery is the capability to comprehend the substance of learning expansively, and be able to offer clarification, as well as apply it (Anderson, 2010). Mastery concept is the fundamental aspect of learning, and the use of technology has proven to overcome the obstacles as the harnessing of science has become an educational research trend. Smith & Bermea (2012) applied the sketching technique as the alternative conception of the plate tectonics. However, media visualization has not been commonly used in Bengkulu particularly on the earth and space topic. Furthermore, previous studies have shown the improvement of earth and science concepts through the use of sketching, visualization, and animation techniques (Prain et al., 2009; Smith & Bermea, 2012; Samsudin et al., 2016; Kali & Linn, 2008). Other than that, analogies, real replicas or diagram were also utilized in some research to advance future science teachers' concept mastery (Jee et al., 2010; Sibley, 2009; Passmore et al., 2014). In other words, technology has facilitated the interpretation of abstract, unobservable concepts such as earth and space. In this case, the animation is most- adapted technology to help students catch a proper understanding of such concepts. Profound comprehension of the connection between scientific independence, technology, and pro-environmental behaviors are necessary for students to support them in various courses (Bezen et al., 2016; Santos & Arroio, 2016; Kastens, 2010).

Geoscience visual representation could aid students for the betterment of their understanding. This research presented multi modus visualization such as animation, graphs, and figures which configured each other to ease the students in comprehending the concepts. The visualization of this research emerged as the results of authentic data analysis with GrADS, which has never been done before. In addition, the results of this research could be later used to support students' thinking process as well as give varying learning experience. The authentic data were computed using the Matrix Laboratory (MATLAB) to produce 3-Dimension visualization (Werts & Hinnov, 2011; Ellwein et al., 2014) while the Indonesian atmospheric data were analyzed using the Grid Analysis Display System (GrADS). In addition, a module was developed referring to the authentic data.

Captivating students' attention to interpreting the GrADS data visualization would be a remarkable learning experience which was expected to result in the improvement of earth and space concept mastery. Making use of the GrADS system in a learning process particularly on the earth and science topic has not been published yet. The GrADS and MATLAB results were approximately indistinguishable yet the GrADS was fairer to be used than the MATLAB.

With this in mind, the researchers frankly said that this research intended to enhance the earth science concept mastery of the future physics teachers for the analysis level especially the earth atmosphere employing the interactive conceptual instruction with the aid of GrADS and visualization.

METHODS

Pre-experimental research was conducted with one group pretest-posttest research design. 23 prospective physics teachers were involved in this study. There were three stages of research including pre-implementation, implementation of one group pre-test post-test design, and postimplementation. In the pre-implementation, kinds of media for visualization to every concept were recognized qualitatively to advance prospective physics teachers' concept mastery.

The studied materials included the composition of air mass, atmospheric pressure, atmospheric temperature, the ozone layer, and incoming solar radiation. In this stage, the learning activities using the ICI model and data collection tools were created. There were four stages in the learning; the focus of concept, textbook usage, interactive classroom, research-based materials. The research-based materials were the results of the GrADS authentic data analysis which measured the net solar radiation in January-December 1990. The output of the GrADS was the display of Indonesian atmosphere actual condition. These visualizations intended to assist the fu-

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ture physics teachers to understand the concepts.

In the implementation step, the ICI was run to 23 future physics teachers in Bengkulu, Indonesia. The participant had never joined the Earth and Space course before. These participants were chosen by using the Convenience Sampling technique. The data of prospective physics teachers' mastery were obtained from the pretest and posttest. The mastery differences found in the pretest and posttest score were then computed as the N-Gain <g> (Hake in Jackson et al., 2008).

$$\langle g \rangle = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}}$$

Description:

 S_{pre} = pretest score; S_{post} = posttest score; S_{max} =maximum score

Some instruments were needed in this research to collect the data. The quantitative data of concept mastery were collected through multiple choice questions while the qualitative data of prospective physics teachers' responses were collected through open-ended questions. The instruments employed were authenticated by a proficient team. There were four professionals partook in authenticating the instruments. The instruments used in this research were verified by 34 prospective physics teachers. Based on the experts and instrument implementation, it concluded that the research' instruments were valid and reliable. The sample of question is as follows: "Based on the graph of annual solar movement, the incoming solar radiation on 23,5° of the northern hemisphere at summer solstice is.... (Note: BBS is southern hemisphere; BBU is northern hemisphere; 0° is equator).

The classroom activities carried out in this lesson are presented in Table 1

 Table 1. The Classroom Activities

The focus of concept:
Picturizations as to help com-
prehend the concept

Textbook usage: Library research to keep up with the latest terms, or keywords of the visualized concepts	Interaction: Interactive discussions among stu- dents during
Research-based materials: The output of the GrADS program which displays the actual Indonesian atmosphere used to support the students to comprehend the notion	learning process

In the pre-implementation stage, the type visualization was qualitatively examined for each concept. The visualizations were in the form of animations, figure, graphs, and GrADS picturization. The examination of visualization type was to ensure that the students have had an appropriate understanding to avoid misunderstanding, also, advance their thinking skills. These kinds of visualization were then adopted to the developed learning program.

RESULTS AND DISCUSSION

This research aimed to describe the enhancement of prospective physics teachers' concept mastery known from the differences between the post-test and pre-test results. The students' early knowledge was known through the pre-test and the increase was examined through the post-test. The below Table informs the pre- and post-test of the students.

Understand- ings	Compositions of air mass	Atmospheric pressure	Atmospheric temperature	Atmospheric temperature	Ozone layer	Incoming solar radiation
Taxonomy level	C2 understanding	C3 applying	C2 understanding	C3 applying	C4 analysis	C4 analysis
Correct answers in Pre test	13%	30.5%	52.1%	39.1%	30.5%	47.8%
Correct answers in Post test	30.5 %	95.7%	100%	91.3%	47.8%	95.7%
Difference between pre and post	17.5%	65.2%	47.9%	55.2%	17.3%	47.9%
N-Gain (Im- provement)	0.2	0.93	1	0.86	0.25	0.92
Category	low	high	high	high	low	high

Table 2. The Data of Correct Answer at Pre-Test and Post-Test

Table 2 provides the dissimilar between the correct answers at pre-test and post-test for each concept; also, the improvement of pre-service physics teachers' mastery. The Bloom's revised taxonomy stages were adopted. The influence of the learning process was specified on the enhancement of mastery aspects (C2). Based on data displayed in Table 2, there was a shift in the students' mastery concept seen from the high increase of atmospheric pressure, atmospheric temperature, and incoming solar radiation mastery. Furthermore, there was 52.1% of correct answers on the pre-test for atmospheric temperature materials and 100% of correct answers on the post-test. This made it the highest improvement among others. On the other hand, there was only 13% of correct answers on the pre-test for air mass composition and was increased by 17.5% to become 30.5% on the post-test. However, the lowest increased was on the analysis (C4) of the ozone layer which scored an improvement of 17.3% although the other C4 of incoming solar radiation scored high (47.9%).

Table 3. The Distribution of N-gain

N-Gain	Criteria	Prospective Physics Teachers (%)
<i>g</i> > 0,7	High	30.44%
$0,3 \le g \le 0,7$	Medium	69.56%
<i>g</i> < 0,3	Low	none

Table 3 informs the enhancement distribution of concept mastery on each N-Gain level. A student's concept mastery was calculated from each student's understanding of all concepts. The data of the students' increase in all concept mastery elucidated that no one had low concept mastery and all of them categorized as the medium as the N-Gain average score was 0.69. It appears in Table 3 that 30.44% of future physics teachers were in the high category and other 69.56% of them were in the medium category.

Those remarkable improvements emerged as a result of the use of various visualization types. It seems that different type of visualization has a different impact. The learning of air mass composition, which scored the least, used tables and graphs. A distinct difference between the two C4 aspects was quite interesting. The C4 of incoming solar radiation, which scored higher, utilized the combination of animation and GrADS visualization. Supposedly, this compilation influenced their concept mastery in analysis level as it helped the students to understand the concepts easily and clearly. Furthermore, Table 3 shows that most students are in the high and medium category based on the N-gain for concept mastery. The use of visualization media was closely related these pleasant results since it enabled students to watch the unobservable phenomena of Earth and Space especially the atmospheric. This was supported by the results of the questionnaires which revealed that most students considered media visualization, especially animation, as the most helpful aid.

The display of the GrADS output by analyzing the authentic data has given an expressive effect for the research. The findings indicated that the learning processes supported by researchbased materials had the advantage of being able to describe the actual condition of nature. The display of the GrADS output by analyzing the authentic data of real solar radiation in 1990 is presented in Figure 1.



Figure 1. The GrADS Output Displaying Actual Condition of Indonesia Solar Radiation on the Atmosphere in March, July, September, and November 1990

The above visualizations are the analysis results of surface net solar radiation from GrADS which is influenced by latitude and position during annual solar movement. The incoming solar radiation influences temperature and pressure in the atmosphere while the colors indicate the different amount of solar radiation. For instance, the northern hemisphere has surplus solar radiation on July and deficit of solar radiation in July 1990. Having such details, this kind of visualization could support learning the atmospheric pressure, atmospheric temperature, and incoming solar radiation concepts and the correlation between each concept.

After being provided the actual condition of Indonesia Solar Radiation, the students were asked to relate the net solar radiation and the sun's motion during the year, which is seen in Figure 2.



Figure 2. (a) and (b). The Surface Net Solar Radiation in Indonesia's Atmosphere on March and September 1990; (c). The Annual Solar Movement

The Figure 2a, 2b, and 2c are correlated with each other. Based on Figure 2a and 2b, the students could obviously notice the distribution of solar radiation in Indonesia both on the northern and southern hemisphere while Figure 2c shows the annual solar movement. Therefore, the students could easily draw conclusion why the northern hemisphere of Indonesia has surplus solar Radiation in June 1990. This is parallel with Mountney (2009) who stated that animation that used in learning gives dynamic situational of an object and this is potential to explore logic thinking. Moreover, the concepts of incoming solar radiation and atmospheric temperature, as well as its correlation, could also be explained. This is similar with previous research elucidating that visualization could explain the correlation among various variables (Werts & Hinnov, 2011). Therefore, it supports the opinion suggesting that the collaboration of visual media and authentic data in learning contributes to students' reasoning skills to reach the proper concept mastery (Johan et al., 2018a; Johan et al., 2018b). Improvement of mastery concept is also influenced by the learning process that stimulated student's curiosity and motivation. Similar research stated that virtual visualization as a game in learning activity could improve enthusiasm or interest in learning (Ismawati et al., 2014). Furthermore, this learning potentially enhances the spiritual aspect. It causes earth science learning helped by

GrADS could display the real condition of the earth atmosphere (Johan et al., 2018a; Johan et al., 2018b).

The use of visualization to ease the concept understanding was agreed upon by the students through the questionnaires. Based on the students' responses to the questionnaires, it summed up that: (1) The Earth and Space learning using visualizations was more interesting; (2) The use of visualization, especially animation, has helped them to comprehend the atmospheric concepts easier; (3) The animation was very clear and able to help to simplify the concepts; (4) Animations made the learnings became more enjoyable. Visualizations are also able to foster curiosity and motivation. These learning results were also supported by previous research that stated multimedia teaching materials including text, graphics, images, audio, video, and animation gave more significant effect on students' cognitive (Khoiriah et al., 2016). Other research reported that motivation was important factors for successful learning activities (McConnell & Kraft, 2011; Lee & Pang, 2013).

CONCLUSION

Based on the above results and discussion, it concluded that the earth atmosphere learning through conceptual interactive using visualizations was the potential to improve prospective physics teachers' concept mastery. The prospective physics teachers' concept mastery improved quite remarkably and categorized as medium based on the average N-Gain score of 0.64. The visualization of solar radiation authentic data analyzed using the GrADS helped the students to understand the concept easier and gave them experience about the real Indonesia solar radiation. the improvement of prospective physics teachers' conceptual levels indicated that visualization made the learnings became more interesting and explored their thinking skills. Visualizations give the concept details plainly and showed the relationship of various variables or concepts in the earth atmospheric phenomena. It is expected for future research to exploit other phenomena to be displayed in classes for the betterment of preservice physics teachers' quality.

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THE DETERMINANT FACTORS ANALYSIS OF INDONESIAN STUDENTS' ENVIRONMENTAL AWARENESS IN PISA 2015

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ABSTRACT

This research intended to reveal the determinant factors which could explain Indonesian students' environmental awareness based on the 2015 PISA; also, to find out the influence of Science Proficiency to Indonesian students' environmental awareness based on PISA 2015. The data were obtained from the 2015 PISA database in which there were 6513 Indonesian students participated in the survey. This research employed the Path Analysis continued to the Structural Equation Modelling (SEM) employing the LISREL 8.30. The research results indicated that the environmental awareness of 15-old Indonesian students' enjoyment of learning science equal to 0.41; (2) students' self-efficacy in science equal to 0.16 (3) students' instrumental motivation equal to 0.15; (4) Inquiry-based instruction in science lesson equal to 0.14; (5) students' science proficiency equal to 0.11; and (6) students' epistemic belief equal to 0.04. The higher the socio-economic status of the students, the lower the environmental awareness. A respectable correlation of >0,5 was obtained from the relationship between those 6 variables and environmental awareness.

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Keywords: indonesian students, environmental awareness, PISA 2015

INTRODUCTION

Achieving students' scientific literacy is the foremost objective in science education (Bybee et al., 2009; Roberts, 2013). Further, the essential components of scientific literacy are resource use and environmental quality (Roth & Lee, 2016). Other than that, environmental awareness and pro-environment behaviors are considered as the important outcomes of science education in many countries (Alves et al., 2009). Therefore, science education plays an important role in developing an understanding of scientific principles as a basis for environmental problems.

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A person's ability to interact with the environment especially in facing global challenges such as climate change and biodiversity is influenced by science education. Field research has oriented to the integration of environmental issue into school curriculum as environmental education has been considered as an environmental tool protection since the 1970s (Erbas et al., 2012). Moreover, Hadzigeorgiou & Skoumios (2013) suggested that environmental education is implemented formally in schools. Related to environmental education and sustainable development, Uitto et al. (2011) in his research which included 3626 nine graders recommended the need for students' learning motivation towards environmental issues. Future scientific research and environmental education really need interest, attitudes, and values in teaching environmental problems.

Science education, despite its limitation, offers some opportunities to foster environmental awareness (Littledyke, 2008). In the latest two decades, many science educators have discussed either explicitly or implicitly the needs of environmental awareness (Hadzigeorgiou, & Skoumios, 2013; Testa et al., 2016). In today's age, scientific literacy is highly salient for the full participation of citizens. Of course, an important component of scientific literacy includes the use of resources and environmental quality (Bybee,2008). Since the 2006 PISA, environmental awareness has become one of the indicators of scientific literacy (Sadler & Zeidler, 2009; Byebee et al., 2009).

Environmental awareness defines as the state of a person who has the knowledge and is aware of the environment where people live and tends to influence the development of communities with pro-environmental behavior (Harju-Autti & Kokkinen, 2014). The high level of environmental awareness of a society strongly influences their behavior towards the environment (Franzen & Meyer, 2009). Thus, community support for environmental protection is highly dependent on the level of environmental awareness. Environmental awareness is studied in various countries because of the many environmental problems faced by all countries. There are many environmental agreements between countries that call for fundamental changes in energy production and consumption in both industrialized countries and developing countries. Therefore, to ensure public support for these policies, citizens must have high environmental awareness.

By the time being, the topic of environmental awareness is often approached based on the educational point of view. Environmental awareness is considered an education problem since the high level of awareness is expected to result from further environmental education. There are several cases where environmental knowledge is a limiting factor for increasing environmental awareness. However, in many cases, the development of environmental awareness is highly dependent on environmental motivation. Environmental awareness has long been considered to be strongly influenced by motivation, knowledge, and skills (Harju-Autti & Kokkinen, 2014; Maharani & Dewi, 2015).

How an individual's environmental awareness turns into pro-environment behavior is explained by the Environmental Awareness Pro-Environmental Behavior (EAPEB) model (Harju-Autti, 2013). Some aspects of the EA-PEB model can be explained by several theories about planned human behavior such as valuesbeliefs-norms (VBN) theory (Jakovcevic & Steg, 2013). According to Hansla et al. (2008) in the VBN theory, the intention determinant to acquire pro-environment behavior includes the consequence awareness which arises from individual beliefs about the adverse consequences of environmental problems. Kenter et al (2011) described the VBN theory as a process by which values form an ecological worldview. The study from Gifford & Nilsson (2014) and Liem& Martin (2015) showed the important roles of social and personal norms to foster proenvironment behavior. In addition, Lafuente & Sánchez (2010) established a multidimensional definition of environmental awareness. In the model, they broadly integrated environmental awareness theory from a theological perspective with environmental behavior theory taken from environmental psychology. Therefore, environmental awareness consists of four dimensions namely affective, cognitive, disposition, and active.

Science lessons in schools are very supportive of developing students' attitudes, awareness, and responsibility for the environment. Their scientific skills and knowledge could be used to assess environmental conditions and increase awareness and understanding to be involved in active participation for environmental sustainability. To measure students' environmental awareness, they were asked to respond to seven environmental issues and show how their information about the problems was related: (1) the increase of greenhouse gases in the atmosphere,(2) the use of genetically modified organisms (GMO),(3) nuclear waste, (4) the consequences of clearing forests/other land use, (5) air pollution, (6) extinction of plants and animals, (7) water shortage. The environmental awareness questionnaire of the 2015 PISA appears in Table 1.

No	How informed are you about the following en- vironmental issues?	I have never heard of this	I have heard about this but I would not be able to explain what it is really about	I know something about this and could explain the general issue	I am familiar with this and I would be able to explain this well
1	Increased greenhouse gases in the atmosphere				
2	The use of genetically modified organisms				
3	Nuclear waste				
4	The consequences of clearing forests for other land use				
5	Air pollution				
6	Extinction of plants and animals				
7	Water shortage				

Table 1. The Environmental Awareness Questionnaire of the 2015 PISA

(OECD, 2016c)

Environmental awareness is considered quite important in the science learning aspect by PISA; thus, it seems to have an influence on the Science Proficiency as described in the following figure.



Figure 1. Inter-relation between the Four Aspects in PISA Framework (OECD , 2016c)

Several studies of PISA results have proven the theoretical framework as described in Figure 1. Alves et al. (2009) examined factors that impact environmental awareness and science proficiency as well as the relationship between the two using the 2006 PISA data comprising 300 cases from 22,0000 Canadian students and 9,000 Brazilian students who participated in the PISA survey. The results of the study showed that (1) the students' self-study, science- value, learning experience, economic index, social and cultural status (ESCS) had a significant effect on the proficiency of science; and (2) there was a significant direct influence of proficiency science on environmental awareness. Coertjens et al. (2010) conducted a study of the effects of sex, socio-economy status, immigration status on attitudes of environmental awareness of 15-year-old students. The research used the 2006 PISA data consisting of 4999 students from Flemish, Belgium. The results of the study indicated that there were effects of sex, socio-economy status, and immigration status towards environmental awareness.

Erbas et al. (2012) also conducted a study of factors influencing environmental awareness by utilizing 2006 PISA data which involved a sample of 4942 students from 160 schools. The findings of this study indicated that the interest of 15-year-old Turkish students on the environment varied according to socio-demographic variables such as gender, economy, social and cultural status. The study also showed the interest of Turkish students in school activities related to environmental topics, also, the interest and optimism of parents about environmental problems. Although the relationship of parents' interest and optimism with the students' caring was negative, the level of parents' optimism about environmental issues explained the greatest variation in the students' environmental caring followed by parents' interest in environmental problems. In other words, a

sense of caring and optimistic parents about environmental issues had a relatively strong impact on children's caring, level of awareness and optimism about environmental issues.

Zecha (2010) conducted a study of several factors considered influential on environmental awareness by involving 900 German and 182 Spanish students aged 14 and 15. The results of his research informed that children's culture influenced knowledge, attitudes, and actions related to environmental awareness. The research on factors impacting the scale of attitude to the environment was carried out by Le Hebel et al. (2014). His research required 2124 French students and concluded that (1) there was a connection between environmental awareness and students' interest in learning environmental topics; (2) environmental awareness and extra-curricular activities have relationships; (3) there was a correlation between the environmental awareness and students' personal value. Uitto et al. (2011) conducted a study of the relationship between student interest in environmental issues, attitudes to the environment and biocentric values in school science learning. The survey was conducted using the ROSE (Relevance of Science Education) questionnaire on 3626 ninth graders. The results of the study show that: (1) the attitudes and value factors have a significant correlation; (2) the interests and attitudes were uncorrelated; and (3) girls had a stronger positive attitude than men in the environmental and biocentric values.

Saricam & Sahin (2015) examined the relationship between environmental awareness, environmental attitude, curiosity and exploration at the 13 or 14-year-old students using structural equation modeling (SEM). The results showed that high-ability children scored higher on environmental awareness, environmental attitude, curiosity and exploration than low-ability children. The SEM analysis also proved that the better the curiosity and exploration of high-ability children the higher the environmental awareness and attitude. Employing the 2006 PISA data for the European Union, Duarte et al. (2017) examined family influences, school characteristics, and social interplay or peer group attitudes to the environment. The main object of the research is the existence of social interactions, such as the important role of a family's characters and school's characters. The importance of the social context of adolescents as a strategy for environmental education is the finding of the study.

Since participating in the 2000 PISA, science education in Indonesia has undergone a tremendous transformation to create a foundati-

on for prosperity and sustainable development. Between 2012 and 2015, science performance among 15-year-old Indonesian students increased by 21 points. This makes the education system in Indonesia considered the fifth fastest among the 72 countries participating in the PISA study (OECD, 2016d). Indonesian high school students (grade 10 or higher) performed better in science, with an average difference of 45 points from their peers who were in grade 9 or below (OECD, 2016d).

The 2015 PISA results for Indonesian students in Science Proficiency was 403 or ranked 62 of 72 participants. These results were better than in 2006, which scored 393 while seen from the level of proficiency, Indonesian students were at the level 2 of the 6 levels of ability measured in the PISA study (OECD, 2016a). In the attitude aspect, the acquisition of Indonesian students' environmental awareness score was -0.5 (WLE score). Therefore, it concluded that Indonesian students' environmental awareness was below the average of all students participating in the 2015 PISA survey. The PISA 2015 also asked the students about their beliefs about the nature of scientific knowledge and the validity of Epistemological beliefs. Indonesian students, on the other hand, were far below the students in OECD countries to agree on the current view of the nature of science, especially about how scientific ideas develop. For instance, about six out of ten students in Indonesia reported that ideas in science or science books sometimes change, compared to eight out of ten students in all OECD countries (OECD, 2016d).

Science education at schools ideally influences students' environmental awareness. Nevertheless, there has been no research that studies the relationship between Science Proficiency in schools and Indonesian students' environmental awareness. Similarly, there has been no study on factors impacting the environmental awareness of Indonesian students that are connected simultaneously to the Science Proficiency at schools. Research is necessarily carried out to find out the extent of the Science Proficiency effect on Indonesian students' environmental awareness; also, to examine the dominant factors influencing the environmental awareness of Indonesian students. These factors are beneficial for further development of science learning model to enhance Indonesia students' environmental awareness. The search of determinant factors from Science Proficiency and awareness of Indonesian students based on the PISA data is a more complex study that may even lead to the design of a model. This is due to the large number of variables affecting the Science Proficiency in the PISA survey such as the students' background, parents' background, school background, teachers' background, and learning process.

From several previous studies, either those using the PISA data (Alves et al., 2009; Coertjens et al., 2010; Erbas et al., 2012; Duarte et al., 2017) and primary data (Zecha, 2010; Le Hebel et al., 2014; Saricam & Sahin, 2015) showed that there have not been many studies on the influence of science learning aspects on students' environmental awareness. In accordance with the framework of PISA 2015 as described in Figure 1, this study limited the identification of factors affecting the environmental awareness and the influence of Science Proficiency on Indonesian students' environmental awareness. In this regard, this study was limited to several variables that were directly involved in science learning and socioeconomic status. The research objectives were described as follows: (1) to find the determinant factors explaining the environmental awareness of Indonesian students based on the 2015 PISA data; and (2) to reveal the influence of Science Proficiency on environmental awareness of Indonesian students based on the 2015 PISA data.

METHODS

The research data were taken from the PISA database accessible via the OECD page at http:// www.oecd.org/pisa/data/2015database/, the data code is PUF_COMBINED_CMB_STU_ QQQ_Zip. There were 519,334 students responded from 72 countries and 921 variables related to students. The number of Indonesian students involved in the PISA survey was 6513 and more than half of the sample was in grade 9 (OECD, 2016d: 2).

According to the OECD standards, the desired population in each education system consists of 15-year-old children who attend school in grade 9 or higher. To provide a valid estimate of student achievement and characteristics, the sample of PISA students must be chosen in a way that represents the full population of 15-year-old students in each education system. The sample design for the 2015 PISA was a stratified systematic sample. There are two types of stratification samples used, namely explicit and implicit. Explicit stratification is done by grouping schools into separate strata. The example of explicit stratification variables is state or territories of a country. For Indonesia, this explicit stratification referred to the results of the National Examination which were divided into three criteria; high, medium, and low (OECD, 2015). The National Examination is formulated for all schools throughout Indonesia and regulated by standard policy assessments and evaluations issued by the Ministry of Education and Culture. In these policies, the ministry regulates the materials and subjects to be tested, as well as how the National Examination is implemented, and the thresholds that must be achieved by students as graduation requirements. The implicit stratification is basically the unique sorting of the schools in each explicit layer by a set of stratification variables implicitly designated. Type of school, urbanization, and minority composition are examples of implicit stratification variables. The implicit stratification is a way to ensure the allocation of school samples that are rigorous and proportionate so as to ensure the representative samples. This can lead to an increase in the reliability of survey variable estimates as long as the stratification variable is implicitly related to PISA proficiency at the school level. For Indonesia, the adopted implicit stratification was the criteria for school funders, school types, and regions (OECD, 2015).

The previous studies using the PISA data have emerged at least five variables involved in science learning and one socio-economic status variable that sufficiently affected the Environment Awareness (ENVAWARE) and Science Proficiency (PVSCIE). The five variables are: (1) students' epistemic beliefs or so-called the Epistemological beliefs (EPIST); (2) students' enjoyment of learning science or called Enjoyment of Science (JOYSCIE) variables; (3) students' instrumental motivation or variables (INSTS-CIE); (4) students' self-efficacy in science or the Science Self-Efficacy (SCIEEFF) variable; and (5) Inquiry-based instruction in science lesson (IBTEACH). Some variables related to family background such as parental education, parental work, number of houses owned, learning facilities, availability of books, etc. are summarized in one variable called the student's economic, social and cultural index (ESCS) (Alves et al., 2009; Coertjens et al., 2010; Erbas et al., 2012; Duarte et al., 2017). Research using primary data involving 1182 to 3600 students showed that there were several variables that influenced environmental awareness, namely: (1) attitudes and interests in the environment, (2) knowledge about the environment, (3) curiosity, (4) gender and (5) intelligence (Zecha, 2010; Le Hebel, 2014; Uitto et al., 2011; Saricam & Sahin, 2015).

Students' epistemic beliefs are individual representations of the nature, structure, and sour-

ce of science, for example, what is considered as "true" and how the validity of an argument is formed. Such beliefs have been proven in direct contact with the student's ability to acquire new knowledge in science and science learning achievement in school. (Mason et al., 2013). Epistemological beliefs (EPIST) were measured by a questionnaire of 6 items arranged in a Likert scale with four categories: strongly disagree, disagree, agree and strongly agree (OECD, 2016a).

Students' enjoyment of learning science in the 2015 PISA study is called the Enjoyment of Science (JOYSCIE) variable. Enjoyment of Science measured the students' learning enjoyment of science through their responses ("strongly agree", "agree", "disagree" or "strongly disagree") with five items consisting of the following statements: (1) pleasure in learning science topics; (2) reading preferences about science; (3) pleasure in doing scientific topics; (4) enjoyment in acquiring new knowledge from science; and (5) interest to learn about science. The science enjoyment index was built to summarize the students' answers (OECD, 2016c).

instrumental motivation Students' (INSTSCIE) for learning science is an impetus for learning science because students consider science to be very useful for them, their future studies, and careers (OECD, 2016a). This variable assesses whether students feel that science is relevant to their own needs and career prospects through their responses ("strongly agree", "agree", "disagree" or "strongly disagree") with four statements: (1) working on science at school is very useful as it will help your future occupation; (2) what is learned in science subjects is very useful since it is needed for your future occupation; (3) learning science in school is very valuable because it will enhance your career prospects, (4) knowing a lot of things in science will help get a job (OECD, 2016c).

The term "self-efficacy" is used to explain students' beliefs that their actions can produce something desired such as solving difficult problems or achieving goals. Self Efficacy refers to the assessment of future-oriented competence in achieving certain goals within a specific context, which requires scientific capabilities such as explaining phenomena scientifically, evaluating and designing a scientific investigation, or interpreting scientific data and evidence (Mason et al., 2013). In the 2015 PISA, self-efficacy was called the Science Self-Efficacy (SCIEEFF) variable. This Science Self-Efficacy asked the students to state how easily they carry out the following tasks: (1) identifying science questions underlying the newspaper reports about health problems; (2) explaining the frequency of earthquakes is more common in some regions than elsewhere; (3) explained that the treatment of disease can be done by giving antibiotics; (4) identifying science questions related to waste disposal; (5) predicting how environmental changes will affect the sustainability living of certain species; (6) interpreting scientific information given to food labels; (7) discussing new evidence about the possibility of life on Mars; and (8) identifying a better explanation of two explanations about acid rain formation (OECD, 2016c: 155). The student responses categorized as: (1) I can do it easily; (2) I can do this with little effort; (3) I will struggle to do this; and (4) I cannot do this.

Inquiry-based instruction level in science lesson is the extents to students' experience the inquiry-based science learning (investigation). In the 2015 PISA, the Inquiry-based level instruction in science lesson was abbreviated as IBTEACH. Inquiry-based instruction in science learning refers to how to involve students in experiments, direct activities, and challenge students and support them to expand conceptual understanding of scientific ideas. The best students are expected to understand, explain, debate scientific ideas, design, experiment and communicate. In the PISA study, this was performed by asking the students the frequency ("never or almost never", "in some lessons", "in most lessons" and in all lessons ") of the following statements: (1) Givingstudents the opportunity to explain their ideas; (2) Giving students the opportunity to spend time in the laboratory doing practical experiments; (3) Students are invited to debate science questions; (4) Students are involved in drawing conclusions from experiments that they have done; (5) The teacher explains how scientific ideas can be applied to a number of different phenomena; (6) Giving students the opportunity to design their own experiments; (7) Involving students and teachers in debates about investigations; (8) Teachers discuss the relevance of real-life science concepts; and (9) Students are involved in investigations to test ideas (OECD, 2016c). An inquiry-based science learning index combines these nine statements.

Socioeconomic status variables (ESCS) are one of the variables that are not directly related to science learning, yet it is suggested by many researchers to be strongly related to science proficiency and environmental awareness (Schmidt et al., 2015). Socioeconomic status is a broad concept summarizing various aspects of students, schools, or school systems. In the PISA survey, a student's socio-economic status was estimated by an index of economic, social and cultural status (ESCS). Some variables that correlate with students' family backgrounds such as parental education, parental work, number of household items that are considered material wealth, and the number of books or other educational resources available at home are elements of the ESCS variable. The Principal Component Analysis (PCA) is used to combine several economic, social and cultural status variables in the ESCS. This was done for international comparison purpose. For the reporting aim, the scale value of the ESCS was standardized to have a zero average and one standard deviation for the student population in OECD countries, given the same weight for each country.

Environmental awareness (ENVAWARE) in the 2015 PISA study was measured by knowing the condition of students whether or not they knew information related to environmental issues. ENVAWARE were used from the questionnaire. ENVAWARE is a score calculated from the student responses to a question that asks about various environmental issues (see Table 1). The environmental issues raised in the 2015 PISA survey included: (1) the increased greenhouse gases in the atmosphere; (2) the use of genetically modified organisms; (3) nuclear waste; (4) the consequences of deforestation for land; (5) air pollution; (6) the extinction of plants and animals; and (7) the lack of water. The students' responses were divided into four categories: (1) I have never heard of this; (2) I have heard of this but I cannot explain what really happened; (3) I know something about this and can explain the problem in general; (4) I know this and I can explain it well (OECD, 2016c)

This study employed the path analysis (Loehlin, 1998) and continued to the structural equation modeling (SEM) (Bowen & Guo, 2011) with the help of LISREL 8.30 software (Jöreskog & Sörbom, 1996). The path analysis aimed at finding both the direct or indirect effect of the variable on environmental awareness while the SEM was to confirm the hypothesized theoretical model. Furthermore, the path analysis was employed to analyze the relationship within the complex variables; thus, it cannot be done by multiple regression. There are many dependent variables in complex models so that a series of regression equations are needed (Gudono, 2011). Each variable was not tested for validity because all items used in the PISA study were validated beforehand using the Item Response Theory (Hambleton et al, 1991).

RESULTS AND DISCUSSION

The results of the 2015 PISA study for several Indonesian student attitudes variables related to science are informed in Table 2.

Table 2. The Attitude variable Scores Related to Science Learning, Environmental Awareness, and Socio-Economic Status of Indonesian Students based on the 2015 PISA Results

No	Variables	Score in WLE (Warm's weighted Mean Likelihood Estimation)
1	Epistemological beliefs	-0,3
2	Enjoyment of Science	0,65
3	Instrumental motiva- tion	0,81
4	Science Self-Efficacy	-0,51
5	Inquiry-based instruc- tion in science lesson.	0,26
6	Environmental Aware- ness	-0,5
7	ESCS	-1,87

(OECD, 2016 a ; OECD, 2016b)

The scores presented in WLE ranged from -2 to +2 with the mean of 0. Table 1 informs that the Environmental Awareness of Indonesian students was 0.5 digit below the average of all students involved in the 2015 PISA study. Similarly, both the Epistemological Beliefs and Science Self-Efficacy were under the average acquisition of all students. In addition, the ESCS of Indonesian students was very low; almost 2 digits under all students' ESCS in the 2015 PISA. These results reaffirmed that the economic, social and cultural status of Indonesian students was indeed very low compared to other countries. For the level of Science Enjoyment, Instrumental motivation, Inquiry-based instruction in a science lesson, the Indonesian students were above the average achievement of students from all countries participating in the 2015 PISA survey. Indonesian students' Science Proficiency scored 403, ranked 62 of 72 participating countries. This was an improved achievement compared to 2012.

To facilitate the SEM analysis, the Environmental Awareness variable was abbreviated as ENVAWARE, the Science Proficiency as PVSCIE, Epistemological beliefs as EPIST, Enjoyment of Science as JOYSCIE, Instrumental motivation as INSTSCIE, Science Self-Efficacy as SCIEEFF, Inquiry-based instruction in science lesson as IBTEACH, also, social, economic, and cultural status as ESCS. The results of SEM analysis with the LISREL 8.30 software are presented in Figure 2. The criteria for goodness of fit test (GFT) of the model are informed in Table 3.



Figure 2. The Determinat Factors of Environmental Awareness of Indonesian Students based on the 2015 PISA Results

GFT Size	Criteria	Results	Conclusion
P value	\geq 0.05	0.09	very good
λ^2 / df	≤ 5	2.4	very good
Root Mean Square Error of Approxima- tion (RMSEA)	\leq 0.08	0.015	very good
Goodness of fit index (GFI)	\geq 0.9	1	very good
Adjusted Goodness of fit index (AGFI)	\geq 0.9	1	very good
Comparative fit index (CFI)	\geq 0.9	1	very good
Normal fit index (NFI)	\geq 0.9	1	very good
Icremental fit index (IFI)	\geq 0.9	1	very good
Non Normed fit index (NNFI)	\geq 0.9	1	very good

Table 3. The Criteria of Goodness of Fit Test (GFT) in SEM

(Kusnendi, 2008; Ghozali & Fuad, 2005)

Of all the parameters explained in Table 2, it shows that out of ten criteria, the results of SEM analysis can be declared acceptable. One of the characters of the Likelihood Ratio Test (λ^2) is that the higher the value, the lower the relati-

ve P-count value, and vice versa. It was desirable that the Likelihood Ratio Test be as small as possible so that the P value turned larger. Another characteristic of λ^2 statistics is its sensitivity to sample size (Lomax & Schumaker, 2012; Hair et al., 1998). The larger the sample size, the obtained λ^2 statistics tend to be greater with smaller P-values. Thus, for large statistical samples, the λ^2 tends to reject the model (Joreskog & Sorbom, 1996). However, it turned out that this did not occur in the SEM analysis conducted in this study. Having the sample size of 6513, the value of λ^2 was 4.81 and the P value met the requirements of 0.09. This indicated that the model produced in this study had a high absolute fit measure (AFM). The AFM informs the ability of the model to estimate in absolute terms the population covariance matrix based on the sample covariance matrix. Two measures of absolute suitability that are the most important LISREL version are the Likelihood Ratio Test (λ^2) and the Root means Square Error of Approximation (RMSEA) (Joreskog & Sorbom, 1996). All relationships within the variables presented in Figure 1 were significant at the 95% confidence level as shown in Table 4 and Figure 3.

Table 4. The Estimate and Test: The Determinant Factors of Indonesian Students' Environmental

 Awareness based on the 2015 PISA Results

Path	Path Coefficient	Standar Eror	Standardized Path Coefficient	t	R ² Determinant
IBTEACH → ENVAWARE	0.14	0.011	0.14	13.48	
JOYSCIE \rightarrow ENVAWARE	0.39	0.013	0.41	29.73	
INSTSCIE \rightarrow ENVAWARE	0.33	0.016	0.15	8.57	0.59
SCIEEF \rightarrow ENVAWARE	0.14	0.013	0.16	10.20	0.07
$EPIST \rightarrow ENVAWARE$	0.031	0.011	0.04	2.91	
$ESCS \rightarrow ENVAWARE$	-0.55	0.210	-0.04	-2.64	
PVSCIE \rightarrow ENVAWARE	0.029	0.0075	0.11	3.79	
JOYSCIE → PVSCIE	0.39	0.15	0.10	2.61	
$EPIST \rightarrow PVSCIE$	0.13	0.063	0.04	2.07	0.15
ESCS → PVSCIE	22.93	0.65	0.40	35.15	
ENVAWARE \rightarrow PVSCIE	-1.08	0.23	-0.28	-4.67	

Note: the t-table value at 95% and n > 150 is ± 1.95 (Ghozali & Fuad, 2005: 81)



Figure 3. The Significance Test of the Determinant Factor Effect on Indonesian Students' Environmental Awareness

On the basis of Table 3, the seven variables influencing the environmental awareness of Indonesian students gave 59% of determination coefficient, this means that the seven variables were able to explain variations in environmental awareness scores by 59% while the other 41% was explained by other variables. With standardized path coefficients, it appeared that the students' enjoyment of learning science had a positive effect on environmental awareness of 0.41, followed by the students' self-efficacy in science of 0.16, the students' instrumental motivation of 0.15, the inquiry-based instruction in science lesson of 0.14, the students' science proficiency of 0.11 and the students' epistemic beliefs of 0.04. The economic, social and cultural index of Indonesian students had a negative effect of 0.04 on environmental awareness but had a positive effect of 0.40 on the students' science proficiency. This means that the higher the economic, social and cultural index of Indonesian students, the lower their environmental awareness. Similarly, it was known that environmental awareness had a negative effect of 0.28 on the students' science proficiency. Moreover, Figure 3 shows that the variable of students' enjoyment of learning science, students' self -efficacy in science, students' instrumental motivation, students' Inquiry-based instruction in science lesson, students'epistemic beliefs correlated each other yet the five variables did not correlate with the economic, social and cultural index of the students.

The influence of students' enjoyment of learning science, students' self-efficacy in science and Students' epistemic beliefs on students' environmental awareness was consistent with the results of previous studies (Le Hebel et al., 2014). For Indonesian students, it was seen that the Students' epistemic beliefs had less influence on environmental awareness than students' enjoyment of learning science and students' self-efficacy in science. The research results showed that motivation had a strong influence on environmental awareness as shown by previous research (Hansla et al., (2008), Harju-Autti, 2013). The inquirybased instruction in a science lesson on Indonesian students also contributed a strong influence on environmental awareness. This was in line with several previous studies that inquiry-based learning gave a positive effect on students' environmental awareness (Saricam & Sahin, 2015). Referring to the previous studies (Alves et al., 2009), the science proficiency of Indonesian students have proven to possess a strong direct influence on environmental awareness.

Previous studies have proven that socioeconomic status encouraged environmental awareness, but this could not be found in Indonesian students where the economic, social and cultural index had a negative effect of 0.04 on environmental awareness (Coertjens et al., 2010; Erbas et al., 2012). The results of this study indicated that Indonesian children of higher socioeconomic status possessed lower environmental awareness. This was supported by several studies which showed that environmental awareness is strongly influenced by children's culture, family, school characteristics, and social interaction (Zecha, 2010; Duarte, 2017). For Indonesian students, it concluded that community culture, school culture, and social interaction were likely to have a stronger influence on students' environmental awareness than socioeconomic status. It means that the community culture, school culture and social interaction of Indonesian students did not support the development of an environmental awareness attitude. However, the economic, social and cultural index of Indonesian students turned out to be very greatly impacted the science proficiency of 0.04%. The relationship between environmental awareness and science proficiency of Indonesian students is presented in Table 5.

Table 5. The Relationship between Environmen-
tal Awareness and Science Proficiency of Indone-
sian Students Referring to the 2015 PISA

No	Influence (standardized)	Direct	Indirect	Total
1	PVSCIE ENVAWARE	0.11	0.00	0.11
2	ENVAWARE PVSCIE	-0.28	0.01	-0.27

The above Table 5 informs that the direct influence of science proficiency on environmental awareness was 0.11. This means that the higher the science proficiency of Indonesian students, the higher the environmental awareness. Therefore, the research results concluded that science learning in Indonesia emerged a positive impact on the students' environmental awareness. Meanwhile, the effect of environmental awareness on science proficiency was -0.27 which means that the higher the environmental awareness, the lower the students' science proficiency. However, on its indirect influence, the environmental awareness gave a positive effect of 0.01 on Indonesian students' science proficiency. This was due to the strong correlation between ESCS and science proficiency, as well as the negative correlation between ESCS and environmental awareness. In addition, this research provides a recommendation for implementing the environmental education intensively as a separate subject to reach a parallel increase of environmental awareness and science proficiency.

The correlation level within the variables involved in this study is presented in Table 6. It appeared that there was a fairly strong correlation between the Inquiry-based instruction in a science lesson with the students' enjoyment of learning science, students' self –efficacy in science, students' instrumental motivation, and students' epistemic beliefs. Also, there was a strong correlation between the students' enjoyment of learning science with the students' self-efficacy in science, students' instrumental motivation, and students' epistemic beliefs. Similarly, a strong correlation was shown between the students' instrumental motivation with the students' self –efficacy in science and students 'epistemic beliefs. In addition, there was also a strong correlation between the students' self–efficacy in science and the students' epistemic beliefs.

				-				
	ENVAWARE	PVSCIE	IBTEACH	JOYSCIE	INSTSCIE	SCIEEF	EPIST	ESCS
ENVAWARE	1							
PVSCIE	-0.08	1						
IBTEACH	0.55	-0.07	1					
JOYSCIE	0.74	-0.07	0.57	1				
INSTSCIE	0.71	-0.08	0.57	0.8	1			
SCIEEF	0.68	-0.07	0.54	0.74	0.83	1		
EPIST	0.58	-0.06	0.46	0.63	0.72	0.74	1	
ESCS	0.01	0.4	0.02	0.00	0.00	0.02	0.00	1

Table 6. The Correlation between the Variables Influencing Environmental Awareness

There were several weaknesses of this research both methodologically and substantially. The use of path analysis is basically referred to the correlational analysis. Furthermore, the disadvantage of statistical correlation analysis is its dependence on sample size. If the sample size is too large, the correlation coefficient decreases, while if the sample is small, the correlation coefficient rises. This study employed a sample size up to 6513 students so that the actual correlation would be higher than the correlation coefficient appeared in the analysis results.

Environmental awareness measurements in the 2015 PISA study were carried out by analyzing the students' condition whether or not they knew the information related to environmental issues. The environmental issues used in the 2015 PISA Survey included: (1) the increased greenhouse gases in the atmosphere; (2) the use of genetically modified organisms; (3) nuclear waste; (4) the consequences of deforestation for land; (5) air pollution; (6) the extinction of plants and animals; and (7) the lack of water. This is certainly less comprehensive to see the students' environmental awareness aspects since it contains not only cognitive aspects but also other dimensions like affective, cognitive, disposition, and active (Lafuente & Sánchez, 2010).

There is something interesting from the results of this study that socio-economic had a negative effect of -0.28 on the environmental awareness of Indonesian students. This means that the higher the socioeconomic status of Indonesian students, the lower their environmental awareness. There needs to be further research related to this because in general the higher the socioeconomic status the higher the level of environmental awareness as in Australia (Thomson et al., 2017), Turkey (Öztürk, 2018) and in most PISA 2015 participating countries (OECD, 2016a). This is reinforced by research using primary data in Malaysia that students with a more complete background of facilities and learning resources will have higher attitudes, knowledge and environmental awareness (Aminrad et al., 2013).

CONCLUSION

The 15-year-old Indonesian students' environmental awareness based on the 2015 PISA results was positively influenced directly by (1) the students' enjoyment of learning science; (2) the students'self -efficacy in science; (3) the students' instrumental motivation; (4) the inquirybased instruction in science lesson; (5) the students' science proficiency; and (6) the students' epistemic beliefs. Science learning in Indonesia has proven effective in increasing the students 'environmental awareness as evidenced by the research results showing that Indonesian students' science proficiency contributed a positive influence of 0.11 on environmental awareness. Meanwhile, Indonesian students with higher socioeconomic status possessed lower environmental awareness. There was a quite large correlation of >0.5 between the students 'enjoyment of learning science, students' self-efficacy in science, students 'instrumental motivation, Inquiry-based instruction in science lessons, students' epistemic beliefs with the environmental awareness.

Indonesian science learning requires to strengthen those six aspects to increase their environmental awareness. Further, it is necessary to strengthen the environmental education materials so that Indonesian students' increase in environmental awareness will be in line with science learning achievements at school. Further research is needed as several studies indicated that environmental awareness is strongly influenced by children's culture, family, school characteristics, and social interaction (Zecha, 2010; Duarte et al., 2017; Lee & Shi, 2014).

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THE IMPLEMENTATION OF CONTEXTUAL LEARNING TO ENHANCE BIOLOGY STUDENTS' CRITICAL THINKING SKILLS

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ABSTRACT

One of the life skills exceedingly be required in the globalization era is critical thinking skills; therefore, every level of education has a role in enhancing critical thinking skills of students, especially biology students'. This research aimed to determine the efforts to enhance the critical thinking skills of students' in biology subject through a Contextual Teaching and Learning (CTL). This research used a quasi-experimental method with a total sample of 62 X grade students at SMA Negeri 4 Sintang. The data of critical thinking skills were obtained from pre- and post-test results with essay test instruments. The data were analyzed descriptively employing an inferential statistic with T-test. The inferential statistical analysis revealed that there was a difference in the critical thinking skills between the CTL learning and the expository learning (t = 5.98 > 1.83). The posttest average score of students' critical thinking skills in the CTL learning was 82.56 and categorized as very good. The post-test average score in the expository learning was 68.37 and categorized as fair. The average score of critical thinking skills in the CTL learning increased by 36.06 while the average score of critical thinking skill in the expository learning increased by 19.42. The results of this research concluded that CTL learning was better to enhance the critical thinking skills of students' in biology subject on the learning material of environmental pollution.

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Keywords: critical thinking skills, CTL learning, biology education

INTRODUCTION

The low quality of education can be seen from teachers' teaching styles. In general, the learning process in high school level remains to use conventional learning such as textbook and teacher-oriented which result in a passive and unrelated learning to real life. Consequently, students' critical thinking skills are not developed well and finally influence their learning outcome. This is line with Wulandari et al. (2015) who stated that the low students' critical thinking skills were initiated by passive learnings. The low critical thinking skills can be seen from a research

*Correspondence Address E-mail: ybustami07@gmail.com conducted by Muhlisin (2012) which revealed that 80,9% biology students' critical thinking skills belonged to a low category. Furthermore, Fuad et al. (2017) showed biology students' critical thinking skills scored only 21.89 averagely and categorized as low.

The low biology students' critical thinking skills were caused by less optimal learning strategy, models, method and process (Bustami & Corebima, 2017). The field facts explained that teachers commonly employ expository learning. Teachers become the primary source and informant, resulting in active teachers yet passive students. In addition, students were not given much opportunity to express their opinions on the concepts being studied. This certainly can cause the students' low critical thinking skills. This is parallel to Hairida (2016) that a teacher-centered teaching-learning process could not improve students' critical thinking skills.

Anazifa & Djukri (2017) said that learning activities in schools have not yet improved students' critical thinking optimally. More importantly, the increase in students' creativity and critical thinking skills in learning biology has not been a serious concern in the learning activities. Research by Choy & Oo (2012) showed that many students' could not think critically because their teachers could not integrate critical thinking into their instructional practices every day. Muhlisin et al. (2016) also explained that the learning method or learning model used is less able to critical thinking skills develop. This was in tune pinion Corebima (2016) revealed that the learning process of biology is almost certainly not interested in empowering critical thinking skills of learners.

In fact, one of the life skills required in this globalization era is critical thinking skills (Khasanah et al, 2017; and Anazifa & Djukri, 2017). The critical thinking skills is an essential skill in life and the working world; also, it has an effective function in all other aspects of life to improve human beings quality. According to Abed et al. (2015) and Wartono et al. (2018), critical thinking skills are a superior ability which plays an important role in all aspects of life. The critical thinking is a reasoned, reflective thinking emphasizing on making decisions about what to believe and do (Novitasari, 2015). Learners having critical thinking skills will be able to ask the right questions, give effective and efficient information, have a plausible reason, be creative, incorporate relevant problem-solving, make decisions, and have consistent as well as credible conclusions (Bustami, 2009; Ku, 2009; Fisher, 2009; Carter et al., 2016). In addition, Facione (2010) said that the core of cognitive skill is the critical skill, and Corebima (2009) explained the test indicator achievement is basically the effect of the success of critical thinking.

Based on the above facts, it is important to improve biology students' critical thinking skills through various innovative learnings. Innovative learning can make the students actively involved in learning, to do a collaboration and self-directed learning. Innovative learning could shift the educational paradigm from teaching to learning and from teacher-centered to student-centered (Bustami & Corebima, 2017; Karim et al., 2018). One of the innovative learning strategies is a Contextual Teaching and Learning (CTL). According to Khoiron & Sutadji (2016), CTL is a learning process that helps teachers to associate the teaching materials with real situations and encourage the students to arrange a scientific approach and apply it in daily life. CTL enables students to connect the content of teaching materials with the daily context to find the purpose of learning (Susialita, 2016). The CTL concept was also revealed by Muslich (2009) and Rusman (2011) who elucidated that contextual learning helps teachers in connecting what is conveyed using a different world of students and encourages the students to think by discovering and connecting their knowledge to the surrounding reality.

On the other hand, CTL also allows students to work together and share ideas as well as encourage students to be confident to express their opinions and be able to explain the results of the discussion in front of their friends. Group discussion provides opportunities for students to participate and think together to complete learning tasks to understand the studied materials and prepare to present answers (Wulandari et al., 2015). The characteristics and stages of CTL allow biology students to enhance critical thinking skills.

Considering the importance of critical thinking skills and the need of active learning by linking the learning materials to the real-world situations, it is necessary to conduct a research on the implementation CTL learning to improve biology students' critical thinking skills in learning environmental pollution. This research aimed to enhance biology students' critical thinking skills through CTL learning. The research hypothesis was that CTL learning could enhance students' critical thinking skills in biology subject.

METHODS

This research used a quasi-experimental method with pretest-posttest non-equivalent groups design consisting of two classes, namely experimental and control class aiming at comparing the critical thinking skills of biology students' in the experimental and control class. Each class was given a pretest and a posttest using the same test items related to students' critical thinking skills in environmental pollution subject. The treatment class was taught by using the CTL learning, while the control class was taught by using expository learning. The differences in learning activities between the two classes are presented in Table 1.

Table 1. The Differences between	CTL and	Expositor	y Learning
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CTL	Expository Learning
1.Introduction Teacher states the learning objectives	1. Preliminary Teacher states the learning objectives
2.Invitation Students express their prior knowledge associated with their real-world situations	2. Presentation Teacher delivers abstract material to students verbally.
3.Exploration Teacher gives a problem to students to be solved cooperatively in groups through investigation activities	3. Exploration The teacher gives a problem and the students solve the problem individually through student worksheet (LKS).
4.Explanation and Solution Students present the results of their investiga- tion and do question and answer session among the groups accompanied by the teacher	4. Recitation Students do the exercises on the student work- sheet (LKS) given by the teacher
5.Taking Action Students make decisions or conclusions based on their own knowledge	5. Drawing Conclusion The teacher draws a conclusion on the learning material
6.Closing Students work on the quizzes given by the teacher individually	6. Closing Teachers provide reinforcement by asking questions orally to students
The population in this research was all X grade students of SMA Negeri 4 Sintang consisting of 3 classes; XA, XB, and XC with the total of the population was 97 students and the total of the sample was 62 students. There were 32 students in the experimental class (XB), and	teria of critical thinking skills, and feasible to be utilized as the research instrument. The data were analyzed descriptively based on the average score, then an inferentia statistic with T-test was carried out. Before the t-Test, a prerequisite test was done; a normality

30 students in the control class (XC). The sampling techniques of the experiment class employed simple random sampling. This technique was chosen because each sample had similar capability derived from the placement test analysis results.

The data collection instrument was in the form of test questions. The test questions were essay tests related to indicators of critical thinking skills. The students' critical thinking skills were measured based on the indicators developed by Richard Paul and Linda Elder (Ege, 2010) from the Foundation for Critical Thinking which covers: (1) questions to the problems, (2) objectives, (3) concepts, (4) assumptions, (5) information, (6)interpretation and drawing conclusions, (7) points of view, (8) implications and causes. The test items had been validated by an expert team and had been tried out to know the validity and reliability of test items. The results of the validity calculation showed that the t-count was larger than the t-table (the validity value of the t-count was 55.76 and the reliability of the r-count was 299.81). This means that the test items were already valid and reliable so that they met the cri-

v 1 e and homogeneity test. The test results on both pretest and the posttest for each sample from the population were normally and homogeneously distributed (value: p>0.05). Therefore, it could be proceed to the parametric analysis (hypothesis test) through T-test.

RESULTS AND DISCUSSION

The average score of critical thinking skills of biology students was obtained from the pretest and post-test average scores of class XB and XC. The range of critical thinking skill categories is presented in Table 2.

Table 2. The range of Critical Thinking Skill Categories

No	Range	Categories
1	80 -100	Very good
2	70 - 79	Good
3	60 - 69	Fair
4	50 - 59	Low
5	\leq 49	Very low

The descriptive results showed that there was an increase in the average score of students' critical thinking skills in biology subject both in the experimental (CTL learning) and control class (expository class). The average score of biology students' critical thinking skills in CTL learning was bigger than in expository learning. The detailed explanation of the increase is presented in Table 3.

 Table 3. The Pretest and Posttest Average Score of Biology Students Critical Thinking Skills

No.	Learning Method	Sc	ore		
		Pre- test	Post- test	Increase	
1	CTL	46.50	82.56	36.06	
2	Expository	48.95	68.37	19.42	

The descriptive analysis results in Table 3 show that the pre-test average score of in the experimental (CTL learning) and control class (expository class) categorized as low. The pre-test average score in CTL was 46.50 and in the expository learning was 48.95. The post-test average score of students' critical thinking skills in CTL was 82.56 and categorized as very good while in the expository learning was 68.37 and categorized as fair. The critical thinking skills of students' average score in CTL increase by 36.06 while in the expository learning increased by 19.42. The increase of students' critical thinking skills in biology subject could be illustrated in Figure 1 showing that the average score of students' critical thinking skills before and after the learning was different between the CTL and expository learning.



Figure 1. The Histogram of Biology Students' Critical Thinking Skills Average Score

The research results showed that CTL could enhance biology students' critical thinking skills. These research results are in line with the research conducted by Komalasari (2012) and Sugiarti (2012) which elucidated that there was an increase in students' critical thinking skills through CTL. Other researchers have also shown that there was an increase in students' critical thinking skills on colloids concept by using the CTL (Wulandari et al., 2015). The improvement of critical thinking skills could not be separated from the selected approach; CTL. The learning process employing CTL requires students to be brave to actively participate in exchanging ideas, expressing their opinions and explaining the discussion results in front of their friends (Wulandari et al., 2015). The courage to express opinions sharpens the students' critical thinking skills. In addition, according to Ridhayani & Manurung (2010), CTL could improve students' conceptual understanding since it is supported by the increased of students' critical thinking skills.

The purpose of T-test was to describe whether there were differences of the critical thinking skills average score between the biology students' in the experimental and control class. The recapitulations of the T-test results are presented in Table 4.

Table 4. The Pre-test and Post-test Analysis of Critical Thinking Skills (CTS)

Test	t-count	t-table (0.05)	Description	Conclusion
Pre-test of experimen- tal and control class	-0.58	1.83	H ₀ accepted	No difference of critical thinking skill
Post-test of experi- mental and control class	5.98	1.83	H ₁ accepted	There was a difference of critical thinking skill

The T-test results analysis of the pretest showed that there was not any difference in the critical thinking average score in both the experimental and control class are displayed in Table 4. The analysis results revealed that the t-count was smaller than t-table. Thus, the requirements of quasi-experimental research were met, and that both the experimental and the control class must have the same thinking skills. The T-test results for the posttest data in Table 4 indicated that there was a different average score between the students in the experimental and control class on the environmental pollution subject. The t-count was higher than t-table; thus, it concluded that CTL was better than the expository learning in improving students' critical thinking skills. This research is in line with the research conducted by Manao (2013) and Kurfiss (1988) that students' critical thinking skills with CTL were significantly different from those in conventional learning. This corresponds to the opinion of Johnson (2002) who revealed that CTL was more productive and able to reinforce students' conceptual understanding because CTL embraces a constructivism, in which the students are led to discover their own knowledge.

On the other hand, the stages of CTL enable to encourage critical thinking skills. The CTL stages such as invitation and exploration stage would support students to express their initial opinions within a group so that they will be trained in giving their arguments about the studied materials. According to Ariyanti et al. (2013) learners who often exchange ideas, information, and argument in groups would increasingly form critical thinking skills.

In addition, the explanation and solution stage require students to conduct an investigation in groups. These stages urge students to be cooperative in conducting an investigation in order to be able to solve the given problem. This is similar to DeHaan (2009) that discussion and mutual help in solving problems will hone students' critical thinking skills. Stage of explanation and solution also encourage students to interpret, analyze, interpret and assume existing data. Interpretive skills of analyzing, interpreting and assuming are the hallmarks of critical thinking. Finally, the last stage was taking action. Here, the students are trained to make decisions and draw conclusions. Contextual learning could provide opportunities for the students to improve, extend, and apply their knowledge and skills in various activities both in schools and daily life. Contextual learning emphasizes higher-order thinking and knowledge transfer by gathering, analyzing, and synthesizing information from different points of view (Burhanuddin, 2012). In other words, CTL requires the students' to experience rather than memorize, to think, and to be active. As a result, they were able to construct knowledge based on their own experience.

CONCLUSIONS

Based on the analysis results and discussion, it concluded that the critical thinking skills' average score of the students in Biology before the implementation of CTL was very low. However, after the students experienced learnings with CTL, their scores enhanced and categorized as very good. Moreover, there was a difference in the average score of critical thinking skill posttest in the experimental (CTL) and control class (expository learning). In addition, the students' critical thinking skills who learned using CTL were better as well as significantly different from those who learned to employ expository. Thus, CTL was better than the expository learning in improving students' critical thinking skills, particularly on the environmental pollution topic.

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THE NEED ANALYSIS OF MODULE DEVELOPMENT BASED ON SEARCH, SOLVE, CREATE, AND SHARE TO INCREASE GENERIC SCIENCE SKILLS IN CHEMISTRY

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ABSTRACT

Science generic skill is very important for students to solve every problem in learning processes and daily life. The purpose of this research was to explore the students' needs of the chemistry module based on search, solve, create, and share (SSCS) to increase science generic skills. This research employed a descriptive qualitative method. There were 61 students in XI Grade from two Senior High Schools at Surakarta. The data were collected using questionnaires sheets, interviews, and materials analysis. The research revealed that the module and teaching materials used in the schools have not empowered the science generic skills maximally; also, the teachers remained to adopt discourse method which resulted in a teacher-centered learning. Such learning made the learning activities seemed monotonous, uninteresting, and less motivated the students in building concepts. Thus, the students required alternative teaching materials to increase their science generic skills. In sum, it is necessary to develop a chemistry module on the atomic structure which oriented to the SSCS.

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Keywords: chemistry module, science generic skill, SSCS model

INTRODUCTION

A curriculum is, of course, a cultural product, and liable to shift in response to social trends and fashions (Taber, 2016). One of the Indonesian Government efforts to advance education is issuing the 2013 Curriculum. It is a student-centered learning which trained 3 aspects of knowledge, attitude, and skills. The 2013 curriculum is applied to all subjects in schools including the chemistry subject. Fin et al., (2008) defines chemistry as a branch of natural science (science), with regard to study the structure and composition of matters, changes that can be experienced by the materials and other phenomena

*Correspondence Address E-mail: deanitanastiti@gmail.com which accompany material changes. The content of chemistry in the form of concepts, laws, theories, is basically the product of a series of processes using a scientific attitude. These three aspects of chemistry are equally important since there will be no chemical knowledge without a process involving chemists thinking and scientific attitude

The content of chemistry and 2013 curriculum has the same targets that must be possessed by students, namely aspects of knowledge, attitude, and skills. Studying chemistry can support the development of thinking skills, teamwork, communication skills, creativity, and metacognition (Taber, 2016). The success of increasing students' understanding of science can be assessed from their fundamental ability while they are in the learning process (National Research Council, 2000). This initial ability is known as generic science skills. Generic science skills are intellectual abilities arising from the combination or complex interaction between science knowledge and skills (Tawil & Liliasari, 2014). Generic science skills emerge with the development of knowledge and skills within disciplinary areas of various

sciences (Pitman & Broomhall, (2009). The generic science skills have an important role in supporting learning, especially in science learning to emphasize the aspects of the learning process (Agustina, 2016). The science generic skill indicators according to Brotosiswoyo in Tawil & Liliasari (2014) are shown in Table 1.

Table 1. Generic Science Skills Indicators According to Brotosiswoyo (2000)

Generic Science Skills	Indicators		
Direct observation	Using as many senses as possible in observing natural experiments/phe- nomena Gathering the facts of the experiment or the natural phenomenon Searching for differences and similarities		
Indirect observation	Using a measuring instrument as a sensing device in observing experiments or natural phenomena Collecting facts from experimental results of physics or natural phenomena Looking for differences and similarities		
Awareness of the scale	Recognizing natural objects and high sensitivity to numerical scales as microscopic or macroscopic scales		
Symbolic language	Understanding symbols, symbols, and terms Understanding the quantitative meaning of units and magnitudes of equa- tions Using mathematical rules to solve problems or phenomena of natural phe- nomena Reading a diagram, table, and mathematical mark		
Logical frame	Looking for a logical relationship between two rules		
Logical consistency	Understanding the rules Rule-based arguments Describing the problem based on the rules Drawing the conclusions of a phenomenon based on rules or preceding laws		
Cause and effect law	Expressing the relationship between two or more variables in a certain natu- ral phenomenon Estimating the cause of natural phenomena Revealing phenomena or problems in the form of sketches of images or graphs Expressing phenomena in formulas Applying alternative problem solving		
Mathematical modeler	Expressing the relationship between two or more variables in a certain natu- ral phenomenon Estimating the cause of natural phenomena Revealing phenomena or problems in the form of sketches of images or graphs Expressing phenomena in formulas Applying alternative problem solving		
Building concepts Abstraction (Sudarmin, 2007)	Added a new concept Describing or abstracting abstract concepts or events into the real-life every- day life Creating visual animations of abstract microscopic events		

People realize that science generic skill is important, yet its implementation is not as expected (Faradilla et al., 2018; Ramlawati et al., 2014). The results of observations conducted at two high schools in Surakarta showed that teachers have not trained students' skills in learning activities. The questionnaires and interviews revealed that chemistry teachers knew that they lacked empowering students' generic science skills. The teachers only trained some indicators of generic science skills such as direct observation, indirect observation, symbolic language, and awareness of the scale (Nastiti et al., 2018). The interview with the chemistry teachers at both schools revealed that they had no idea what learning model/ method s/he was using. However, the observation results made clear that the teachers applied the discourse methods which oriented to knowledgetransferring only without any students' involvement. Although the teachers have developed their own teaching materials and module, yet the analysis showed that those learning tools have not yet empowered students' skills maximally. Therefore, the teachers need an alternative module with learning method oriented to empower the students' generic science skills.

The efforts to support the teachers to maximally increase students' generic science skills inspired the researchers to develop a module based on the SSCS model (Search, Solve, Create, and Share) for the atomic structure and the periodic table of elements. The SSCS model is one of the learning models that can increase students' skills, especially generic science skills. A handbook by Pizzini (1991) describes the sense of the four stages of SSCS, and the 'search, was a factfinding process in discovering who, what, where, and how. 'Solve' means finding the alternative sorting out the will used in solving a problem as well as planning the problem-solving steps. Next, 'Create' is the implementation of plans determined on the 'solve', i.e. by using use creative thinking and analytical skills. The last stage is 'Share' that is communicating solutions of the problem with colleagues (Pizzini, 1991). The adaptation of the four SSCS model in the learning process was expected to increase the students' interest, vivacity, creativity, and communication skills; also, affect the students' generic science skills. This corresponds to some research indicating that there was an improvement of students' skills and conceptual understanding after joining a learning using the SSCS model (Kurniawati & Siti, 2014; Rosawati & Dwiningsih, 2016; Yusnaeni et al., 2017). Based on the problems above, this research intended to make an early analysis of the students' need for an SSCS-based chemistry module.

METHODS

This research employed a descriptive qualitative method. The purpose of this research was to explore the students' needs of the chemistry module to increase generic science skills. The purposive sampling technique was applied to select the participants (Sugiyono, 2013). The participants of this study consisted of 61 students from two senior high schools in Surakarta, Indonesia. They were XI grader who learned the atomic structure and periodic table of elements. Furthermore, seven chemistry teachers involved in the interview stage to ensure the validity of data. The data were analyzed with the percentage calculation by the following formula (Ali & Asrori, 2014).

$$\mathsf{P} = \frac{n}{N} \ x \ 100\%$$

Description :

P = Percentage score (%); n = Number of scores obtained; N = Maximum score

The instruments used in this research were questionnaires, interview guidelines, and materials analysis. The questionnaires were handed out to the students and teachers. The validity test adopted Aiken's formula resulted in the value of 0,87 -1,00 and the average value of 0,89. Hence, the contents were declared valid by five validators (Aiken, 1985). The students' questionnaires consisted of 13 questions (4 questions about learning method, 5 questions about learning materials, 2 questions about teachers' method in the learning process, and 2 questions about students' needs).

The students' interview guideline covered 9 open-ended questions to find out their reasons for giving yes or no answer for each question. The interview aimed at finding out information about the process of learning activities and problems faced during learning. The teachers' interview guidelines comprised 19 open-ended questions about teaching-learning processes, teaching materials, students' skills, teachers' needs, and outcomes from the learning process. The analysis of teaching materials and module was adapted from BSNP 2016 assessment textbook which integrated the aspects of generic science skills. The analysis results of the adopted teaching materials and module intended to know the extent of fulfillment of each generic science skill indicator in two Senior High Schools at Surakarta.

RESULTS AND DISCUSSION

The observation was done for collecting information directly about the learning process in two Senior High Schools in Surakarta. It revealed during the observation that the teachers remained to apply the discourse method in learning process. The students were given handouts of learning materials developed by the teachers. However, the teachers' were more active than the students, which did not give tangible impacts on the increase of students' potentials. Such method led to the lack of students' activity. Instead, they only listened and recorded information obtained from the teachers' long explanation.

Questionnaires were given to the students to seek information about their needs of chemistry module. The questionnaires pertained to the students' learning style, needs, learning materials, and teachers' the teaching methods. The results of the questionnaire analysis were reinforced with the results of interviews with the students. As many as 95% of the students were enthusiastic about following the chemistry lesson though they considered it one of the most difficult subjects requiring high-level of intention. This corresponds with Ardiansah (2016) who agreed that chemistry is a misconception-prone subject as there are a dozen analogies for students to be understood. 73% of the students stated chemistry subject is difficult because of many materials and abstract formulas contained in it. Moreover, previous studies have revealed that students only completed general chemistry yet lacked a conceptual understanding of several fundamental topics (Cracolice et al., 2008; Burrows & Mooring, 2015). Learners may have difficulties in differentiating between key aspects of different atomic models; for example, confusing electron shells and clouds (Ruengtam, 2013).

The students, through the questionnaires, stated that they performed practicums in chemistry classes. The availability of laboratory and library have helped them to understand the chemistry concepts (73%), the students used textbooks or other handbooks to learn about chemistry concepts (65%) such as student worksheets (45%) and textbooks available on bookstores (34%). The students (67%) had difficulties in studying the chemistry concepts from books due to its elusive comprehensiveness and explanatory techniques. Most of them (96%) said that although the teachers have employed special teaching materials in learning chemistry concepts such as module, student worksheets, and power points, it did not give many contributions to their comprehension of the atomic structure and the periodic table of elements (83%). The students (63%) declared that the atomic structure and the periodic table of elements were elusive, abstract materials.

Below is presented in Table 2 the data of the National Examination analysis at both upper secondary schools in Surakarta during the last 3 years (BSNP, 2016).

Table 2. The Percentage of National Examination on Questions of Atomic Structure and PeriodicTable of Elements in Two Schools in Surakarta

Indicators of Subject	Academic Year	Sch	Cit/Reg	Prov	Nat
Determine the element notation and its relation to	2013/2014	55,73	63,30	60,09	65,09
atomic structure, electron configuration, chemical bonding type, molecular formula, molecular form, and the nature of the compound it produces, and the location of elements in the periodic table.		54,00	63,30	60,09	65,09
Determine the element notation and its relation to	2014/2015	57,93	62,74	50,59	59,60
atomic structure, electron configuration, chemical bonding type, molecular formula, molecular form, and the nature of the compound it produces, and the location of elements in the periodic table.		36,96	62,74	50,59	59,60
Given an elemental notation from 2 different classes,	2015/2016	55,90	51,60	53,54	43,89
learners can choose the most appropriate statement about the different properties of the two elements ap- propriately.		41,11	51,60	53,54	43,89
Given a picture of the periodic system of elements		68,94	74,43	72,37	67,94
with elemental notation, learners can determine the exact configuration of electrons, atomic numbers, and atomic numbers.		54,74	74,43	72,37	67,94
Given the following elemental notation of the atomic		73,29	71,91	63,94	58,77
number, learners can define the graphic that indicates the specified nature of the specificity correctly.		50,53	71,91	63,94	58,77

Description:

Sch= School; Cit/Reg= City/Regency; Prov= Province; Nat= National

A central concern in chemistry education is students' understanding and knowledge (Taber, 2014). The students' knowledge of the atomic structure is built in schools while their understanding of scientific terms might be supported by the learning sources used both inside and outside the class (Zarkadis et al., 2017). Nevertheless, the National Examination analysis showed that the atomic structure and the periodic table of elements materials at two senior high schools in Surakarta were not able to achieve the city/regency, province, and national average value. This means that chemistry learning in the school was not run well. In addition, the result of an interview with some students suggested that the students found it difficult to comprehend such abstract matters like protons, electrons, neutron, isotope, and theories of atom, determining of quantum numbers, configuring electrons of several atoms, determining periods and classes of an atom by atomic number and quantum number.

The students (98%) stated that they had been given teaching materials in the form of modules to study the atomic structure and the periodic table of elements. One of the teachers of the two senior high schools has developed a chemical module on atomic structure materials and the periodic table of elements, but the module has not been model-specific to train students' generic science skills (Tawil & Liliasari, 2014). The highest percentage of generic science indicators achievement was 66.6% for the two from the ten indicators of atomic structure and the periodic table of elements, while the other material indicators were below 50%. However, more than 50% of the students stated that the module was enough to help in understanding the atom structure and the periodic table of elements but 83% of students stated that they remained to have difficulties in understanding the atomic structure and the periodic table of elements through teaching materials and methods applied by the teachers. Moreover, languages seemed to be another burdensome as they mostly did not understand the terms used in the textbook.

The students (95%) said they had never been taught using Search, Solve, Create, and Share (SSCS) learning model. Most of the teachers still used direct instruction strategy and discourse method when teaching their students. The teacher assumed that with these strateges, the subject-transfer would be fast and match with the estimated time. Therefore, according to the 2013 Curriculum, learning should be carried out using the student-centred learning model, and one of which is the Search Solve Create and Share (SSCS) learning model. The SSCS model helped the students to develop advanced cognitive abilities (Chen, 2013), such as creative thinking and generic science skills. The use of SSCS model has proven to give students' positive responses in the learning process and increase students skills (Mulyono & Lestari, 2016).

Most of the students (91%) stated that they need alternative teaching materials that can help the remaining materials of atomic structures and the periodic table of elements. The students (85%) agreed if there should be developed materials in the form of chemistry modules based on Search, Solve, Create, and Share (SSCS) makes it easier to understand the atomic structure and the periodic table of elements. Parmin & Peniati (2012) stated that modules are components that have an important role in the learning process. The availability of modules can assist students in obtaining information about learning materials. The research done by Burmeister & Eilks (2013) indicated that students who were given the module had a high post-test score compared to students who did not use any module in the lesson. Moreover, they also revealed that: (1) students were interested in using and reading the module; (2) module made students active in the learning process such as reading and understanding modules, asking and discussing with group friends, also, solving problems exist in the modules; and (3) students' problem solving skills increased after using metacognitive-based mathematics modules.

Based on the interview with seven chemistry teachers, it was known that the teacher used discourse method, question and answer method, and discussions as a method to transfer knowledge. All of the teachers have developed their own lesson plan, but science generic skills have not been included in the lesson plan. The schools did not yet support chemistry learning to increase students' generic science skills. On the other hand, the teachers stated that students' generic science skills belong to the low-moderate category (Nastiti et al., 2018). Some of the teachers (71%) developed teaching materials and module on atomic structure and the periodic table of elements, yet the material teaching and the module did not integrate with specific teaching method aimed at increasing students' skills. All of the teachers stated that the needed an alternative teaching materials which can increase the students' skills especially the generic science skills.

The development of SSCS-based module is necessarily done to improve the students' generic science skills. It is essential to enhance generic science skills since they can be applied across a variety of subject domains yet take longer to acquire than the domain-dependent (Lim in Anwar, 2014). Generic science skills are the combination of knowledge and skills related to cognitive, affective, and psychomotor (Wahyuni, 2016). Generic skills define as the set of skills or abilities essential to fulfilling the three potential outcomes of higher education, namely the needs and requirements of employers in the marketplace, lifelong learning, and good citizenship (Hadiyanto & Ibrahim, 2013).

Overall, based on the analysis results, the students need an SSCS-based Chemistry Module oriented to the increase of generic science skills. The learning process with SSCS method has proven to have a great influence on the students' roles in establishing their own competence and knowledge through search, solve, create and share stage (Rahayu et al., 2018; Khabibah et al., 2017).

CONCLUSION

The need analysis indicated that the school materials have not empowered science generic skills maximally. Further, the teachers remained to use discourse method which resulted in a teacher-centered, monotonous, uninteresting learning. Such method has proven to be unable to contribute to the students' generic science skills improvement seen from the last three-year National Examination results. Therefore, an SSCSbased chemistry module is greatly needed. It is expected that this new kind of module could foster the students' generic science skills with its strengths to meet the demand of the 21st-century.

This research plays a role as a reference for future research to develop the SSCS-based chemistry module oriented to the improvement of generic science skills. The developed module is expected to pay attention to subject indicators, generic science skills, and SSCS model.

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THE INFLUENCE OF LEARNING MODELS AND LEARNING RELIANCE ON STUDENTS' SCIENTIFIC LITERACY

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ABSTRACT

This research aimed to identify the influence of two learning models and learning reliance on students' scientific literacy. The method used was the treatment by 2 x 2 level. The participants were 36 students from the Department of Biology Education who were grouped into two categories based on the reliance questionnaire score, i.e., categories of high and low. The data were collected through scientific literacy tests, data analysis using two-path ANOVA formula followed by the Tukey test. The results showed that there was an influence on the interactions between the learning models and learning reliance on students' scientific literacy seen from the ANOVA test results which obtained F = 29.88, α = 0.05. The Tukey test analysis identified; (1) Scientific literacy of college students who used the Science, Technology, Society (STS) model was higher than those who adopted the Problem-Based Learning (PBL) Model with Q = 4,74 at α = 0.05; (2) The scientific literacy of students having high learning reliance using the STS learning model was better than those applying the PBL with Q = 11,78 at α = 0.05; (3) The scientific literacy of students having low learning reliance using the STS learning model was lower than those using the PBL with Q=5.07 at α = 0.05. It concluded that the STS learning model could improve the students' scientific literacy. In other words, the STS learning was more useful for the high reliance students than those with low reliance.

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Keywords: learning reliance, STS, scientific literacy

INTRODUCTION

The rapid development of science, technology, and society requires people to have necessary skills beyond reading, writing, and arithmetic skills to survive in life. The ability to read and write through the script, in the past several centuries generally interpreted as "literacy." Through education, it is expected to form science and technology-literate humans, as a bridge connecting to the environment to play a role as a human resource quality. The science referred to in this

*Correspondence Address E-mail: ratini.jamhur@gmail.com case is the "Science" concerning the object of nature (IPA), social, and technology. The various abilities of science mentioned above summarized in a concept called "Scientific Literacy." The purpose of scientific literacy education is to build a scientifical literacy society, that is, a social issue. Thus, the importance is not only the science concept mastery but also the thinking skills (Suwono et al., 2017; Holbrook & Rannikmae, 2009). Contended that scientific literacy extends beyond the mastery of foundational knowledge of scientific knowledge and apply it to relevant social contexts. Scientific literacy is a multi-literacy in which individuals must develop fluency in coordinating these multiple modalities of scientific representation at proper times in the curriculum, and when viewed from a critical standpoint, the science literature also includes the ability to question and appropriate scientific knowledge in personally relevant circumstances (Trauth-Nare, 2015; France, 2011; Toharudin et al., 2011).

Educational experts and practitioners continually strive to find the best solution to help students find the knowledge, skills, and attitudes needed in the life of society. Various learning models are built to get effective and efficient ways to achieve the goals of learning/education, such as learning model of Science, Technology, Society (STS). The STS learning model is a form of learning that combines understanding and utilization of science, technology, and society so that the concept of science can be applied through skills that benefit students and society (Klein et al., 2001; Owen et al., 2012). The STS learning model is developed to increase the literacy of individual scientists to understand how science, technology, and society influence each other, and to improve the ability to use knowledge in making decisions (Putra, 2013). The curriculum of primary education has included a study on the basis of attitudes, personality, and knowledge development like sanitation, nutrition, and health. Therefore, environmental literacy is essential to be developed among students. Future teachers are very potential to create the right environment because they will be the agents of change in society. Moreover, future teachers have to pass on ethical values and characters in order to the sustainability of the environment (Farida et al., 2017).

Irregularities in healthy behaviors continue to occur in some communities, for example: adding hazardous ingredients in food management, consuming liquor or drugs, and letting waste pollute the environment. It alleged that such deviations occur because the learning system (especially science) conducted in schools that did not achieve the proper learning objectives of science. The learning model applied only to the development of cognitive ability (textual), while the real problem faced in life is contextual and it has not yet mastered. The further analysis results of the 2009 PISA data for Indonesian children are as follows: (1) The achievement of scientific literacy of students is low, with the average of 32% for the overall aspect consisting of 29% for content, 34% for the process, and 32% for the context; (2) The diversity of students' scientific literacy among provinces in Indonesia is relatively low; and (3)

The ability to solve the problem of children in Indonesia is as low as Malaysia, Thailand, or the Philippines.

The level of students' scientific literacy that is considerably low caused by several factors, including school infrastructure, human resources, and school organization and management also influenced students' literacy achievement significantly (Ardianto & Rubini, 2016).

Field observations indicated that the discussion of chemicals in the classroom was limited to the content of the book/literature. There is no clear link between the material learned and the real problems that develop in the community. Derek Hodson Science Education is a form of indoctrination to a particular worldview so that young people do not question the underlying science. Derek Hodson Science education is incomplete if it does not involve students in preparing for and taking action on matters of social and political importance (Giordano, 2017; France, 2011; Sadler & Zeidler, 2009).

The results of interviews with students revealed that chemistry lessons are too abstract and elusive. Chemistry has been called the central science. Hence, the chemistry learning provides a unique context within which to consider the relationship between knowledge and social responsibility. This is what the public conscience of learners examined (Donald & Kovac, 2012). However, in the classroom, the lecturers presented several examples of problems in the community related to chemicals, but the students were not facilitated to investigate until they found a solution to problem-solving. The chemistry final examination results of the 2014/2015 academic year revealed that 113 students obtained the class average score of 50,5; the highest score was 77 and the lowest score was 28. Thus, it is considered necessary to optimize other learning models for enhancing the results of chemistry science learning.

In this study, the researchers believed that the STS learning model contributes to encouraging harmonious knowledge and skills through self-efficacy. Learners are parties who need to feel comfortable and fun in the learning process (Suparman, 2012; Akcay & Yager, 2010). Besides, teachers/lecturers are instrumental in conditioning facilities physically and mentally so that effective learning event is achieved. Learning reliance is seen as a person's autonomous capacity in selflearning. Self-learning does not mean learning alone, yet the self-study or independent learning with or without a teacher (Rusman, 2011; Toyokawa et al., 2017).
METHODS

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This research was conducted using the experimental method involving three kinds of variables, namely: scientific literacy as the dependent variable, learning model as the independent variable, and learning reliance as the attribute variable. There were two kinds of learning model applied; STS learning in the experiment class (A1) and Problem-Based Learning (PBL) in the control class (A2). Learning reliance (B) as the attribute variable covered two categories, namely high learning reliance (B1) and low learning reliance (B2). Thus, the design of this research was

"Treatment Design by 2 x 2 Level".

The target population in this study was all 930 students majoring in Natural Sciences Education (Mathematics, Physics, and Biology Education), Faculty of Education Sciences, Muhammadiyah Metro University. The available populations were 64 Biology education program students in the second semester of academic year 2015/2016. These students were split into two parallel classes; 32 students in Class A, and 32 students in Class B.

The STS learning model scheme is shown in Figure 1 and the PBL model learning scheme is displayed in Figure 2.



Figure 1. The Scheme of Science Learning Process with STS Model



Figure 2. The Scheme of Science Learning Process with PBL Model

The types of data collection instrument employed were: 1) test, to measure scientific literacy through multiple-choice and descriptive questions; and 2) questionnaires, to measure the self-learning data. The validity of data collection instruments was determined through validity and reliability test techniques. The validation tests were performed in two stages; (1) content validation; and (2) empirical validation. The content validation refers to an assessment of the extent to which the instrument represents the desired content.

The empirical validation conducted on the test on 33 Biology Education students in the 3rd semester who have studied carbon compound. The validity of multiple-choice items (dichotomized grains) was calculated using the Biserial Point correlation formula while the reliability coefficient was calculated using the Kuder-Richardson formula 20 (KR-20). The validity of essay test (polytomy items have no discrete score) was computed using Product Moment correlation formula, and its reliability was analyzed employing the Alpha Cronbach formula through a validation test instrument to measure scientific literacy. There were 40 items of valid and reliable multiple-choice items with the coefficient reliability of 0.8961. Moreover, 4 essay items were also valid with the Alpha Cronbach coefficient reliability of 0.4181. Valid questionnaires consisting of 33 items had the coefficient reliability of 0.8947. The learnings were carried out eight times in the experimental class and control class.

The operational differences in the learning between the two models are presented in Table 2. Some elements of learning activities carried out in the experimental class and control class were made similarly for the subject matter of the discussion including the materials (Hydro Carbonyl, Carbonyl, Amine, Benzene) and its derivatives as well as natural and artificial polymer compounds (plastics), Napza, Petroleum, and food additives. The classes were split into eight groups. The learning of each class lasted in 8 x 100 minutes.

Table 2. The Differences in Learning Operations in the Experimental and Control Class

Elements of	Ac	rities	
Learning	Experimental Class	Control Class	
Learning model	Science Technology Society (STS)	Problem-Based Learning (PBL)	
Core activities of learning (group)	Lecturer facilitates the process of prob- lem formulation in the society based on the investigation results.	Lecturer presents community's real prob- lem as a stimulus to generate an investiga- tion.	
	Looking for alternative troubleshooting solutions using brainstorming method.	Looking for alternative troubleshooting solutions using discussion method.	

The scientific literacy data of the test results were analyzed by descriptive statistics to obtain the mean/standard values, standard deviations, minimum values, and maximum values. The data analysis with inferential statistics was conducted to test the research hypothesis. The data analysis was done on the 2-way ANOVA (Two-Way Analysis of Variance). Before the statistical data analysis was carried out, a pre-requisite analysis was done to test the Normality using the Liliefors while the Homogeneity test adopted the Chi-square formula. As a result, each group of data was normally distributed, and the intergroup comparing had a homogeneous variant.

Table 4. The Scientific Literacy Scores

Self-Reliance		The Scientific Liter Based on Learn	- Total Lina	
Learning (B)	Data	STS (A ₁) (Class Experiments)	PBL (A ₂) (Class Control)	Total Line
		A ₁ B ₁	A ₂ B ₁	B ₁
	n	9	9	18
II air abt (D)	Mean	72.00	49.83	60.83
Height (B_1)	SD	4.74	8.89	12.35
	Max	79	69	79
	Min	65	40	40

		A_1B_2	A_2B_2	B ₂
	n	9	9	18
	Mean	36.89	46.28	41.94
	SD	6.51	10.41	9.98
Low (B_2)	Max	48	62	62
	Min	26	25	25
		A ₁	A ₂	
	n	18	18	
	Mean	54, 83	47.50	
Total column	SD	16.98	11.08	
	Max	79	69	
	Min	26	25	

RESULTS AND DISCUSSION

Below is presented the detailed explanation based on the data analysis results;

Test of Hypothesis 1

Student Scientific literacy Using the A_1 (STS learning model) was higher if compared to the class using the A_2 (PBL Model).

 $\begin{array}{l} A_1 \colon A_2 \\ \text{Hypothesis Statistic:} \\ H_0 & \vdots & \mu_{A_1} = \mu_{A_2} \\ H_1 & \vdots & \mu_{A_1} > \mu_{A_2} \end{array}$

Test Criteria: Reject H_0 if Sig < 0.05

It obtained F=4,75 at the significance level of 5% and F=4,07 at the significance level of 1%. Based on the test criteria, then the H₀ was rejected at 5% and 1% significance level, that was 'The average scientific literacy score of students who learnt using the STS learning model (STS; A₁) was 53,83 or significantly greater than those using the PBL model (PBL: A₂) 47,50.

Test of Hypothesis 2

The ANOVA results obtained p = 0,05; which means that there was an influence of the interaction between learning model and learning reliance to scientific literacy. Thus, it argues that the learning had a significant effect on the value of students' scientific literacy depended on its learning reliance.

After proving that the interaction between learning model and learning reliance affected the scientific literacy, the analysis continued with the Tukey test to test the simple effect, indicated by the mean differences between A in each group B; $(A_1B_1 : A_2B_1 \text{ and } A_1B_2 : A_2B_2)$.

Test of hypothesis 3

The scientific literacy of students who had higher learning reliance using the STS Learning Model A_1B_1 was higher when compared to those the PBL (A_2B_1) Learning Model.

 $\begin{array}{l} A_1B_1: A_2B_1 \\ \text{Hypothesis Statistic:} \\ H_0 & : \boldsymbol{\mu}_{A_1B_1} = \boldsymbol{\mu}_{A_2B_1} \\ H_1 & : \boldsymbol{\mu}_{A_1B_1} > \boldsymbol{\mu}_{A_2B_1} \end{array}$

Test Criteria: Reject H_0 if Sig < 0.05

The Tukey test resulted in the Q=11.78 (p 5%) and Q=4.60 (p 1%). Referring to the test criteria, then H₀ was rejected either at the significance level of 5% or 1%, which was: 'The scientific literacy of students having high self-reliance in the class employing the STS learning (STS; A₁B₁)= 72 or significantly higher than those using the PBL (PBL; A₂B₁) = 49.83.

Test of Hypothesis 4

Scientific literacy of students who had low learning reliance using the STS Learning Model (A_1B_2) was lower if compared to those using PBL Model (A_2B_2) .

$$\begin{array}{l} A_1B_2: A_2B_2 \\ \text{Statistical Hypotheses:} \\ H_0 \\ H_1 \end{array} : \begin{array}{l} \mu_{A_1B_2} = \mu_{A_2B_2} \\ \mu_{A_1B_2} < \mu_{A_2B_2} \end{array}$$

Test Criteria: H_0 is rejected if Sig > 0.05

The Tukey test obtained Q=-5.07 (p > 5%) and Q=4.60 (p >1%). Referring to the test criteria, then the H₀ was rejected either at significance level of 5% or 1%, it means that "Scientific literacy of students having low learning reliance in the class applying the STS learning model (STS; is the A,B_{2}) = 36.89 was lower than those in the class were

using PBL model (PBL; A_2B_2) = 46.28. The use of STS learning model in chemistry learning was more effective than the PBL model in improving the students' scientific literacy particularly in Basic Chemistry of carbon compound materials. The STS learning model has the main characteristic of discussing a community's real issues. The discussed problems are figured by the students as the basis for the next activity: investigation. The STS learning model embraces constructivism learning theory and is implemented through a contextual approach; thus, it makes the experience more relevant to real-life problems in society. Constructivism is a learning process that emphasizes the active, creative, and productive awakening of knowledge by prior knowledge and from meaningful learning experiences (Hosnan, 2014; Bonney et al., 2009). Constructivist views imply that a teacher's role is to co-collaborate, guide, facilitate and coordinate the learning process, while the student's role is to participate in the process of acquiring and constructing knowledge actively. Therefore, it enables students to actively create their knowledge based on their previous and new experience through investigation, questioning, discussing, and reasoning (Zhukova, 2017; OECD 2009; Leonard, 2002; McCoaghan, 2008). In line with that, Richey et al. (2010) stated that learning refers to the relatively permanent change in a person's knowledge or behavior due to experience. The learning model of STS gives the effect of accompaniment in the form of critical thinking skill improvement, higher-level thinking and problem-solving skills covering cognitive, affective, psychomotor, and religious aspects (Wisudawati & Sulistyowati, 2014).

The PBL model facilitates students to take an active role in the class through a series of activities to think about issues related to daily life, find procedures to find needed information, solve problems, and present solutions to the problems (Abidin, 2014; Lewinsohn et al., 2015). The problem-based learning model is similar to the STS learning model in terms of providing an authentic experience, constructing knowledge, and integrating the learning context in real life naturally in order to encourage the active learning process. The PBL and STS learning model place problematic situation as a learning center, attract and retain an interest of learners to be able to express their opinion in multi-perspective. The difference is that the issues discussed in the STS learning were excavated from the students, while the lecturer presents the problems discussed in the PBL lesson. This difference has proven to have a significant effect on the learning process and results.

Literacy of science defines as an understanding of science and its application in solving real problems in society. Many science topics have suggested for science education such as Climate Change, 'greenhouse gas' emissions from factories, modes of transportation, and energy generation stations. However, the researchers pointed out that there are many other science topics in life such as health and social justice, pharmaceuticals, biotechnologies, toxic chemicals, and agricultural research and practices (Dos Santos, 2014; Bencze, 2009; Cronin, 2010). Literacy enables the development of new and more powerful forms of understanding including science, mathematics, and technology (Tobin, 2015). PBL learnings impress as completion of learning tasks given by lecturers, while in the STS learnings, students solve the problem themselves. Scientific literacy development is enhanced when learning contextualized in an exploration of socioscientific issues (Bay et al., 2017). Students are excited about conducting field investigations, tracking information across multiple sources, pursuing several learning methods such as discussion, questioning, experimentation or demonstration. Literacy is constantly evolving, and how teachers must evolve with it (Botzakis, 2014).

The ANOVA test results showed that the significance $< \alpha 0,05$, which meant that there was a significant interaction between the learning model and the learning reliance on the scientific litearcy. The results indicated that learning models and learning reliance determined the succes of students' scientific literacy improvement in learning carbon compound materials. Any different learning model applied to students who have different level of learning reliance will achieve different scientific literacy.

Through the STS learning model, on the discussion of 'properties and benefits of polymer compounds', the students found out the idea that the use of plastics in everyday life is more appropriate for durable equipment. As for packaging of tableware or drinking, it should not use plastic for some reasons: 1) some common materials for food package (e.g., Styrofoam) could release plastic molecule particles when exposed to heat; (2) common plastic food packaging has a lifespan of only for 15 minutes, then disposed

of into trash. This would increase the amount of plastic waste on earth; (3) plastic waste has become a real pollutant for the soil and water environment as it is difficult to be decomposed by bacteria; (4) if the plastic is burned, it would cause smoke which is a pollutant of the air.

From this discussion, the students expressed their attitude as an alternative solution to the problems caused by the use of plastics: (1) avoiding plastic materials for packaging, food, and beverage equipment, also; b) avoid using a singleuse plastic material (e.g., crackle bags and straws) and replacing it with other (or plastics) durable materials; and c) creating posters to persuade people to use recyclable and decayable materials.

This finding is consistent with the results of previous studies; that STS learning on Colloidal (Chemical) materials at MAN Kuta Baro Aceh could improve learning results and obtain positive responses from the students. In the exploration stage, the students could explore critical issues in a local and global scope. At the concept application stage, they might define how to manage factory exhausting gas, purify water and minimize the use of materials that can cause river pollution. The students were happy to learn the colloid materials. Associated with daily life using STS learning, they were more curious, dared to ask for an opinion. Also, such learning is able to cultivate environmental awareness (Rintayati et al., 2014).

Chemical educators have a responsibility to equip students in developing the scientific and technological insights of the social dimension and help improve their ability to devise solutions to their impact. There are many situations in which the society looks to science for accurate information, and guidance. The examples in the modern world include the scientific discourses on the state of the ozone layer, the likelihood of catastrophic earthquakes, tsunamis, or volcanoes, and the threat of radioactive sources in the environment, and current international issues such as solid wastes, atmospheric pollution, deforestation, deforestation, biological warfare and human cloning (Donald & Kovac, 2012).

Further analysis of the ANOVA with Tukey test showed that Qcount = 11.78> Qtable = 3.20 at α 0.05 or 4.60 at α 0.01. Thus, the H0 was rejected, which meant that the scientific literacy average of students who had a high learning reliance using the STS learning model was 71.56, or significantly higher than the scientific literacy average of students who applied the PBL model which amounted to 49.33. In an issue-oriented classroom, students analyze and discuss personal, societal, and global issues that require an application of the relevant scientific evidence. Learning in the context of issues can help people in the global community (Lenz & Willcox, 2012).

The students with high learning reliance set a learning goal to improve the mastery of the materials and determine the success of learning by comparing it with the results that have been achieved by themselves before, not compared to the results achieved by his friend. Self-learning means learning in an initiative with or without a teacher (Rusman, 2011). The students with high learning reliance were more responsible for making decisions in their study groups while the students with low learning reliance were apathetic in their group (Wahyuni & Sunarno, 2012). There were two kinds of factors that influenced the learning reliance; internal and external factors. The internal factors included psychological factors such as self-efficacy, learning motivation, attitudes, interests, a focus on control, self-discipline, and learning habits. Meanwhile, the external factor comprised natural environmental, socioeconomic, teachers, teaching methods, curriculum, subjects, and facilities (Wang et al., 2008; Woolfolk, 2009; Johnson & Johnson, 2009).

This research results showed that the highreliance students applying the STS learning model reached a greater value of scientific literacy tests than the students who employed the PBL model. In other words, the STS learning model was useful to improve the students' scientific literacy to learn about carbon compounds particularly for those who had a higher score of learning reliance.

On the other hand, the low-reliance students who used the STS learning model had the average scientific literacy score of 36.89, or lower than those adopting the PBL model (46.28). It was evidenced by the Tukey test results of $Q = \alpha$ at 5.07 0.05 significance level, or $Q = \alpha$ 0.01 at 4.60. Hence, it was suggested that in improving scientific literacy, the low-reliance students apply the STS learning model.

Both the STS and PBL model intend to lead the development of real problem-solving skills. As for the difference, the problems discussed in the STS learning model are determined by the students, while the lecturer presents the problems discussed in the PBL model. The two models lead the lecturers/teachers to organize students in groups to conduct an investigation and literature study as the attempts to solve problems. The focus of the course is not on teaching specific topics within specific disciplines, yet on how scientific knowledge is constructed. Students immersed in the entire process of doing science while experiencing firsthand how aspects of Nature of Science (NOS needs to be considered when constructing scientific knowledge (Koenig et al., 2012).

The principle of "Dewey" i.e., learning by doing and experiencing ensures that schools should become a laboratory for search troubleshooting. The PBL was developed based on the cognitive psychological theory, which states that learning is an active process of someone in constructing his knowledge through interactions with a learning environment designed by a teacher/lecturer. Such learning patterns are appropriate for students who have a low learning reliance but less appropriate for those with high learning reliance since they would intentionally select their methods or learning resources they think more appropriate. Vygotsky's zone of proximal concept with the development of the scaffolding idea reinforced with Bruner revealed that learning occurs through a process of social interaction assisted by teachers and peers who are better able to overcome the problems encountered, and the effort to master a skill that slightly above the current level of development (Woolfolk, 2009).

Through the PBL model, the students are expected to be involved in the research process which urges them to identify problems, collect data and use the data to solve problems. Students will be involved very intensively so that motivation to continue learning and keep finding out is increasing. The learning process that gives students the opportunity to be actively involved in building knowledge contributes to the development of thinking skills (Ardianto & Rubini, 2016).

However, the more the freedom is given to the students in problem-based learning, the more the supervision is needed. The mistakes made in identifying problems have made the students anxious about finding new information. Similarly, in the stage of analysis and report writing, the students were not yet used to think holistically; so, they experienced difficulties in taking the conclusion. In such circumstances, lecturers are very necessary to provide assistance. It appeared that the low-reliance students tended to do only learning activities which assigned to him. They were less initiative to select another learning resource. Based on some of the above description, the lowreliance students could learn and achieve better when learning with the PBL model. As a result, the high-reliance students' scientific literacy was lower when studying using the STS learning model.

CONCLUSIONS

The overall results of the hypothesis testing showed that there was an influence of the interaction between the learning model and learning reliance on scientific literacy. In sum, the STS model was more useful for improving the students' scientific literacy in comparison with the PBL model. The high-reliance students' scientific literacy was better when studying using the STS learning model, on the other hand, the low-reliance students were suggested to apply the PBL model in order to enhance their scientific literacy. The researchers expected that future studies creatively modify the picked learning model so that it will be suitable for the students' state of reliance in relation to the enhancement of scientific literacy.

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THE DEVELOPMENT AND VALIDATION OF CONCEPTUAL KNOWLEDGE TEST TO EVALUATE CONCEPTUAL KNOWLEDGE OF PHYSICS PROSPECTIVE TEACHERS ON ELECTRICITY AND MAGNETISM TOPIC

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ABSTRACT

The conceptual knowledge test is an efficient way to measure the conceptual knowledge of physics prospective teachers on electrical and magnetism topic. The employed instrument was physical questions in the form of multiple-choice options. The process of developing and validating the conceptual knowledge test consisted of 5 steps: (1) content analysis; (2) construction of multiple-choice items; (3) readability test and expert validation; (4) limited tryout; and (5) large-scale application. The instrument validation test through trials was conducted in order to obtain the data related to difficulty index, discriminating power, distractor functionality, and reliability coefficient value that was then analyzed using ITEMAN version 3.0 program. The participants were 215 physics prospective teachers of a university in Makassar city. The instrument validation resulted in 40 items that consisted of 26 items for electricity and 14 items for magnetism. The instrument is called Conceptual Knowledge Test-Electricity and Magnetism (CKT-EM). The value of the reliability coefficient (α) (Alpha Cronbach) of 0.87 indicated that the instrument of conception test on electrical and magnetism topics was valid and sufficient to measure students' conception on electrical and magnetism topic.

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Keywords: conceptual knowledge-test, electricity and magnetism, readability test, validity, reliability

INTRODUCTION

Educational research related to the development of students' conceptual knowledge in the world of science education (physics) has been done for the past decades since Conceptual knowledge has been a primary review in learning science (Boorman & Rushworth, 2009; Duschl, 2008; Rittle-Johnson & Star, 2009; Fang et al., 2016). Conceptual knowledge is an important element

*Correspondence Address E-mail: rahmawatisyam@unismuh.ac.id to solve problems (Streveler et al., 2008). There are numerous previous studies about conceptual knowledge related to subject-matter or content in physics such as electricity and magnetism (Dega et al., 2013; Gok, 2012; Sadaghiani, 2011; Stelzer et al., 2010). Furthermore, conceptual knowledge is often approached from the viewpoint of semantic networks, because all retrieval and inference are based on traversing such networks (Koponen & Nousiainen, 2018). Electricity and magnetism are the important concepts that have to be learned by students as it plays a central role in determining the structure of the natural world and is the foundation of most current and emergent technology (Dega et al., 2013; Tiruneh et al., 2017). Therefore, it is important to explore students' conceptual knowledge of electricity and magnetism topic.

A variety of tests have been developed to measure students' conceptual knowledge of electricity and magnetism. Unfortunately, an extensive literature review on electricity and magnetism conceptual knowledge indicated that there are very few valid and reliable instruments applicable to measure students' conceptual knowledge of electricity and magnetism. Some examples of instruments that have been widely used in a number of previous studies focused on static electric for electricity topic. They are conceptual Survey of Electricity and Magnetism (CSEM), Brief Electricity and Magnetism Assessment (BEMA), Electricity and Magnetism Conceptual Assessment (EMCA), Colorado Upper-division Electrostatics (CUE), and Critical Thinking Skills in Electricity and Magnetism (CTEM) (Tiruneh et al., 2017). These instruments have been used to measure students' difficulties in some conceptual areas from electricity and magnetism (Gok, 2012; Pollock, 2009; Sadaghiani, 2011; Tiruneh et al., 2017). The Conceptual Survey of Electricity and Magnetism (CSEM) is a multiple-choice test that consists of 32-question. This instrument comprises eleven categories of question about conductor and insulators, Coulomb's law, force and field superposition, force, work, electric potential, magnetic force, Faraday's law, and Newton's third law. Based on the characteristics of the CSEM instrument, it tests electrical content, particularly on static electricity. In the CSEM instrument, no single item is found which tests dynamic electrical content needed in this study. Therefore, this study focused on developing instruments on dynamic electricity and magnetism topic.

Another similar instrument that can be used to measure students' conceptual knowledge of electricity and magnetism topics is Brief Electricity and Magnetism Assessment (BEMA). BEMA was developed by Ding (2014). This instrument is a 30-item multiple-choice test which covers the main topics discussed in both the traditional calculus-based E&M physics curriculum and the matter and interactions curriculum (Matter & Interactions II: Electric and Magnetic Interactions). It was re-evaluated through Rash Analysis (Ding, 2014). This instrument is specifically designed for students' knowledge of electrical and magnetic courses. Electrical and magnetic contents tested in BEMA have a more complex level of difficulty than the CSEM instrument. All items of the BEMA instrument are taken from the curriculum and the electrical course materials given in the fourth or fifth semester in college. Unlike the CSEM instrument, all items of this instrument are basic electrical and magnetic contents which are part of basic physics subject. Nevertheless, the BEMA instrument was not in accordance with the needs of this study because the content provided focused on more complex electrical and magnetic materials and there are no items intended to test dynamic electrical materials.

McColgan et al. (2017) has developed an instrument to assess students' conceptual knowledge of electricity and magnetism. This instrument was named electricity and Magnetism Conceptual Assessment (EMCA). It includes 30 multiple-choice questions with a completion time of 30-40 minutes. Some topics covered in this instrument include electrostatics, electric fields, circuits, magnetism, and induction. This instrument is inspired by the CSEM and BEMA, yet it focuses on assessing the content of electricity and magnetism in the introductory physics course. This instrument is in accordance with the content that will be tested in this study. However, the weakness in this instrument lies in the content which mainly talks about static electricity instead of dynamic electricity. On the other hand, the basic physics course curriculum in the second semester discusses more dynamic electrical. Based on the weaknesses of previous studies about the development of conceptual knowledge tests, we designed a form of test that could assess the conceptual knowledge of pre-service physics teachers on electricity and magnetism topic with the distribution of sub-concepts based on the results of the initial survey conducted through questionnaires administered to a number of physics prospective teachers.

Electricity and magnetism review in Basic Physics course was generally given in the first year. The scope of electricity and magnetism is broad enough. Therefore, there were some physics prospective teachers had difficulties to master the materials though they have passed it. The results of an initial survey conducted on pre-service physics teachers who have contracted Basic Physics course showed that they experienced difficulties in some electrical concepts especially in dynamic electrical and magnetism subtopic (Rustaman et al., 2017). This finding was then followed up by conducting a survey of prospective teachers' conceptual knowledge related to electricity (dynamic electricity) and magnetism materials to support the prior findings. In other words, an instrument that measures physics prospective teachers' conceptual knowledge of electricity and magnetism topic was required in particular content areas.

An instrument is said to be good if it had three characteristics; valid, reliable, and usable (Gronlund, 1985; Secolsky & Denison, 2012). There were several approaches that can be used to perform instrument validity namely content validity, construction validity, and criterion validity (Gronlund, 1985; Mehrens & Lehmann, 1991).

The purpose of this study was to describe the results of the development and validation of the conceptual knowledge test to measure physics prospective teachers' conception of electricity and magnetism topic, certainly in sub-topics that considered being difficult by them according to the questionnaires. The instrument design of conceptual knowledge on electricity and magnetism topic should not only assess physics prospective teachers' conceptual knowledge but also detect their difficulty level about electricity and magnetism.

METHODS

This was developmental research intended to validate test. Clifton & Schriner (2010) explained that the step of developing and validating test items consist of five steps including content, format, writing the stem, and writing the choice. Furthermore, Erdogan et al. (2009) revealed that the development and validation of instruments or tests require eight steps, they are literature review, development of item pool, validation of item pool, constructing initial draft, taking expert opinion, pilot testing, administration of the instrument, and calculation of validity and reliability. Therefore, the research method used in this research was developmental as it in accordance with the research purpose that was to describe the development and validation of conceptual knowledge test on electricity and magnetism topic. The test took place in one of the universities in Makassar. A number of 105 physics prospective teacher consisting of 62 woman and 43 men participated in this research. They were second year physics prospective teachers who have contracted Basic Physics courses.

The CKT-EM instrument covered 45 items before being validated. After validation, the number of items reduced by 5 becoming 40 consisting of 26 items about electricity and 14

items about magnetism. The form of CKT-EM instrument was multiple choice with five choices of answers provided along with the reasons. The developed electrical material distributions included electric current, electric potential difference, electromotive force, resistance, energy and electrical power, dc circuit, and Kirchhoff I & II law. Meanwhile, the magnetic material distributions included forces in electric charge moving in magnetic fields caused by straight wires, and coils. Readability validation was measured based on the consideration of 5 physics prospective teachers. Furthermore, the content validation was performed by three expert judgments using assessment rubric. The empirical validation was done through tryout using physics prospective teachers' responses which then were analyzed on ITEMAN Version 3.0 program.

The instruments used in this study were questionnaires, readability assessment sheet, and validation sheet for expert judgment. First, the questionnaires intended to identify the materials of Basic Physics course that were perceived as difficult by physics prospective teachers. Second, readability assessment sheets were to get the responses of 5 students about the degree of instrument readability. Generally, a test's readability validation is examined from 3 main components: (1) the clarity of words and sentences; (2) grammar; and (3) the clarity of instrument guidance (Brookhart, 2010). Scaling is a method used to assess each aspect, and this research employed the Likert Scale. In Likert, subject read every statement in the questionnaire and evaluate the question based on the categorized answer (Clifton & Schriner, 2010; Svetina & Levy, 2014; Tarrant et al., 2009). The score ranged from 1 to 5; 1 indicates 'very bad', 2 is bad, 3 is fair, 4 is good, and 5 is excellent. The data were analyzed both qualitatively and quantitatively. Furthermore, the results of quantitative data analysis were converted into qualitative form. The categorization of scoring is explained in Table 1.

Table 1. Conversion of Average Score Interval

The Average Score Interval	Categorize
$X \ge \overline{X} + 1.SBx$	Very good
$\overline{X} + 1.SBx > X \ge \overline{X}$	Good
$\overline{X} > X \ge \overline{X} - 1.SBx$	Bad
$X < \overline{X} - 1.SBx$	Very Bad

Based on Table 1, the interpretation of the readability test average score after being converted into the rating scale is shown in Table 2.

ment Readability Test				
Average Score Interval	Category of test readability	Judgment		
≥ 4	Very clear	Without revision		

Few revision

Full revision

Rejected

Clear

Enough

Not Clear

Table 2. Average Score Interpretation of Instrument Readability Test

The validation sheet was employed to validate the test contents through expert judgment by 3 experts. There were 3 elements which should be assessed by the experts: (1) the accuracy of content; (2) the accuracy of problem construction; and (3) language aspect. The used assessment technique was a rating scale system in which validators provide a score on the validation sheet. The validation results from all validators were analyzed to prove instrument content validation. To assess each aspect of the statement, the Likert scale was employed. For the favorable statement, 1 is very bad, 2 is not good, 3 is fair, 4 is good, and 5 is very good. The content validation resulted were examined quantitatively in the form of validators' agreement level using an inter-rater method. To find out this agreement, the researchers utilized the validity index proposed by Aiken (Aiken, 1988). The content validity index of each item was calculated using Aiken's Formula Index as follows.

$$V = \frac{\Sigma s}{n(c-1)} \dots$$
(1)

Description:

V = rater agreement index about content validity; $s = total \text{ score}; n = number of validator}; c = number of categories which can be chosen by validators$

Table 4. The Blue Print of CKT-EM

The value of s was calculated using the formula s = r - 10, where r = category selection scores rater and 10 was the lowest score in the scoring category. Index V values ranged from 0-1. Criteria for determining validity were categorized by the coefficient of the V content validity index (Aiken, 1988). The categorization of the content validity index (V) is shown in Table 3.

 Table 3. Expert Validity Category

Value of Validity Index (V)	Category
$\begin{array}{l} V_{account} \leq 0.40 \\ 0.40 < V_{account} \leq 0.80 \\ V_{account} > 0.80 \end{array}$	Low Moderate High

RESULTS AND DISCUSSION

The results and discussion of this study are divided into three parts: (1) The development of Conceptual Knowledge Test; (2) The Validation of Conceptual Knowledge Test; and (3) The Reliability of Conceptual Knowledge Test.

The Development of Conceptual Knowledge Test

The instrument of knowledge of electrical concept and magnetism was developed from several sources (Nugroho & Setiawan, 2009; Thohir et al., 2013). The initial number of items was 45 numbers in the form of multiple choice with the reasons. The comparison of electrical matter and magnetism item number was 1: 2. Material distribution and item number are shown in Table 4. Furthermore, all of the items on the CKT-EM test were validated. Instrument validation results eliminated 5 items; the item number 8, 16, 21, 30, and 33. The final design of this CKT-EM test produced 40 items.

Materials	Indicators (Learning goals)	Number of Items
Electric current	Applying electric current concept in circuit	1, 2 3, 4, 5
Potential difference		6, 7, 8, 9
Electromotive Force	Applying electric charge conservation (electric current conserva- tion) in circuit	10, 11 12, 13
Resistance	Applying potential difference in circuit	14, 15, 16
Electric Energy and power		17, 18 19, 20, 21
Direct current circuit	Applying electromotive force in a direct current circuit	22, 23, 24 25, 26 27, 28

 $4 > X \ge 3$

 $3 > X \ge 2$

X < 2

Kirchhoff's Rules		29, 30
The force of charged particles moving in a magnetic field	Defining battery's potential difference when it is connected to lamp and other loads	31, 32, 33, 34, 35 36, 37
Magnetic force acting on a current-carrying conductor	Defining wire's size and temperature affects its resistance	38, 39, 40, 41 42
Coil carried a steady current	Applying the electric power concept in circuit	43, 44, 45

The Validation of CKT-EM

The process of test validation consisted of 3 stages: (1) the readability of instrument, (2) the expert validation, and (3) the validity of instrument

Readability test was performed by five second-grade physics prospective teacher who have passed Basic Physics course. There were 3 elements developed into 9 assessment aspects (Brookhart, 2010; Gronlund, 1985). The nine criteria were: (1) the use of brief, clear, and assertive action verbs or command; (2) a series of sentence questions and answer choices is a necessary statement only; (3) choice of logical answers in terms of material and in accordance with the command questions; (4) the length of choice of answers is relatively the same; (5) the use of language in accordance with Indonesian rules; (6) words are easily understood (not ambiguous); (7) the use of sentences/ communicative statements; (8) suitability of illustrations (in the form of tables, graphics, drawings, diagrams etc.); and (9) clear and legible illustrations of tables, graphs, drawings, diagrams or others. The results of the readability test showed that the average score for all items was in the range of 3.2 to 4.8 with a score ranging from 1 to 5. According to Table 2 related to the average interpretation of the test instrument assessment scores, the results of the readability test categorized as "very clear" and "clear". The summary outline of item classification based on the readability categories appears in Table 5.

Table 5. The Category of Instrument ReadabilityTest

Rating scale	Category	Number of Items (%)	Judgment
≥ 4	Very clear	24 (53.33)	Without revision
$4>X\geq 3$	Clear	21 (46.67)	Few
$3 > X \ge 2$	Fair	0	revision
<i>X</i> < 2	Not clear	0	Full revision
			Rejected

The result of students' responses to the readability test instrument could be classified into three elements as seen in Table 6.

 Table 6. Students' Responses to the Readability

 Test

Response Aspects	Number of Test Items	Total of Test Items (%)
The use of un- familiar words	33,34,35,41,42	5 (11.11)
Sentence ambi- guity	12,14,16,23,26, 31,32,33,36,40, 41,43	12 (26.67)
The unclear illustration of picture, symbol, table, graphic,	19,21,23,27,33, 38,40,42,44,45	10 (22.22)

Table 6 shows that there are a number of questions that need to be revised both in terms of words, sentences, and illustrations. In addition, from this input, it can also be said that there are some issues that need to be revised in the mild revision category.

Instrument' validation data from three experts was analyzed with descriptively quantitative through the determination of content validity index using Aiken's Formula. The results of determining the content validity index of all items were further categorized based on their validity level referring to Table 3. The summary of the items' content validity level is presented in Table 7.

Table 7. The Category of Items' Content Validity

Validity index (V)	Category	Number of item (%)
$\begin{array}{l} V_{count} \leq 0.40 \\ 0.40 < V_{count} \leq 0.80 \\ V_{count} > 0.80 \end{array}$	High Moderate Low	0 42 (93.33) 3 (6.67)

Table 7 showed that item 16, 22 and 36 were in a low category. The low index of content validity (V) of the three items was then cross-checked with notes in the form of comments, suggestions and input validator. The results of re-checking on item 16 and 22 to the input of the three validators indicated that there were some errors in the process of composing the problem, namely: (1) less communicative sentences; (2) less precise use of words including at some points of the answer choice; and 3) discrepancies between items and indicators to be measured. Meanwhile, the error found in item 36 was a less obvious picture.

After validating the test instrument contents, instrument trials to some Physics prospective teacher as the empirical validation stage was carried out. The empirical validation results were then analyzed using the ITEMAN version 3.0 to determine the discriminating power, difficulty level, and distractor functionality of test. In addition, the need to test the instrument was to determine reliability coefficient value (α) of the test instrument showing the level of instrument' validity and reliability whether it was feasible to use or not.

A test's discriminating power is a measurement of items' effectivity in distinguishing between high and low scores of a test (Aiken, 1988). The quality of multiple-choice items could be determined by discriminating power coefficients. Nitco (1983) and Damayanti et al. (2018) established a decision rule of an item that is divided into three types based on the value of the distinguishing power coefficient; accepted, revised, and rejected. The three types of decisions are: (1) if the discriminating power coefficient is greater than 0.3, then the decision on the item is accepted; (2) The item is revised when the discriminating power coefficient is between 0.10 and 0.29; and (3) the item is rejected if the discriminating power coefficient is below 0.10. Interpretation of the discriminating power analysis data of the items was presented in Table 8.

Table 8. The Distribution of Items' Criterion

 based on Discriminating Power Index

Discriminating Power (p value)	Criterion	Number of Items (%)
> 0.3	Accepted	14 (30.11)
0.10 to 0.29	Revised	26 (58.78)
< 0.10	Rejected	5 (11.11)

Table 8 showed that the total number of items worthy of use as a test instrument was 90% and 10% of the items were not feasible in terms

of items' discriminating power coefficient.

The difficulty level of items is generally defined by the term percentage or proportion that responds correctly (Anastasi & Urbina, 1997). In this case, the proportion of correct answers was the comparison between a numbers of test participants who answered correctly on the items analyzed compared to the total number of test participants. The main reason for using problemlevel analysis of difficulty level was to select a number of items that have the appropriate degree of difficulty level (Aiken, 1988). The difficulty level category is determined by a coefficient (p) and divided into three categories: (1) difficult, if the value of coefficient p is greater than 0.3; (2) medium, if coefficient p is between 0.3 and 0.7; and (3) easy, if the p-value is greater than 0.7. The results of ITEMAN version 3.0 item analyses for the difficulty level of items showed the varying p values spread into the three categories of difficulty levels. Furthermore, the difficulty level category was presented in Table 9.

Table 9. The Distribution of Items based on Difficulty Level Index

Difficulty level (p)	Criterion	Number of Items (%)
p < 0.3	Difficult	24 (54)
$0.3 \le p \le 0.7$	Medium	19 (42)
p > 0.7	Easy	2 (4)

One of the important elements in the analysis of multiple-choice item is the functionality distractor. The purpose of functional distractor analysis was to know whether the provided distractor made sense or not. The distractors should be reasonable so that it would probably be selected by at least 5% of all test takers (Chavda et al., 2015). Based on this statement, Mukherjee & Lahiri (2015) distinguished the effectivity of distractor level over two types of non-functional distractors; Non-Functional Distractors (NFDs) and Effective Distractor (ED) distractors. The distractors of a question item categorized as NFD if the number of selected distractors was <5% of the total number of test takers. Conversely, the distractors were categorized as ED when selected by 5% or more of test participants. Next, the researchers determined the efficiency distractor (distractor efficiency / DE) of each item based on the number of NFD items in %. If a given item contains three or more NFDs, then its DE value is 0%. Furthermore, if the item consists of two, one, or zero NDF, then DE is 33.3%, 66.6%, and 100% respectively. The distribution of item clustering based on the characteristics of the distractors was shown in Table 10.

 Table 10. Item Classification based on Functional Distractor Level

Daramatar	Number of Items' NDF				
Falameter	0	1	2	≥3	
Total (%)	2 7 (60)	1 0 (22.22)	5 (11.11)	3 (6.67)	
DE (%)	100	66.60	33.30	0	

Table 10 shows that the number of questions that all the answer choices worked well there was 60% of the 45 items.

The Reliability of CKT-EM

One of the important aspect considered in a measuring instrument is the test reliability, which refers to the consistency of scores obtained by the same test participants when re--tested by the same test in different situations or from one measurement to another (Anastasi & Urbina, 1997; Thorndike, 1971). Therefore, the reliability level of a test or measuring instrument is a very important consideration.

The determination of the reliability coefficients of this test employed the ITEMAN version 3.0 program. The results of test instrument reliability analysis showed that the coefficient value of Alpha (α) was 0.56 from 60 prospective physics teachers. The value of the test reliability coefficient was 0.56, which according to Remmrers et al. (1965), it was applicable for research purposes. The value of the reliability coefficients interprets that the instrument was acceptable. Therefore, the CKT-EM test instrument was reliable to measure students' conceptual knowledge.

The revised CKT-EM instruments were further tested to 215 prospective physics teachers. The result of a larger application revealed that the coefficient of Alpha was 0.87. This value is sufficient based on a report by Thorndike (1971) that alpha coefficients in the range 0.58-0.81 indicated that the instrument had satisfactory reliability for scales containing five items each.

CONCLUSION

Research on the development and validation of the concept knowledge test instrument on electrical and magnetism topic has produced 40 items. The test instrument validation stages ranged from validation of instrument legibility, content validity, and test instrument testing have resulted in valid and reliable instruments with a reliability coefficient of 0.87. Therefore, it concluded that the concept of a knowledge test instrument on electricity and magnetism topics was feasible to use.

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THE DEVELOPMENT OF INTEGRATED SCIENCE INSTRUCTIONAL MATERIALS TO IMPROVE STUDENTS' DIGITAL LITERACY IN SCIENTIFIC APPROACH

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ABSTRACT

Integrated science and integration of literacy skills are relevant issues to be investigated in science education. This research aimed at determining the validity of integrated science materials and examining the practicality and effectivity of the use of integrated science materials in the scientific approach. The type of this research was research and development. The development of integrated science materials consists of seven stages, namely identifying potentials and problems, collecting information, designing a product, validating the product, revising product, doing limited testing, and revising product. Instruments for collecting data included validity assessment, practicality assessment, written test, and performance assessment. The data were analyzed by descriptive statistics and paired comparison test. Based on the data analysis, there were three results of this research. First, the validity of integrated science instructional materials classified as very high with an average value of 83.2. Second, the integrated science instructional materials were practical according to the science teachers and students with an average value of 86.11 and 89.66 respectively. Third, the integrated science instructional materials were effective in the scientific approach to improving the aspects of knowledge and digital literacy including scientific, functional, and visual literacy at 95% confidence level. These results indicated that employing integrated science instructional materials could overcome the problem of integrated science teaching and improve the digital literacy of students in terms of scientific, functional, and visual literacy. These digital literacy components are also useful for students to get success in their real future life.

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Keywords: integrated science, instructional material, digital literacy, scientific approach

INTRODUCTION

Learning in the 21st-century should have contexts, be linked to community life, be studentcentered, and be collaborative. Learning has context means that the content of learning materials must be associated with the real world. In this way, the material discussed in the school is close to the daily life of the students. In the learning

*Correspondence Address E-mail: asrizal@fmipa.unp.ac.id process, students must be more involved actively to construct their competences. Competence construction in learning is done collaboratively. Hence, these four learning principles are the essence of 21st-century learning.

Integrated science learning is a proper way to apply the essence of 21st-century learning. In integrated science learning, students are encouraged to connect the learning materials to realworld contexts. Students are involved actively in exploring the real-world contexts which are relevant to the learning materials, conducting the collaborative investigation, and communicating the investigation results. Thus, the learning process can be implemented holistically, authentically, meaningfully, and actively (Wiyanto & Widiyatmoko, 2016).

Keeping in mind that the integration in learning is very important, The Indonesian Ministry of Education and Culture has established that science learning in the 2013 curriculum must be implemented in an integrated pattern. The content of the subjects comes from sub-discipline of science that is physics, biology, and chemistry. In other words, science learning should be integrated from those sub-discipline contents. The concept of science integration in the 2013 curriculum has been shown in both the core and basic competence. One basic competence has been integrating the science concepts of the sub-discipline of physics, biology, chemistry, and earth science and space (Pratiwi & Muslim, 2016). In addition, in science development framework, scientific competence is connected to daily life, technology, and environment. Therefore, the 2013 curriculum has emphasized the importance of integration in science learning.

The Indonesian Ministry of Education and Culture also has promoted the school literacy program to improve students' literacy. Literacy is important for students to know, understand, and apply.

Therefore, in science learning, science teachers need to develop students' literacy so that they can obtain success either in their learning or real life. Integrated learning will gain knowledge and skills and make learning more meaningful to students as it is connected to the real world context. This integrated learning is more effective to improve the understanding and experience of students (Sunhaji, 2016). Integration in the curriculum could result in a greater intellectual curiosity, improve attitude, enhance problem-solving skills, and heighten achievement (Alghamdi, 2017). Integrated science learning allows students to get a direct experience in receiving, saving, and applying scientific concepts. Moreover, they are trained to discover the concepts by themselves holistically, meaningfully, authentically, and actively (Wiyanto & Widiyatmoko, 2016).

However, the actual conditions in schools do not match with the expected conditions. There were at least three real conditions found in schools. First, junior high school science learning was conducted separately (Pursitasari et al., 2015). Ardianto & Rubini (2017) also stated that teachers remain to teach science as a separate science into a sub-discipline of chemistry, physics, and biology. Science teachers generally find some difficulties in applying integrated science learning (Parmin et al., 2015). Second, the separation of integrated science textbooks into sub-disciplines of physics, biology, and chemistry (Asrizal et al., 2017). Third, Indonesian students' low literacy in reading, math, and science (OECD, 2013). These real conditions indicate that there is a problem to be investigated.

One of the alternative solutions to this problem is to develop integrated science instructional materials equipped with digital literacy. An important reason for this solution is that instructional materials can be used to facilitate teachers in implementing integrated science learning and students in studying science holistically and authentically. These instructional materials should be connected to the real-world contexts. On the other hand, the integration of digital literacy in learning is also important to encourage successful students in learning and in daily life.

Instructional materials are an important tool in a learning process of all subjects (Lyimo & Too, 2017). Olayinka (2016) defined instructional materials as an essential and significant tool required for teaching and learning school subjects to promote efficiency and improve students' performance. Akpan et al. (2017) also explained that instructional materials as an object or device that aids teachers to present their lessons sequentially and logically to the students. On the other hand, Okobia (2011) stated that instructional materials as an object or device which helps teachers to make learning meaningful. Thus, instructional materials are required by both teachers for making effective learning and students for improving their performance in the learning process.

Instructional materials have some important roles in the learning process. The first role is to a more interesting, practical, realistic and meaningful learning (Olayinka, 2016; Saad, 2017; Zhang et al., 2013). Onyia (2013) said that instructional materials make simple learning, practical, effective and understandable to the students. The second role is to develop the knowledge, skills, attitudes, and values of students in the learning process (Saglam, 2011). The third role is to make learning easy, help memorize the things needed (Akpan et al., 2017). The fourth role is to let teachers and students to participate actively and effectively in learning. The fifth role is to enhance the learning outcomes, save time, increase students' interest, and facilitate retention of students' memory (Awolaju, 2016). Another role of instructional materials is to develop self-confidence, self-actualization, and motivation of students in learning (Olayinka, 2016; Saad, 2017).

There are several types of instructional materials which can be used in learning. Instructional materials can be divided into three major categories based on their sensory appeal, namely audio, visual and audio-visual (Akpan et al., 2017). Instructional materials include textbooks, workbooks, cassettes, CD-ROMs, videos, photocopied handouts, newspapers, etc., and they are used to impart knowledge (Hidayati, 2017). Instructional materials involve student's textbooks, teacher's guide, and reference books, maps and globes (Lyimo & Too, 2017). Other types of teaching materials are textbooks, worksheets, workbooks, module, worktext, and manuals (Selga, 2013). An important thing, in this case, is instructional materials are a tool that can help teachers and students in the learning process and in making the learning more effective. In this research, instructional materials are integrated into science learning materials equipped with digital literacy.

Prior research results showed that the use of instructional materials provides a positive effect on students' academic achievement. The instructional materials adopted in secondary school learning have a positive effect on students' performance (Nwike & Chaterine, 2013). Adebule & Ayoola (2015) stated that a significant difference existed between the performance of students taught with and without instructional materials. The research results of Olayinka (2016) also concluded that the students taught with instructional materials obtained excellent achievement scores compared to those taught without any materials. This explained that the use of instructional materials in learning has given a significant effect on the performance of students.

Integrated science instructional materials is an essential and meaningful tool necessarily applied aiming at promoting learning efficiency and improving students' performance. In this case, integration of science can be conducted by using the intra-disciplinary approach (Mubita & Kalimaposo, 2016; Drake & Savage, 2016; Bain et al., 2017). Furthermore, the integration of digital literacy into instructional materials is also needed to support a school literacy program. The digital literacy comprises basic, scientific, economic, technological, visual, information, and multicultural literacy (Turiman et al., 2012; Soh et al., 2012). On the other hand, Safeeq (2013) elucidated that digital literacy consists of functional, visual, scientific, technological, information,

cultural, and global literacy. In learning, digital literacy requires students to make meaning in multimodal ways, using basic, scientific, technological, visual, gestural, spatial, information and multicultural literacy and global awareness (Jing, 2016; Fauzan et al., 2013).

The use of integrated science materials is considered important in the learning process. For this reason, researchers were attracted to develop the integrated science instructional materials equipped with digital literacy. The purposes of the research were to determine the validity of integrated science instructional materials according to experts' rational thinking and to determine its practicality and effectiveness when applied in the scientific approach.

METHODS

This was a developmental research intended to create a certain product and to test the effectiveness of the product. This research product was integrated science instructional materials equipped with digital literacy for three components, namely scientific, functional, and visual literacy.

The developmental model employed in this research referred to ten stages from Sugiyono. The referenced criteria were valid, practical, and effective in limited field testing. There were seven stages that have been done: (1) understanding potencies and problems; (2) collecting information; (3) designing the product; (4) validating; (5) revising; (6) implementing limited field testing; and (7) re-revising.

In general, there were three activity groups and seven stages in this research. The first activity group was to conduct a preliminary research. The preliminary research consisted of two stages including understanding potencies and problems and collecting information. The conducted activities included the analysis of curriculum analysis, integrated science textbooks, the students' literacy skills, and the students' learning outcomes. The results of the preliminary research were descriptions of integrated science in the 2013 curriculum, integration of teaching materials in integrated science textbooks, digital literacy, and students' competence.

The second activity group was designing, testing validity, and revising the product. Integrated science instructional materials were designed based on the guidance of the instructional materials development. The integrated science instructional materials consisted of learning guidance, core competence, and basic competence, teaching materials, supporting information, exercises, worksheets, evaluation and feedback from students. The components of the digital literacy integrated into the science instructional materials scientific, functional, and visual literacy. The product of instructional materials was validated by five experts of biology, physics, and chemistry.

The third activity group was to conduct a limited field testing and revising the product. The purpose of this limited field testing was to examine the practicality and effectiveness of the integrated science instructional materials. Based on the weaknesses and problems emerged in the limited field testing, a revision was carried out. The results of the activity were descriptions of the practicality and effectiveness of integrated science instructional materials in the scientific approach.

The employed instrument to examine the validity and practicality was questionnaire sheets which have been assessed and given some suggestions by three education experts. The indicators of the practicality covered usability, convenience, and attractiveness. On the other hand, the effectiveness indicators were the students' improvement of knowledge and literacy skills. The components of digital literacy were scientific, functional, and visual literacy. The instrument for measuring the students' knowledge was written test. This written test has been tested on other school students. The posttest had an average value of discrimination index, difficulty index, and reliability of 0.51, 0.44 and 0.69 respectively. Meanwhile, the instrument for determining the literacy skills components was the performance assessment sheet. This instrument has been designed from the indicators of scientific, functional and visual literacy. Thus, the instruments for collecting the research data were declared feasible.

The research data were analyzed through descriptive statistics and paired comparison test. The descriptive statistics analysis intended to describe more detailed information about the validity data from the experts, the practicality of the product according to the science teachers and students, also, knowledge and digital literacy of students. On the other hand, the paired comparison test was to examine the difference between the two groups of paired data after and before the treatment.

RESULTS AND DISCUSSION

The first research result was the validity of integrated science instructional materials which determined from two indicators, relevance and consistency. Relevance refers to content validity, while consistency relates to construction validity. Based on the validity assessment instrument from the experts, obtained the relevance and consistency value of integrated science instructional materials. There were six indicators which used to assess the validity of integrated science instructional materials, namely content feasibility, construction, integration of science materials, digital literacy, language, and graphics. The score of each validity assessment component is seen in Figure 1.



Figure 1. The Validity Scores of Integrated Science Instructional Materials

The average validity values of integrated science instructional materials varied from 76.0 to 90.2. Four components of the assessment criteria have been in a very valid category; those were construction, integration of instructional materials, digital literacy, and graphics. On the other hand, two components of instructional materials were in the valid category, those were content feasibility and language. The average validity score of the six assessment components was 83.2. This average value classified as a very valid category. Therefore, the average validity score was 83.2 and belonged to a very valid category.

On the basis of the validity test, the experts' suggestions could be grouped into three parts. The first suggestion was to show the relationship among sub-disciplines from physics, biology, and chemistry. To improve the integration within the sub-themes, the connected model was

adopted since it model allows connection within concepts of the sub-disciplines. The second suggestion was to re-read the materials as there were some typographical errors. The third suggestion was to provide/create figures relevant to the learning materials since the initial figures were taken from internet sources.

The second research result was the practicality of the integrated science instructional materials equipped with digital literacy according to science teachers and students. There were three components assessed by the science teachers namely the usability, convenience, and attractiveness. The minimum value, mean value, and maximum score of each practicality component according to the science teachers are shown in Figure 2.



Figure 2. The Practicality Score of Instructional Materials According to Science Teachers

The usability aspect scores varied from 66.67 to 100 and the mean value was 81.11. The convenience scores ranged from 75.00 to 91.67 and the average score was 83.33. On the other hand, the value of attractiveness varied from 81.33 to 91.67 and the average value was 88.89. Therefore, the use of integrated science instructional materials integrated with digital literacy according to science teachers categorized as very practical.

Teachers thought that the integrated science instructional materials were useful as they assisted to accomplish the learning objectives, make science learning better, accelerate learning presentation, improve productivity, and control the time allotment. For the convenience aspect, the science teachers felt that the product eased to control learning materials, students' activities, memorize learning materials, understand science concepts, and improve learning results. On the other hand, for the attractiveness aspect, the teachers agreed that the display, cover, and illustrations were interesting and fostered curiosity. Science teachers as users considered that integrated science instructional materials equipped digital literacy were useful, convenient, and appealing. Thus, the use of integrated science instructional materials equipped with digital literacy was practical in the scientific approach.

The practicality test of the integrated science instructional materials equipped with digital literacy was performed to the grade VIII students at one of Junior High Schools in Padang. The components assessed by the students were the same; usability, convenience, and attractiveness. The minimum, mean, and maximum values of each practicality component assessed by the students are displayed in Figure 3.



Figure 3. The Practicality Values of Instructional Materials According to Students

The usability aspect scores varied from 84.82 to 91.07 with an average value of 87.80. Further, the convenience aspect score between 83.93 and 91.07 with an average value of 87.12. In addition, the attractiveness scores ranged from 91.96 to 96.43 with an average value of 94.05. Overall, the three aspects' average value was 89.66. Thus, the use of integrated science instructional materials equipped with digital literacy according to students categorized as practical and very practical.

The third result was the effectiveness of the integrated science instructional materials on the aspects of students' knowledge and digital literacy. Therefore, a pre-test and post-test were carried out. The descriptive statistics score of pre-test, post-test, normality test, homogeneity, and paired comparison test can be observed in Table 1.

Statistical	Scores			
Parameters	Pretest	Posttest		
Mean	47.57	81.07		
Median	52.00	80.00		
Mode	52.00	76.00		
Standard deviation	11.99	6.41		
Variance	143.81	41.03		
Minimum	16.00	72.00		
Maximum	64.00	96.00		
Range	48.00	24.00		
P-value of normal- ity test	0.038	0.013		
P-value of homoge- neity test	0.0	002		
Z-value of Wilcox- on signed rank test	-4	.63		

 Table 1. The Data Analysis of Students' Knowledge Aspect

Based on the data analysis results, the average value of the pre-test and post-test were respectively 47.57 and 81.07. The post-test average value was higher than the pre-test. The P value of the pre-test and post-test in the normality test was smaller than the significance level $\alpha = 0.05$. This means that the data of pre-test and post-test were not normally distributed. In the F test, the value of P was 0.002 or smaller than the value of significant level a=0.05. These results indicated that both data of pre-test and post-test did not have the same variance.

The data of pretest and posttest did not own both normal distribution and same variance. Hence, the Wilcoxon signed rank test was used to analyze the data (Shan, 2014; Imam et al., 2014). The Wilcoxon test was used to analyze the differences from the observed results of two paired data. This test can be included in non-parametric statistics. The Z value for the 28 students was -4.63. At a significant level of 0.05, the value of a half of significant level was 0.025, then the area under the curve F (z) = 0.475. The value of the Z table for this area under the curve F(Z) was 1.9. The value of the calculated Z was outside the acceptance area of the Ho hypothesis. The hypothesis test results indicated that there was a significant difference in the knowledge aspect of students before and after they employed the integrated science instructional materials. Hence, the use of integrated science instructional materials was effective in the scientific approach to improve the knowledge aspect of grade VIII students at 95% confidence level.

An investigation was also done to determine the effectivity of the integrated science instructional materials on the students' digital literacy which consisted of scientific, functional, and visual literacy. In this case, functional literacy comprised writing and describing information while scientific literacy covered scientific concepts, scientific processes, and scientific contexts. Meanwhile, visual literacy consisted of visual interpretation and visual use. The scores of the statistical parameters on functional, scientific, and visual literacy before and after using the integrated science instructional materials are presented Table 2.

Table 2. The Scores of Statistical Parameters on

 Digital Literacy

Statistical	Sc	ores
Parameters	Pretest	Posttest
Mean	47.57	81.07
Median	52.00	80.00
Mode	52.00	76.00
Standard deviation	11.99	6.41
Variance	143.81	41.03
Minimum	16.00	72.00
Maximum	64.00	96.00
Range	48.00	24.00
P-value of normal- ity test	0.038	0.013
P-value of homo- geneity test	0.	002
Z-value of Wilcox- on signed rank test	-4	1.63

Table 2 explains that the average value of scientific, functional, and visual literacy of the students before using the integrated science instructional material were respectively 54.58, 49.27 and 47.44. On the other hand, the average value of scientific, functional, and visual literacy of students after using the integrated science instructional materials were respectively 68.59, 68,39 and 62.92. The average values of the three aspects of digital literacy after using the integrated science materials equipped with digital literacy were higher. The P value for the students' literacy data before and after using the integrated science instructional materials indicated a normal distribution. Furthermore, the group of students' literacy data before and after using the integrated science instructional materials on the F test possessed the same variance.

The data characteristics have met the statistical parameters. For this reason, a paired comparison test can be used to determine the difference of students' digital literacy after and before using the integrated science instructional materials. From the paired comparison test, t-values were obtained for functional, scientific, and visual literacy of -18.43, -26.37 and -16.94 respectively. On the other hand, the two-tailed test was obtained with a significant level of 0.05 and freedom degreed of 27, then the value of t in the table was 2.05. The third t-value of the three digital literacies was out of the acceptance area of the null hypothesis.

The hypothesis test results indicated that there was a significant difference in functional, scientific, and visual literacy after and before employing the integrated science instructional materials in the scientific approach. In other words, the use of integrated science instructional materials equipped with digital literacy could give a meaningful impression in promoting students' digital literacy. The significant growth of digital literacy symbolized that the use of integrated science instructional materials was effective in the scientific approach particularly to augment the scientific, functional, and visual literacy of students at 95% confidence level.

Overall, the integrated science instructional materials equipped with digital literacy were declared valid in terms of content, construction, language, integration of teaching material, integration of digital literacy and graphics according to the experts. Moreover, the use of integrated science instructional materials in scientific approach was declared practical referring to the science teachers and the students. This elucidated that the teachers and students, as users, agreed that the integrated science instructional materials were useful, convenient, and appealing. In addition, the use of integrated science instructional materials equipped with digital literacy was effective in the scientific approach to improve the students' academic achievement. This result showed that the learning objectives can be achieved in terms of knowledge, attitude, and skills. The skill aspect of this research was described by scientific, functional, and visual literacy under the scope of digital literacy.

These research results aligned with the research findings done by Effiong & Igiri (2015) which explained that the use of instructional materials gave a positive effect to the academic achievement of students. Similarly, the research results of Eze (2017) also showed that the use of instructional materials was effective in learning

characterized by an improvement in academic achievement and retention of students. Furthermore, other research also proved that instructional materials supported the improvement of digital literacy. Yenni et al. (2017) explained that the use of science teaching materials could improve the content aspect and scientific literacy of students for the environmental pollution topic. In line with this, Ekantini & Wilujeng (2018) found that science worksheet based on education for environmental sustainability was effective to increase scientific literacy. Thus, the research results were relevant to other studies which could support the skills which required in the 21-st century.

From the results that have been achieved, it can be stated that the use of the integrated science instructional materials equipped with digital literacy in the scientific approach was practical and effective to improve the students' knowledge and digital literacy. As an implication of the research results, science teachers may employ the materials as an alternative to learning resource in science learning. In addition, students can also use the integrated science instructional materials as one of the learning sources to construct knowledge and digital literacy in a science subject. Therefore, this research product was an alternative solution in applying integrated science learning and promoting the school literacy program.

CONCLUSION

The research concluded that the integrated science teaching materials owned generic criteria for a high-quality product in terms of validity, practicality, and effectiveness in the scientific approach. The validity was described into six components namely content, construction, integrated science teaching, integration of digital literacy, language, and graphics. These findings indicated that integrated science instructional materials have met the criteria of relevance and consistency. The use of integrated science instructional materials was practical in the scientific approach according to science teachers and students in the aspects of usability, convenience, and attractiveness. Moreover, the science teachers and students agreed that the use of instructional materials was useful, convenient, and appealing to support teaching processes. Besides, the use of integrated science instructional materials was effective in the scientific approach to improve aspects of knowledge and digital literacy including scientific, functional, and visual literacy. This means that the use of integrated science instructional material provided significant effects on knowledge and

digital literacy. Therefore, science teachers could use the integrated science instructional materials as an alternative to improve knowledge and digital literacy of students.

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THE EFFECTIVENESS OF GUIDED INQUIRY AND INSTAD TOWARDS STUDENTS' CRITICAL THINKING SKILLS ON CIRCULATORY SYSTEM MATERIALS

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ABSTRACT

Critical Thinking Skills (CTSs) are fundamental skills possessed by students to adapt to the external challenges of 21st-century. To empower students' CTSs, Guided Inquiry and INSTAD may work effectively. This research aimed to see the effectiveness of guided inquiry and INSTAD toward students' critical thinking skills. This research was a quasi-experimental. The instrument to get the CTSs data was a valid essay test according to Facione. The sampling technique employed was the intact group sampling method. The number of participants involved was 188 XI grade science program students of SMAN 7 Surakarta; a middle-quality school. The total number of research sample was 64; 32 students in the Guided Inquiry class and the other 32 students in the INSTAD class. Hypothetical test using ANCOVA resulted in a 5% of significance level. The results indicated that there were significant differences of CTSs on circulatory system topic between the INSTAD and Guided Inquiry class. The students who experience the INSTAD class has higher CTSs than those joined the Guided-Inquiry class.

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Keywords: critical thinking skill, guided inquiry, INSTAD

INTRODUCTION

The 21st-century is an era of science where technology has developed rapidly. The required skills to face the 21st-century challenges were not only about teaching reading, writing, and arithmetic but also about how to use and develop thinking skills became the high-order thinking skills (HOTS) (Borstner & Gartner, 2014; Collins, 2014). Brookhart (2010) defined higher-order thinking includes a list of skills or procedures performed by critical thinkers. Critical thinking skills are one of the HOTS needed for making purposeful, reflective and fair-minded judgments about what to believe or practical issues in the future. Therefore, critical thinking becomes very important as the real problems in today's life have been more and more complicated (Mutakinati & Anwari, 2018). Students' CTSs and HOTS should also be optimally empowered in school learnings.

Critical thinking skills have a long-term benefit in the field of education as it can assist students in solving problems encountered in the learning process and its application in everyday life (Kaddoura, 2011). Meanwhile, the shortterm goal of the CTSs in the learning process is to strengthen students' conceptual understanding (Khasanah, et al, 2017), especially in the natural sciences (IPA) subject. In other words, the students' CTSs are needed to overcome problems in everyday life.

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Facione (2011) classified critical thinking skills into several aspects: (1) Interpretation; (2) inference; (3) evaluation; (4) explanation; (5) analysis; and (6) self-regulation. The interpretation aspect requires students to be able to categorize and explain the meaning of terms. The analysis aspect is related to researching ideas, identifying and analyzing arguments. The evaluation aspect refers to the skills to assess opinions. The inference aspect consists of the skills to look for evidence and alternatives. The explanation aspect is the skills to express results, justify procedures, and present data. Finally, the self-regulation aspect deals with the skills to monitor students' self-learning. These aspects must be possessed by each student to face nowadays challenges as competition has become a very normal thing. This is parallel to Fong et al. (2017) who stated that students who have critical thinking skills tend to be more competent than students who are less critical.

According to the observation results at XI MIPA of SMAN 7 Surakarta of critical thinking skills test compiled based on the Facione indicators revealed that the aspect of interpretation was 45,81%; the analysis was 33,59%; the evaluation was 30.01%, the explanation was 24.84%, the inference was 27.01%, and the self-regulation was 62.50%. The critical thinking skills scores between 25-43,75% were included in a low category, 43,76-63,15% in a medium category and 63,16-80,00% in high category (Saputri et al., 2017). Based on the observation results, the critical thinking skills of XI MIPA students in SMAN 7 Surakarta remained low.

Students' critical thinking skills could be optimized by applying an inquiry-based learning model (Asyari et al., 2016; Boleng et al., 2017; Zubaidah et al., 2017). The inquiry-based learning demands students to actively build their own knowledge, make reasoning, and compare new concepts with the early concepts (Putra et al., 2016). The inquiry-based learning also concerned about the process of learning instead of the product, which is compatible with the essence of integrated sciences (IPA) learning. An IPA Learning orients to the comprehension process; therefore, it could train students' thinking skills, solve problems, and lead students into self- regulated learners i.e. independent learners through a series of activities (Lederman et al., 2013).

Inquiry-based learning is a very suitable learning model for IPA learning, also on Circulatory System Study Materials (Retnawati et al., 2017). the circulatory system study material has many abstract concepts, so it cannot be understood simply by memorizing it. Scientific work contained in both models allows students to observe directly, conceptualize, and deduce new knowledge that has been obtained from the experimental activities. For example, the question of the principles of blood classification. Through the scientific approach, students can immediately observe how the clump process occurs or not, what is agglutinin and antigen, so that students can then conclude the principles of blood classification. In addition, through these activities students are able to train aspects of critical thinking skills i.e., interpreting, analyzing, concluding, evaluating, self-regulation, and explaining (Weaver et al., 2016).

Scott et al. (2010) stated that guided-inquiry teaching has six stages; observation, formulating problems, hypothesizing, designing and executing experiments, analyzing data, and communicating. The observation stage intends to reveal students' early conception which assists teachers to recognize their initial understanding and ideas. The next stage is to formulate problems, make hypotheses, design and carry out experiments. These three phases give students the opportunity to do independent scientific work. The next stage of analyzing the data requires students to develop their thinking skills to get the final conclusions from the performed experiments; thus, they are expected to use higher-order thinking skills. The last stage is communicating aiming at providing students with the opportunity to present the experimental results so as to be able to train their explaining skills.

The weakness of the Guided-Inquiry model was the time limitation to perform scientific work in IPA learning. The low-level academic students even should try harder to keep up with the pace of other higher-level academic students when the time is very limited (Duffy & Azevedo, 2015). The guided-inquiry learning which focused only on the application of the learning model would be difficult to accommodate the training of low-level academic students' CTSs. To solve this problem, it is important to conduct scaffolding of Higher Academic (HA) and Lower Academic (LA) students. The scaffolding of HA and LA students in IPA learning could be effective if the scientific work is performed in a cooperative group (Nussbaum et al., 2009).

In addition, the empowerment CTSs of the students with different academic levels is obviously essential. A potential learning model to improve the HA and LA students' critical thinking skills is the Inquiry-Student Team Achievement Development (INSTAD). INSTAD is a new learning model which integrates the investigative aspect from the guided-inquiry model and collaborative aspect from STAD model (Prayitno & Suciati, 2017). Previous research result on the INSTAD has shown great improvement Students' Science Proses Skills and Scientific Outcomes. Thus, the INSTAD is assumed to be able to improve students' CTSs more effectively than the Guided-Inquiry.

According to Prayitno (2017), the INSTAD has five phases. The First phase is problem orientation which not only requires students to find problems from the presented phenomena but also organizes learning where students are split into teams of 5 people with heterogeneous academic skill levels. The next phase is collaborative inquiry work. This stage demands students to conduct IPA concepts by scientific work in a different way. The unification of various academic skill levels is intended to foster the scaffolding process through peer tutorials. As a result, the aspect of self-regulation and explanation could be optimized further than in the Guided-Inquiry model. The third phase is the presentation, performed after the collaborative concept-forming activity. The next phase is the individual test and team recognition, which is not included in the Guided-Inquiry. The individual test trained students to evaluate the received IPA concepts during the learning process through practice questions. Then, each student should calculate the individual progress scores, team scores, and team rewards. The last stage is the monitoring, which trains students to evaluate their learning improvement after the series of activities they performed (Sulistijo et al., 2017).

Based on the explanation above, it was necessary to do a research aimed to test the effectiveness of Guided-Inquiry and INSTAD towards the students' critical thinking skills.

METHODS

This research was quasi-experiment with 2x1 factorial design (Creswell, 2012). The research sample was treated for five meeting, and the CTSs were measured at the end of the treatment. The independent variable of this research was the Guided-Inquiry and INSTAD teaching models, while the dependent variable was the students' critical thinking skills. The analysis of this research employed descriptive statistical analysis and inferential statistics. The data of critical thinking skills were collected with a sort of essay test. The test instrument for retrieving the critical thinking skill data referred to the Facione indicators.

The participants of this research involved 188 students of XI grade science class at SMAN 7 Surakarta as middle-quality school. The researchers decided to choose middle-quality school assuming that it has more various academic skill level than low or high-quality schools. The intact group sampling has previously been done for the equality test (Creswell, 2012). The equality test in this study was done to the students' examination scores using the test of Komolgorov-Smirnov Normality and Levene's homogeneity. The normality and homogeneity test results indicated that the population had equality. After the equality test obtained, we did match the class test using the ANOVA. The ANOVA results suggested that there were no significant differences of each class' thus, the researchers directly chose two sample groups; XI-Science 2 as the experimental group 1 which would be treated using the INSTAD model and XI-Science 3 as experimental group 2 which would adopt the Guided Inquiry model.

The instrument was a written test compiled using the rubric of critical thinking skills developed by Facione (Facione, 2011). Before starting the assessment, the validity and reliability index of the essay test were tested. The validity test was conducted through an expert analysis and empirical test. Three expert lecturers from Post-Graduate Programme of Teaching and Education Knowledge Faculty of the Sebelas Maret University of Surakarta were selected in analyzing whether the test was appropriate for measuring the critical thinking skills indicators and whether it was consistent with the learning materials. The expert judgments declared that the test was valid with a validity index of 3.80.

The implementation of learning models during the research was controlled by six observers based on observational instruments to check the consistency of the model's implementation. The INSTAD teaching model was applied by considering the criteria of the grouping method. Groups in each treatment class were divided into six of five members each. Two or three students with high academic skills were put together with lower academic skills students in order to guarantee the peer scaffolding in this model. Whilst, in the Guided-Inquiry learning model, a random grouping system was applied.

This study lasted four times in class with consistent group member. Each meeting was run for 90 minutes. The first meeting discussed the blood components, and the second meeting was about the blood type. The third meeting talked about the organs and mechanisms of the circulation system. The fourth meeting was about the disorders and abnormalities in the circulation system. The last meeting was an examination to carry out the critical thinking skill data retrieval using the validated questions.

The data analysis employed the ANCOVA test. Prior to that, the normality and homogeneity tests were performed. In order to eliminate the variation of critical thinking skills among the research samples, the pre-test scores or the baseline of the students' CTSs were used as covariates. The Kolmogorov-Smirnov parametric statistical analysis was adopted for testing the data normality. The pre-test score was 0.070 and the posttest score was 0.052 i.e. in the normal category, whereas the Levene homogeneity test concluded that homogeneous variants were at 0.54.

RESULTS AND DISCUSSION

The results of the critical thinking skill tests on the learning model data source are presented in Table 1.

 Table 1. ANACOVA Test Results Students' Critical Thinking Skills

Source	Type III Sum of Squares	df	Mean Square	р.
Corrected Model	1157.156ª	2	385.719	.000
Intercept	9354.534	1	9354.534	.000
Model	165.554	1	165.554	.039
Pretest	285.968	1	285.968	.008
Error	2219.898	60	36.998	
Total	376939.438	64		
Corrected Total	3377.054	63		

The ANCOVA assumed that there were no group differences at the pretest; therefore, the first step was looking at the p.values of pretest as the covariate. Table 1 showed that the p.value of pretest data source was 0.008 (<0.050), which indicated that the sample had a significant difference for the baseline. It means, most of the research participants experienced a critical thinking skill improvement. Then, the Model data source obtained the p.values of 0,039 (<0,050), showing a significant difference in the learning model's impact on critical thinking skills. The results of the students critical thinking skills taught with the Guided-Inquiry and INSTAD were visualized in Table 2.

Table 2. Critical Thinking Skills in DifferentLearning Models

Model	XCTS	YCTS	Gain	CTScor
Guided Inquiry	30.636	71.721	43.68	73.205
INSTAD	31.719	79.752	50.45	79.924

Description:

XCTS (The average result of critical thinking skills pre-test); YCTS (the average result of critical thinking skills post-test); CTScor: (The average corrected critical thinking skills)

Based on the Ancova test results shown in Table 1, there was a significant difference in students' critical thinking skills improvement between the guided inquiry and INSTAD learning model. Table 2 indicates the students' critical thinking skills in INSTAD class had a corrected average value of 81.093, higher than the Guided Inquiry which was only 75.205. Table 2 also shows an increase in critical thinking skills of the Guided-Inquiry class by 143%, while the IN-STAD class had a higher increase of 159%. This results revealed that the INSTAD model had a higher potential to improve critical thinking skills than the Guided Inquiry model.

Differences in the students' critical thinking skills between the Guided Inquiry and IN-STAD class were also analyzed based on every aspect of critical thinking skills. Figure 2 visualizes the score differences of each critical thinking skill aspect in the Guided Inquiry and INSTAD class.



Description:

A: Interpretation, B: Analyzing, C: Explanatory, D: Evaluation, E: Concluding, F: Self-regulation

Figure 1. The Differences between the Two Learning Models on Each Aspect of Critical Thinking Skills Figure 1 informs that the students' interpretation skill in the INSTAD teaching model obtained the highest score than others, whereas the evaluation skill in the Guided-inquiry teaching model had the lowest percentage. Although the students' ability to interpret, analyze, evaluation, concluding, and self-regulation in the INSTAD class was higher than in the Guided-Inquiry class, the explanatory skill of the Guided-Inquiry class was better.

The Collaborative group formation phase for inquiry work which places the heterogeneous academic level of students made an obvious difference for the INSTAD model compared to others (Prayitno & Suciati, 2017). In addition, the teachers also provided the materials of circulatory system phenomena which became the investigating issue such as anemia, accidents, and blood transfusions. The cases were able to stimulate the students' curiosity before the learning began. The scaffolding process worked so well that each group member with a higher academic level was able to guide the lower academic members to achieve ZPD (Zone of Proximal Development) (Azizah et al., 2018). Scaffolding supported the students at the beginning of a lesson and then gradually turned over the responsibility of them to operate on their own (Gillies & Haynes, 2011). Peer tutors among group members in the IN-STAD model were more active than the Guided-Inquiry class. The scaffolding process between peers has fostered each students' critical thinking skills, especially the self-regulation which score higher in the INSTAD class (Garrison & Akyol, 2015).

- LA1: No determining part of heart (the experiment using Cow Heart), then ask to HA1
- HA1: Prompting and probing (ask to LA1), then Observe and verbalizing the cow heart, the right and left heart can be distinguished by observing the valve
- LA1: No determining the location of Aorta, ask to HA2
- HA2 : Prompting and probing (ask to LA1), then LA2 explaining the location of Aorta (on his answer), then Making concep map (between the part of Heart)

Figure 2. The Examples of Peer Tutoring between HA and LA Students in the Collaborative Group of INSTAD

The increasing aspect of explanation indicated that the students started to be trained to describe the information illustrating the content of the information clearly (Facione, 2011). After treatment using both models, the students were able to explain the procedures for measuring a person's blood pressure, identify between normal and abnormal blood pressure, and provide the experimental results, such as explaining the structure and function of circulatory organs. A good explanation cap skills will be seen when a student expresses her opinion with confidence (Zhou et al., 2013). Their activities of constructing the concepts, drawing a conclusion, presenting to others have been proven to improve students' critical thinking skills, especially the explanation aspect (Sampson & Clark, 2008; Forawi, 2016).

The class presentation stage required the students to act as the presenter in charge of explaining the experimental results. The students presented the various components of blood, the principle of blood type, and other concepts obtained during the scientific work. Both learning models have stages that enable students to communicate the experimental results. However, the collaborative group of INSTAD learning tended to make the lower academic group members became less confident when explaining something so that students were more likely to have a higher academic member to explain it. The lack of confidence resulted in the less optimal explanation skill. (Damavandi & Shekari, 2010; Ramli et al., 2017).

The results of this research showed that there was a difference in critical thinking skills between the INSTAD and Guided-Inquiry models. Thus, it is parallel with the previous research stating that the INSTAD has a higher potential to enhance learning process than the Guided-inquiry (Prayitno et al., 2017; Prayitno & Suciati, 2017; Sulistijo et al., 2017). However, it should be kept in mind that these results are specific to study the effect of different teaching models in students critical thinking skills.

The differences between INSTAD and Guided-inquiry were seen from the differences in their activities of inquiry work. The collaborative team fostered the low academic students to determine their own scaffolding process since peer tutoring provides longer study time for low academic students (Wass et al., 2011). Adequate study time is obviously able to improve the critical thinking skills of low academic students.

Based on these research results, the researcher recommended implementing the INSTAD

model especially for the scaffolding process by peer tutoring to nurture students' critical thinking skills. Each of critical thinking skill indicator needs to be trained as it is one of the fundamental skills to master IPA and implement it in everyday life.

CONCLUSION

The research finding supported the theory and the previous research stating that there was a difference in critical thinking skills between the two models. The students who joined the INSTAD class had the highest critical thinking skill indicators except for the explanation. This research was limited to the subject of science in SMAN 7 Surakarta. The research may be continued on the subject of science or other subjects at primary or middle schools. Future research can also focus on other thinking skills such as creativity, problem-solving, scientific literation, and among others.

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ELECTRONIC VERSUS PRINTED BOOK: A COMPARISON STUDY ON THE EFFECTIVITY OF SENIOR HIGH SCHOOL PHYSICS BOOK

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ABSTRACT

This study aimed to examine the effectiveness of senior high school physics book both interactive electronic and printed, viewed from the difference in gender and material characteristics. The research used Quasi-Experimental Design with Non-Equivalent posttest-pretest control group design. The data were collected through physics tests from six senior high schools in Lampung Province, Indonesia and analyzed on ANOVA and multiple comparisons to determine the differences in learning outcomes (affectivity) and interaction between interactive electronic and printed, gender, and material characteristics. The results showed that there were different learning outcomes caused by interactive electronic and printed physics book (p=0.000<0.05). The learning outcomes using interactive electronic books were better than using printed books for both male and female students while gender differences did not affect physics learning outcomes for both interactive electronic and printed books (p=0.000<0.05). There was no interaction between interactive electronic and printed books and gender (p=0.298>0.05). There are differences in learning outcomes caused by physical material characteristics (p=0.000<0.05). Therefore, it concluded that the high school interactive physics electronic book was effectively used as a learning resource for both male and female students.

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Keywords: effectiveness interactive electronic book, gender, physics material characteristics

INTRODUCTION

Many factors could affect students' physics learning outcome, for example, learning resources, material characteristics, students' experience, motivation, teaching method, and the initial competence of students (Hänze & Berger, 2007; Haycock, 2007). Commonly, schools use printed books as a learning resource which has been recommended by the Center of Curriculum and Books (Pusat Kurikulum dan Perbukuan), Ministry of Education and Culture. These books have been subject to content conformity with the existing curriculum. However, there has not been

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any research or study on the conformity of the format and its form.

The government recommends electronic school books for use in schools and purchase copyright from authors. By this way, anyone can print and reproduce the book at the maximum price set by the government. Besides that, students are allowed to download these books in pdf format and use it as learning resources without paying (Andina, 2011). This policy will certainly help students in providing a good and affordable learning resource.

Nevertheless, the question is, why the average Indonesian student learning outcomes is still relatively low (data from PISA/Programme for International Student Assessment score). The

data conclude the average score of Indonesia science literacy in 2015 was 403, and it belogs to rank 62 of 70 countries participant, while another ASEAN countries such as Vietnam is in the 8th rank and Thailand in the 54th. Further analysis of PISA in Indonesia, obtained the fact of the average future career field Indonesian children in science is 15.3% (boys 8.6%, girls 22.1%). Index of learning science motivation is 0.65, whereas the average OECD is 0.02. besides that, the difference of learning science motivation between boys and girls is -0.06. This means that Indonesian girls enjoy learning science more than boys (OECD, 2015). This fact must be followed up with various studies that lead to increasein learning outcomes, of of them is concern in book form which become the main source of learning.

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The use of learning resources become one factor which can influence the learning outcomes. Therefore, as the development of science and technology in the world, requires educators/teachers to modify the learning resource in the form of printed into unprinted. One of the most unprinted learning resources is an electronic-based book. Throughout the literature review, electronic-based books have been defined and described in numerous ways. Most research on electronic-based books defines them as texts that are digital and accessed via electronic screens. There are two formats in which electronic-based books. These are page fidelity and reflow-able digital electronic-based books (Jeong, 2012; Chesser, 2011; Salmon, 2014). Besides, many researchers in higher education have focused primarily upon faculty and student preferences of etextbook formats (Margolin et al., 2013; Kim & Kim, 2013; Robinson, 2011; Jamali et al., 2010; Woody et al., 2010, Kang et al., 2009).

By using electronic-based books, many physical processes can be easily understood and visualized by students. Electronic based-book belongs to an interactive book because written in many kinds of color, some illustrations have a moving, sounds, animation, video, and film (Holaday et al., 2013; Ambarwati & Suyatna, 2018; Suyatna et al., 2018). Electronic books are developed by using software, for example, the Learning Content Development System (LCDS). By using the interactive book, students are able to study by themselves, anywhere and anytime. In order to accommodate it, the interactive book must be created and designed to accommodate it. In preparing interactive book required adequate supporting knowledge, especially in operating equipment such as computers, video cameras, and photo cameras. Such kinds of book are important to be developed in many kinds of subject, for example, physics.

Perhaps, through the use of LCDS-based learning module facilitates physics teacher in delivering physics concept, especially for an abstract concept. Therefore, it can improve students in understanding physics. Because the LCDS-based learning module is able to engage students to be active through the discovery process, and trigger the mindset of students in conceptualization (Nuralinda, 2017). Books developed using the LCDS are also attractive, easy to use, useful, and effective in improving student learning outcomes (Aulia et al., 2017).

Five kinds of the use of a computer in the learning process are drill and practice, tutorial program, demonstration, simulation, and instructional games (Hoseth & McLure, 2012; Reynolds, 2011). The overall use of computer programs above can be seen in an LCDS-based book. LCDS makes it easy to publish e-learning with customizable content, interactive activities, quizzes, games, animations, videos, and other multimedia (Aremu, 2013). The LCDS application has several advantages, among them: (1) developing and publishing content quickly, timely and relevant; (2) delivering Web content in accordance with SCORM 1.2 and can be hosted in a learning management system; (3) uploading or publish existing content; (4) creating rich e-learning content based on Silverlight easily; (5) developing training structures and easily reorganize at any time; (6) developing learning books equipped with animation, images, videos, and interactive questions (Taufani & Iqbal, 2011).

Personality and motivation play important roles in explaining gender differences in school attainment (Steinmayr & Spinath, 2008). According to Huang et al. (2017), male and female are motivated differently when reconstructing their identities, a female is more focused on highlighting the physical situation, while a male emphasizes their achievement. At the age of 14-17, a person's typical characteristics begin to emerge, namely the nature of passive-accept for females and the active-doing for males. Therefore, the appearance of male's behavior seems more intense and explosive while female's behavior seems more controlled by feelings and tied to family traditions and rules (Kartono, 2017). Yukselturk & Bulut (2009) analyzed gender differences in self-regulated learning components, motivational beliefs, and achievement in a self-regulated online learning environment. The results showed that test anxiety explained a large number of variants in female student achievement and two variables

(self-efficacy for learning and performance, and task scores) explained a large number of variants in male student achievement. It was also found that there were no statistically significant mean differences between motivational beliefs, selfregulated learning variables, and achievement in gender programming. Besides, female students also have higher levels of test anxiety than male. It causes the lower course grades for female participants (Chinet al., 2017). They also suggested that the relationship between gender and negative affect may be a significant indicator of an individual's predisposition towards high test anxiety and poor course grades. Further added by the study of Yang et al. (2011), male students are spending more effort than female in online learning while female expend more energy than male on face-to-face learning. There are gender differences to emotional intelligence in some specific aspects (Lopez-Zafra et al., 2012).

Based on the above description, it concluded that gender and the utilization of learning resources is one of the factors that influence student learning outcomes. Therefore, every teacher in the school should have the ability to handle gender differences through the use of interactive learning resources, one of them through the interactive electronic learning of physics. In addition, it is also important to know whether interactive electronic books are suitable as a learning resource to present different physics learning materials.

With this in mind, this study aimed to examine the effectiveness of interactive electronic books of physics in terms of differences in format, gender, and material characteristics.

METHODS

The population of this study was all students of grade XI Senior High School in Lampung Province, Indonesia, year 2016/2017. The sample was chosen by purposive sampling as many as 12 equivalent classes. The first six classes study physics with a source of learning, interactive electronic books. Each class studied a different topic, namely: Elasticity and Hooke's Law, Kinematic, Simple Harmonic Motion, Heat, Impulse and Momentum, Work and Energy. The second six classes studied physics using the printed physics book published by Center of Curriculum and Books, Ministry of Education and Culture. The learning approach of all classes was the scientific approach. To examine the differences in students' learning outcomes caused by the differences in the books form, gender, and the interaction between book form and gender, a factorial design was employed (Table 1).

Table 1. The Factorial Design (2x2)

Attribute		Book Form				
E-b Intera (El	ook active BI)	Printed Book (PB)	Total			
Gender	Male (M)	M-EBI	M-PB	М		
	Female (F)	F-EBI	F-PB	F		
Total		EBI	PB			

In this design, all of the classes were given pretest before treatment and posttest after treatment. The instruments for pretest and posttest were in the form of multiple choices which consisted of 10 items for each different materials or 60 items in total. The instruments had an average Normalized Gain of pre and post-test score (Marx & Cummings, 2007). It was the differences of posttest and pretest score divided by the difference maximum score and pretest score.

A two-way ANOVA is useful when we desire to compare the effect of multiple levels of two factors and have multiple observations at each level (Wobbrock et al, 2011). In this study, the twoway ANOVA was used to examine the differences in learning outcomes caused by differences book form (electronic interactive and printed), gender differences (male and female) and the interaction between book form and gender. A One-way ANOVA test was conducted to examine the differences in learning outcomes caused by differences between the physics of interactive electronic books. The multiple comparison tests were performed to determine the physics materials that led to different learning outcomes.

RESULTS AND DISCUSSION

This research was preceded by the development of LCDS-based interactive electronic books as the learning source covering the topic of elasticity and Hooke's Law, heat, kinematics, simple harmonic motion, impulse and momentum, and work and energy for high school students. In the experimenalt class, the students used the offline LCDS-based interactive electronic book. They were required to access menus, do the simulation, play video, and do an interactive test as an exercise. Meanwhile, in the control class, the teacher

taught the materials and student did the exercises in a printed physics book. The data analysis results of students' learning outcome in each topic and gender are shown in Table 2.

Tonia	The Students' learning outcomes			
тори	Male (M)	Female (F)	Difference (M-F)	Total
Elasticity and Hooke's Law	80.83	73.33	7.50	75.83
Kinematic	80.00	75.83	4.17	78.00
Simple Harmonic Motion	73.75	66.82	6.93	68.67
Heat	83.56	80.83	2.72	81.88
Impulse and Momentum	74.67	70.94	3.73	72.74
Work and Energy	85.38	90.63	-5.24	88.28
Total Average	79.70	76.40	3.30	77.57

Table 2. The Students' Learning Outcome in Each Topic And Gender

Table 3. The Two-way Anova Analysis of Book Form and Gender

Source	Type III Sum of Squares	df	Mean Square	F	р
Corrected Model	1.094ª	3	0.365	17.660	0.000
Intercept	12.876	1	12.876	623.290	0.000
Book Form	0.884	1	0.884	42.801	0.000
Gender	4.431E-5	1	4.431E-5	0.002	0.963
Book Form*Gender	0.023	1	0.023	1.101	0.298

The two-way ANOVA test results are presented in Table 3. The results of the difference between the N-Gain mean between the students (both male and female) using the interactive electronic book with students using printed books obtained p = 0.000 less than $\alpha = 0.05$. This elucidated that there was an average difference of the N-Gain between the students who studied physics by using interactive electronic and printed books.

The students who used the interactive electronic book got higher learning outcomes than those utilizing the printed book. This finding confirms the research done by Rockinson-Szapkiw et al. (2012) stating that students who chose e-textbooks for their education courses had significantly higher perceived effective learning and psychomotor learning than students who chose to use traditional printed textbooks. This acquisition is possible because the interactive electronic book is equipped with animated physical phenomena for moving objects such as kinematics motion which is shown in the example of straight irregular motion, accelerated motion, parabolic motion, impulse and momentum, etc. Thus, object movement can be evaluated directly any time. Through animations, the students were able to differentiate between the harmonic and non-harmonic motion. These findings are supported by other research results, including the effects of dynamic visualization. Dynamic visualization for moving objects is better than static visualization so that the students' learning outcomes increased (Suyatna, et al., 2017; Chesser, 2011). This is in line with the research carried out by Suyatna et al. (2017) which showed that the N-gain average of students' learning outcomes using moving image-assisted was higher than a static object.

Media that integrates a combination of digital text, graphics, animation, and sound in physics learning could attract sight, stimulate students' learning motivation, and produce effective physics learning (Higgins et al., 2018; Faulconer et al., 2018). According to Lin (2009), the animation was created to convey the concept of change and was considered effective in expressing the process. The research results supported the findings that the students' learning outcomes whose learning process was supported by interactive electronic books equipped with animation and simulation of physics laboratory were better than the printed book. The higher learning results were caused by Indonesian printed books which lack experiment procedures. Bancong & Song (2018) analyzed 30 physics textbooks from Grades 10 to 12 which are widely used both by teachers and students. The results showed that the majority of physics textbooks did not mention about thought experiments. Only 6 physics textbooks presented thought experiments at a satisfactory level.

LCDS software as a system development content of electronic learning materials very supports the arrangement and completeness of teaching materials. The LCDS could display text, images, animations, videos, experimental simulations, and quizzes, both online and offline. Experimental simulations contained in interactive electronic books strongly support problemsolving abilities. This is supported by the results of Gunawan et al. (2017) and Ebied & Rahman (2015). According to Sjarif et al. (2016), the use of integrated modules using interactive lectures and workshops could improve students' understanding and skills.

Based on the two-way ANOVA analysis (Table 3), gender differences did not give significant differences in student learning outcomes. The average N-Gain of male students' learning outcomes was not significantly different at the 95% confidence level compared to the N-Gain average of female students' learning outcomes, both in students using interactive electronic and printed physics books (p = 0.963 > 0.05). Male

students studied physics as well as female students. Although there was a difference in sciencelearning motivation between boys and girls, where Indonesian girls enjoy learning science more than boys, the interaction between male and female students during the classroom learning process reduced the differences (OECD, 2015). This finding is different from the research performed by Sahal (2016), male students' learning outcomes were better compared to male students' learning outcomes. This research was conducted on boarding schools where male and female students were separated so that during the learning process, there was no interaction between male and female students. However, this finding also confirms the research result of Hoogerheide et al. (2016) which concluded that gender does not affect learning outcomes, but may influence affective aspects of learning.

The result of two-way ANOVA analysis on the interaction between book format and gender resulted in sig value or probability p = 0.298 >0.05. It shows that there was no interaction between book form and gender. Thus, both male and female students could use either electronic or printed books. The results showed that students physics learning outcomes would be better if their learning was supported by interactive electronic books, both for male and female students when compared by using physics printed book.

The results of one-way ANOVA analysis elucidated that there were differences in learning outcomes seen from the characteristics of physics materials (Table 4).

Table 4. One-Way Anova Analysis for Interaction between Different Physics Learning Materials and

 Students' Learning Outcomes

Source	Type III Sum of Squares	df	Mean Square	F	р
Corrected Model	8380.64 ^a	11	761.877	7.730	0.000
Intercept	1022761.44	1	1022761.44	10376.81	0.000
Material Characteristic	5746.701	5	1149.340	11.661	0.000
Error	16952.688	172	98.562		
Total	135644.64	184			
Corrected Total	25333.333	183			

a. R Squared = .331 (Adjusted R Squared = .288)

Further analysis was done to see an increase in the average learning outcomes on different physics materials. A multiple comparison analysis was used for this (Table 5). Based on the results in Table 5, there were different physics learning outcomes between elasticity and Hooke's Law materials; elasticity and Hooke's

Law with Work & Energy; Motion Kinematics and Simple Harmonic Motion; Motion Kinematics and Work & Energy; Simple Harmonic Motion and Heat; Simple harmonic motion and Work & Energy; Heat and Impulse & Momentum; Impulse & Momentum and Work & Energy. Overall, there were seven pairs of different learning
outcomes occurred. These differences could be evaluated through its mean differences.

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The students' learning outcomes on Work & Energy were higher than Elasticity and Hooke's Law topic. The concept of elastic modulus was still considered difficult by the students since it involved abstract concepts. This is in contrast to the concept of Work & Energy whose examples could be found in daily life. Therefore, it is facile to visualize and simulated. The Kinematics materials are easier than the Harmonic Motion materials although both topics are easily visualized, Kinematics materials are simpler to be represented in various forms.

Table 5. The Students' Learning Outcomes Using Multiple Comparison Test in Different Learning Materials

(I) MK	(J) MK	Mean Difference	р
EHL	K	-2.1697	0.966
	SHM	7.1637	0.063
	Η	-6.0504	0.127
	IM	3.0884	0.829
	WE	-12.4455*	0.000
Κ	SHM	9.3333*	0.008
	Н	-3.8808	0.648
	IM	5.2581	0.364
	WE	-10.2759*	0.003
SHM	Н	-13.2141*	0.000
	IM	-4.0753	0.598
	WE	-19.6092*	0.000
Η	IM	9.1388*	0.002
	WE	-6.3951	0.096
IM	WE	-15.5339*	0.000

*) significant different at 95%

EHL is Elasticity and Hooke's Law, K is Kinematic, SHM is Simple Harmonic Motion, H is Heat, IM is Impuls and Momentum, WE isWork and Energy

The Heat materials were felt easier than Simple Harmonic Motion since the Heat concept was frequently encountered by the students in everyday life. The average difference in learning outcomes for each physics topic was due to differences in material characteristics, and the development quality of interactive electronic books. A good interactive electronic book should have several criteria including the concepts, principles, formulas, and laws which are systematically arranged and supported by images, animations, videos, experimental simulations, and interactive exercise questions.

It cannot deny that each of physics topic has a different difficulty level. There were several topics that can be directly observed, done and learned in the learning so that the students are easier to understand and apply it. However, some other topics are arduously understood as they could not do direct experiments in the learning process. Although computer-aid was utilized, there was a time that the students had to imagine what happens. this imagining skill may vary to each student which; therefore, ultimately affect their learning outcomes.

CONCLUSION

Based on the results and discussions, it concluded that there were differences in physics learning outcome caused by different book forms. The students' learning outcomes using interactive electronic books were higher than printed books. Meanwhile, there was no difference in the average of physics learning outcomes caused by gender both in the experimental and control class. Male students' learning outcomes were not significantly different from female students. Besides. there was no interaction between the interactive electronic book form with gender in terms of learning outcomes, but there was a difference in physics learning outcomes caused by the distinct characteristics of interactive electronic books. These also indicated that interactive electronic books are feasible as a learning resource to present different physics learning materials.

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GEOMETRICAL OPTICS PROCESS IMAGE-BASED WORKSHEETS FOR ENHANCING STUDENTS' HIGHER-ORDER THINKING SKILLS AND SELF-REGULATED LEARNING

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ABSTRACT

This study intended to prove whether process image-based worksheets of geometrical optics could enhance students' higher-order thinking (HOTS) and self-regulated learning (SRL). This was quasi-experimental research of non-equivalent control group design. This research was conducted to grade 8 junior high school students at a junior high school in Jember district studying the geometrical optic. The sample was 70 students; 35 students belonged to an experimental group and the other 35 students in a control group. The HOTS data were obtained from test results and the SRL data were collected from questionnaire results. To determine the effect of using the worksheets on the students' HOTS and SRL, carried out was an independent t-test at a significance level of (2-tailed) $\alpha = 0.05$. The results showed that the worksheets had a significant effect on the HOTS seen from $\alpha < 0.05$ and that the t_{count} = 14,692 (>t_{rable}). Thus, it concluded that the learning with the worksheets had a significant influence on the junior high school students' HOTS and SRL which are required for preparing their life in the 21st century.

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Keywords: worksheets, process image, geometrical optics, HOTS, SRL

INTRODUCTION

Physics is a part of science that taught on senior high school students. Geometrical optics is a part of physics which can be learned through any learning printed media such as student worksheets. The development of science and technology in the 21st-century requires humans to be able to think in higher level or have higher order thinking skills (HOTS) and self-regulated learning (SRL) in overcoming problems in the world and

*Correspondence Address E-mail: indrawatisutarto.fkip@unej.ac.id the everyday life due to the massive challenges that must be faced. The problem is: how to create student worksheets (SW) which can enhance students' HOTS and SRL?

The 21st-century science subject demands the development of students' HOTS since there is a significant relationship between HOTS and students' academic achievement (Ramos et al., 2013; Fariyani et al., 2017; Tanujaya et al., 2017; Gallagher et al., 2012). However, the needs analysis of learning HOTS for generating ideas is more difficult (Heong et al., 2012). Other than that, students are also expected to be independent in learning or so-called the self-regulated learning (SRL) as it would affect their learning outcomes (Cheng, 2011; Law et al., 2008; Alibakhshi & Zare, 2010). Daniela (2015) said that SRL should be involved in learning to enhance academic performance for the secondary school students. Hence, schools should facilitate every learning process of all subjects, especially science, for students to develop their HOTS and SRL.

Science is one of the junior high school subjects covering physics, chemistry, biology, astronomy, and geology; while the essence of science subject is a process, product, and attitude (Sutarto & Indrawati, 2017; Trowbridge & Bybee, 1990). The product of science subject includes facts, concepts, principles, theories, or laws. Meanwhile, the process refers to the way of obtaining the science products which covers ways, methods, or steps taken when solving a problem or finding the product knowledge. Such a process is called a scientific method which consists of seven stages: (1) defining the problem; (2) collecting information; (3) forming a hypothesis; (4) conducting an experiment; (5) recording observation and analyzing the data; (6) drawing up a conclusion; and (7) publishing the results (Passmore et al., 2009). Referring to the same sources, attitude defines as an individual response while conducting the stages of scientific methods such as honesty, objectivity, conscientious, perseverance, and curiosity. In sum, solving a science problem requires several steps done in an experiment.

As mentioned above, science fundamentally comprises process-product. Thus, good science learning does not only discuss product knowledge but also study the process of product making. Schools of a developing country like Indonesia generally do not implement the practice of science process, arguing that there are not sufficient facilities and too much time-consuming.

The practice of science process is needed in learning since it clarifies the logic mistakes of students towards a scientific phenomenon. For instance, provided were two colors (red and blue) mixed into purple (violet), but when asked about the results of mixing the primary colors (red, orange, yellow, green, blue, indigo, and purple), they answered incorrectly. Instead, their answer was black, or even a new color. Furthermore, they marveled that mixing all the colors results in white. This phenomenon indicates that the practice of science process is required in science learning.

The paradigm-shifting of school learning from knowledge transferring into learning transferring has elucidated that not all science topics taught in schools must be equipped with the practice of scientific process. Instead, the practice of science process intends to stimulate students' motor skills in science, and not to examine all science materials. The practice of science process ultimately aims at giving experience to students in examining a science phenomenon empirically, which would enrich their cognitive process in the form of intellectual skills (Conklin, 2005).

Science is a subject discussing either real or abstract events. The real science event is relatively easy to explain, while the abstract ones are quite complicated (Sutarto & Indrawati, 2017). This means that although science learning has been equipped with sufficient learning sources and supported by the practice of the science process, teachers' explanation remains to be needed to teach the abstract concept. However, a learning process involving many teachers' explanation categorized as the knowledge transfer.

In accordance with the communication theory proposed by Severin & Tankard (2001), a new oral/written information is initially accepted by an individual's sense before getting in the memory function stored as the new knowledge and deciphered into codes and pictures. This information coding is strongly influenced by knowledge, experience, codes, or pictures owned by the individual. Next, the new coded information would be stored as the individual's new knowledge. This theory gives an understanding that inaccuracy between the purpose and the individual's comprehension of the information is called misconception, which caused by the individual's inaccuracy in decoding the content. Therefore, helping students depict oral and written information before it is accepted as new information would minimalize the occurrence of misconception.

Objects learned in science are generally related to natural phenomena. Basically, learning natural phenomena is a process of observing the occurrence of a certain phenomenon. The length and abstractness of a phenomenon make it difficult to be understood by students. Thus, proper learning media is necessary for the sake of the students in learning abstract science concepts. Stefanikova & Prokop (2015) explained that using the visual media by pictures could bridge the difficulties of abstract science concept and stimulate students' thinking process. Moreover, pictures as one of the visual media could assist learners in understanding a concept correctly and chronologically (Shabiralyani et al., 2015).

A process image is an image containing the processes or stages of changing the occurring phenomenon. Sutarto & Indrawati (2017) interpreted the process image as a series of the object image (objects, events, or phenomena). The series of images always have a relative difference between one and another in terms of circumstances, position, form, or combination, which wholly depicts a coherent stage. If process images are used to embed a concept, it needs analysis and evaluation skills; in other words, HOTS. Thus, it is possible to learn science concepts by analyzing the steps or the transformation in the process image to make it easier for students to understand the concepts. In its presentation for learning, process images can be manifested through printed media such as student worksheets (SW).

Some studies on learning with process image-based printed media have been previously carried out. Sutarto & Indrawati (2017) have shown that learning with process image-based printed media was effective for the collision concepts taught in senior high schools on the students' picture and graph representation skills as well as learning outcome improvement. Figure 1 is the process image example of collision concepts.



(Sutarto & Indrawati, 2017)

Figure 1. The Collision Process Between Two Objects

The same research was carried out by Zainuri et al. (2017) showing that process image-based worksheets made students active, also, enhanced their learning outcomes and independence. The use of the process image is also effective for learning electrolyte and non-electrolyte solutions of students in high schools (Doymus et al., 2010).

Science subject in junior high schools mostly contains physics, biology, and geology. Geometrical optics is one of the subjects included in the syllabus of junior and senior high school science subjects. Geometrical optics is studied in physics talking about the behavior of light through a ray approach by applying geometrical principles. The rays in the geometrical optics are symbolized by a straight line whose direction of propagation follows the direction of light propagation. The concepts studied in geometric optics are the concepts of propagation, reflection, and refraction.

Interview results with several physics teachers stated that geometrical optics is a relatively simple physics topic. Nevertheless, this opinion turned out to be completely incorrect. Geometrical optics is not easily understood by the students, physic students or even physics teachers (Blizak et al., 2009; Kaltakci & Eryilmaz, 2010; Vitharana, 2015; Kaltakci et al., 2016). The same thing is also shown by the results of the study conducted by Fariyani et al. (2017). The description illustrates the need for media that can help to facilitate students in understanding the concepts of geometrical optics and preventing conceptual errors.

Based on the interview results with several science teachers and observations on the implementation of geometrical optics learning in several regional schools in East Java, it obtained that almost all explanations of geometrical optics materials did not equip with a complete explanation of the process, such as the origin of normal line during the reflection and refraction, lack of complete marking of the beam sequencing at the geometrical optics process, and so on. Therefore, appropriate learning media should be provided to elucidate the process of the beam in forming the object shadows.

As previously explained, the process image-based worksheets are able to guide students to think about the way of analyzing the event process, for example, the way the light falls in the field of reflection (mirror) and the light sequence when falling in the field of refraction; also, interpreting the normal line, the angle of arrival, the bounce angle, and the bias angle. This allows students to more easily capture the provided information. The use of process images requires HOTS especially in analyzing and evaluating. Hence, it is said that the HOTS could be developed through images. The reason why the process image is manifested into printed form was to boost the students' independence learning. Therefore, a proof was needed whether the image process-based worksheets could affect the students' HOTS and instill their SRL.

METHODS

This research aimed at studying the impacts of using the geometrical optics process image-based worksheets on junior high school students to improve their HOTS and SRL. Hence, this was a quasi-experimental research of Static Group Comparison Design or known as Non-Equivalent Control Group design (Fraenkel & Wallen, 2009). The independent variable of this research was geometrical optics process imagebased worksheets while the dependent variable was the higher-order thinking skills (HOTS) and self-regulated learning (SRL). Based on the design, the students in both the experimental class (E) and control class (C) were tested their HOTS and SRL. The research subject was eight graders at one of the junior high schools in Jember Regency.

The instrument for measuring HOTS was two sets of test referring to the 4th (analysis) and 5th (evaluation) level of the revised Bloom's taxonomy (Conklin, 2005). There were 12 argumentative multiple questions each. The first set comprised reflection concepts (four questions of the reflection on a flat mirror, four questions of reflection on a concave mirror, and four questions of the reflection on a convex mirror) and the other set covered refraction concepts (four questions of the refraction on a flat mirror, four questions of the refraction on a concave mirror, and four questions of the refraction on a convex mirror). Of the 24 questions, it obtained 22 valid (logical validation results) and reliable items. The KR-20 reliability coefficient obtained 0.784 (good criteria); so, the reliability was acceptable (Dunn, et al, 2013).

The instrument used to measure SRL was a questionnaire adapted from (Ismail, et al., 2012) which has been declared valid at $\alpha = 0.05$ with a corrected item-total correlation average of 0.79 ($r_{count} > r_{table}$). Fraenkel & Wallen (2009) stated that the minimum requirement of eligibility is r = 0.3 and the instrument is said to be reliable if the Cronbach alpha value is > 0.6 at α = 0.05. Based on the results of the SRL questionnaire instrument trial, the value of Cronbach alpha was 0.986>0.6 which categorized as very high of the value range (0.81-1.00). The developed SRL questionnaires consisted of 40 items containing 11 indicators, namely: (1) seeking information; (2) self-esteem; (3) environmental control; (4) peer learning; (5) self-evaluation; (6) strategy training; (7) controlling environmental

motivation, (8) self-talk about learning efficiency, (9) self-talk about learning achievement, (10) time management, and (11) elaboration (Ismail& Sharma, 2012). The SRL data were analyzed using a Likert scale of 1 to 5. The criteria of SRL were very high (VH), high (H), intermediate (I), low (L), and very low (VL), if the score between 80.1 - 100; 60.1 - 80; 40.1- 60; 20.1 - 40; and 0 - 20 respectively.

To see the effect of the treatment on HOTS and SRL, the data analysis technique used was inferential statistics namely t-test or difference test to compare the students' HOTS and SRL in the experimental and control class. Before performing the t-test, the data must be tested for its normality and homogeneity to determine which type of test should be performed, either parametric or non-parametric. The t-test analysis employed the polled variance formula. Such formula is used when the number of samples is the same (n1 = n2) and homogeneous. To calculate the t-test, the SPSS version 20 for Windows was employed.

RESULTS AND DISCUSSION

This research was carried out to eight graders of junior high school at Jember Regency; one class as the experimental class and the other as the control class consisting of 35 students each. The impacts of process image-based worksheets on the students' HOTS and SRL are explained as follows;

The Impacts of Process Image-Based Worksheets on *HOTS*

The impacts of using the geometrical optics process image-based worksheets for the reflection and refraction concepts on the students' HOTS, especially in the category of descriptive analysis and evaluation in both the experimental control class are presented in Table 1. This study determined two thinking skills because conceptual analyses of process image cannot help students to learn until they reach the creating level.

	Reflection Concept			Refraction Concept				
HOTS elements	E (N	=35)	C (N	=35)	E (N=	:35)	C (N	=35)
-	Μ	SD	М	SD	Μ	SD	М	SD
Analysis	80.1	2.6	70.6	4.4	80.48	1.9	70.0	4.4
Evaluation	80.6	2.1	70.0	4.2	81.51	1.9	69.4	4.6

Table 1. The Descriptive Analysis Results of Students' Hots in the Experimental and Control Class

Table 1 shows that the students' HOTS averages on the concept of reflection and refraction taught using the process image-based worksheets were almost the same; between 80-81 in the experimental class and 69-71 in the control class with the same standard deviation. The difference between experiment and control class is caused by students' control class have several misconceptions of incident and reflection angle, and normal line. There are several students of control class that have difficulties for drawing of image formation process on a spherical lens. Figure 2 shows one form of students' misconception of image formation on a convex lens. Several students said that image is always located in front of an object and the distance object to lens equals image to a lens (red arrows).



Figure 2. The Formation of a Spherical Lens (Convex Lens)

The analysis results of the independent sample t-test for the students' HOTS in the experimental and control class are explained as below.

The proposed hypotheses in this research were: (1) Ho: There was no difference between the average scores of the students' HOTS in the experimental (E) and control (C) class; and (2) Ha: The difference existed between the average scores of the students' HOTS in the experimental and control class. The basis of decision making: If the value was significant or sig. (2-tailed)> 0.05 then Ho was accepted and Ha was rejected; or, if the value was significant or sig. (2-tailed) <0.05 then Ho was rejected and Ha was accepted.

Based on the SPSS analyses of the t-test, it indicated that the sig value. (2-tailed) of the HOTS on reflection and refraction topic, both at the analysis and evaluation aspects was all <0.05. This shows that Ho was rejected or Ha was accepted, meaning that the difference existed between the students' HOTS in the experimental class and the control class. As seen in Table 2, the average HOTS on the reflection and refraction materials for the experimental class was higher. This indicated that the use of process image-based worksheets for geometrical optics had an effect on the students' HOTS. This was consistent with the findings of Sutarto & Indrawati (2017) revealing that the process image-based worksheets were effective for teaching the mechanics topic taught to high school students. The process image is a kind of visual media. Ainsworth et al. (2011) said that scientist making visualizations is integral to scientific thinking. Scientists do not use words only but rely on diagrams, graphs, videos, photographs, and other images to make discoveries, explain findings, and excite public interest. Raiyn (2016) showed that visual learning tools could increase the students' HOTS. Zainuri et al. (2017) also found that there was an effect of the process image-based worksheets for learning the light concept for junior high school students. Next, (Doymus et al., 2010) also found that printed media with process images was effective for learning the electrolyte and non-electrolyte solution materials in high schools. In addition, a clear task for analyzing process images was also influential to generate ideas in students, so that their higherorder thinking skills (HOTS) were developed primarily for analyzing and evaluating skills. This is in line with the results of the study conducted by (Davar, 2012) and Maries & Singh (2017) concluded that productive diagram or process image also improved student's problem-solving. Heong et al. (2013) which stated that generating ideas are highly essential for emerging HOTS.

The Impacts of Process Image-Based Worksheets on *SRL*

Table 2 presents the impacts of the learning with process image-based worksheets for geometrical optics on the students' SRL seen from the average scores of the 11 indicators.

Table 2. The Comparison of Students' SRL inthe Experimental and Control Class

No	Score Range	Criteria	E	С
1	80,1 -100	VH	5	0
2	60,1 - 80	Η	23	0
3	40,1 - 60	Ι	7	8
4	20,1 - 40	L	0	27
5	0 - 20	VL	0	0

Table 2 indicates that the experimental class students had better SRL than the control class students. It informs that the highest, the average, and the lowest SRL score categorized as very high, high, and intermediate, while the control class classified as intermediate, low, and low.

When looking at the score data analyses of SRL, the highest score of experiment class was 90, the lowest score was 45, and the average score was 72.4. The control class' scores of SRL were 52,5 (highest score), 25 (the lowest score), and 38 (average score).

The significant influence of geometrical optics learning with the image process-based worksheets on the students' SRL was examined by the t-test analysis results as described below.

The proposed hypotheses in this research were: (1) Ho: There was no difference between the average scores of the students' SRL in the experimental and control class; and (2) Ha: The difference existed between the average scores of the students' SRL in the experimental and control class. The basis of decision making was; If the value was significant or sig. (2-tailed)> 0.05 then Ho was accepted and Ha was rejected. If the value was significant or sig. (2-tailed) <0.05 then Ho was rejected and Ha was accepted.

Based on the data analysis results, the value of the sig. (2-tailed) for the SRL was <0.05, at df = 68 (t-table = 2,000 at α = 0,05), and the score of t-count = 14.692> t-table was obtained. Thus, the Ho was rejected or there was a difference between the students' SRL in the experimental and control class. If seen from the SRL average and SRL criteria in Table 2, the experimental class students' SRL was better. Hence, it concluded that the learning of geometrical optics with the process image-based worksheets could embed the SRL of experimental class students well. This was in line with the research results of (Zainuri et al., 2017) which revealed that learning with process image-based worksheets could improve students' self-regulated learning. In addition, when students utilize the process image-based worksheets, they automatically have the freedom to learn, such as seeking information, controlling the environment, being efficient in learning, and being able to repeat it (Ismail & Sharma, 2012).

CONCLUSION

Based on the results and discussion, we could conclude that the geometrical optics process image-based worksheets could significantly influence the students' higher-order thinking skills, especially in the aspects of analyzing and evaluating for both reflection and refraction concepts. Besides that, the geometrical optics learning with the help of process image-based worksheets has proven to have a significant effect on the students' learning independence, meaning that the worksheets could instill the students' selfregulated learning.

Furthermore, the researchers suggested that teachers or printed media developers design many more proper process images to stimulate students in analyzing and finding out concepts (HOTS) through their independence of learning (SRL).

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DESIGNING AN INTEGRATED CURRICULUM BASED ON LOCAL PRIMACY AND SOCIAL RECONSTRUCTION PERSPECTIVES OF WEST NUSA TENGGARA, INDONESIA

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ABSTRACT

The purpose of this study was to develop a curriculum model which included local primacy based on the principles of social reconstruction curriculum in West Nusa Tenggara. This study was a developmental research which adopted and modified Borg & Gall developmental model (1983) with the following stages: (1) needs analysis; (2) model development; and (3) model validation. The results of needs analysis indicated that coral reef materials were the main priority of local primacy integrated into the secondary school curriculum in West Nusa Tenggara. The principles of social reconstruction curriculum were implemented in three components as the result of model design, i.e. learning objectives, learning methods (organizational learning strategies, learning delivery strategies, and learning management strategies), and learning results or assessment. The product design model was embraced in instructional tools consisting of syllabus, topic formulation and basic competence, comic learning materials, and assessment instruments. Based on the assessment qualifications on the instructional tools validation test which included three aspects, namely the content aspect, the display aspect and the accuracy aspect of language use, the mean scores were 3.4, 3.8, and 3.4 respectively. Therefore, the overall instructional tools were in a very good category.

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Keywords: curriculum design, local primacy, social reconstruction

INTRODUCTION

Indonesia is an archipelagic country with 13,466 islands with 1,922,570 km2 of land area and 3,257,483 km2 of water area (Giyanto et al., 2017). This strategic geographic position has placed Indonesia on the world's coral reef triangle. Natural treasure in the form of coral reef ecosystem is one of the advantages owned by Indonesia which must be preserved (Sukri, 2011). Based on Law No. 14 of 2011, the extent of Indonesia's co-

*Correspondence Address E-mail: akhmadsukri@ikipmataram.ac.id ral reef area reached up to 2.5 million hectares. With this vast expanse of coral reefs, Indonesia has become one of the world's centers of coral reef diversity with almost 569 species classified into 82 genera (Giyanto et al., 2017).

One of the provinces in Indonesia with a natural treasure of reef ecosystems is the Province of West Nusa Tenggara. The beauty of the coral reef ecosystem and its coastal charm has made West Nusa Tenggara selected as the best province for tourism in the Government Award 2015 event from the Government of Indonesia. In addition, two international awards were also

achieved by West Nusa Tenggara as World's Best Halal Honeymoon Destination and World's Best Halal Tourism Destination at the World Halal Travel Summit & Exhibition 2015 event held in Abu Dhabi, United Arab Emirates (Winarti, 2017).

According to Subijanto (2015), local primacy is one of the potentials that exist in every region to be used as interesting contextual materials to be taught in schools. Furthermore, Marliana & Hikmah (2013) described that local primacy integrated into education can be extracted from various potentials such as natural resources, human resources, geographic, culture, and history. In the context of this research, the local primacy is the primacy of natural resource which is a coral reef ecosystem owned by West Nusa Tenggara.

Coral reef ecosystem materials need to be introduced to the community especially to students for elementary and secondary school (Sukri et al., 2017). It is important to develop students' understanding and knowledge on coral reef ecosystem early on, so that awareness of maintaining and taking care of coral reef ecosystem especially in West Nusa Tenggara can be well-implemented (Sukri, 2011). Ironically, the materials of coral reef ecosystems in West Nusa TenggarA has not yet included in the curriculum for both primary and secondary level. Based on these findings, it is considered urgent to develop a curriculum that integrates local primacy of West Nusa Tenggara province. This is in line with the perspective of social reconstruction in an education world to accommodate local primacy, integrate the environment, solve social problems and substance of potentials around the students (Sukardi, 2016).

Social reconstruction curriculum is a curriculum design centered on problem-solving (Mc-Neil, 1981; Stanley, 1981; Hunkins & Ornstein, 2016), and focuses on issues faced by the society (Sulthon, 2014). The social reconstruction curriculum emphasizes cooperation and interaction, the interaction between learners and other students, the interaction between learners and teachers, the interaction between learners with their environment and other learning resources (Sulthon, 2014; Mubaroq, 2018). With this concept, coral reef ecosystem which is one of the local primaries of West Nusa TenggarA province is considered necessary to be developed into one of the lesson materials taught in elementary and middle schools in West Nusa Tenggara province.

The development of lessons that adopted local primacy in West Nusa Tenggara has been done by Sukardi (2016) who developed a creative economic-based craft and entrepreneurship model with the dimensions of the local primacy industry, namely silver and batik handicraft. There have not many types of research related to the development of curriculum that adopts local primacy in the form of a coral reef ecosystem in West Nusa Tenggara. An initial research done by Sukri et al. (2017) produces a learning tool that adopts the potential of coral reef ecosystem at SDN Gili Matra, West Nusa Tenggara. Furthermore, Sukri et al. (2017) also explained that the materials of coral reef ecosystem can be integrated into the subjects in elementary school for grade 4 on the theme of natural resources, and grade 6 on the theme of animal and plant conservation, as well as ecological balance.

Referring to Sukri et al. (2017), coral reef ecosystem materials need to be developed for secondary school, junior high school (SMP). Therefore, to accommodate the coral reef ecosystem materials into junior high schools, it is necessary to design an appropriate curriculum in accordance with the local primacy characteristics of West Nusa Tenggara province. The purpose of this study was to develop a curriculum model that adopt local primacy based on the principle of social reconstruction in West Nusa Tenggara. This article describes the developed curriculum design based on the principles of social reconstruction.

METHODS

This research adopted and modified the research development steps by Borg & Gall (1983). The research implementation consisted of the following three stages: (1) needs analysis; (2) model development; and (3) model validation. Here are the descriptions of the activities undertaken in the three stages of the study.

The needs analysis adopted the fishbone diagram model (Ishikawa, 1976) to map out the school's support capacity covering aspects of people, materials, procedures, equipment, and environment in the context of curriculum development which included local primacy as the enrichment materials for junior high schools (SMP) according to the 2013 curriculum in Indonesia. The needs analysis was carried out through Focus Group Discussion (FGD) activities involving science teachers in junior high schools, principals, and curriculum development teams from the Office of Education, Youth and Sports (DISPO-RA) of North Lombok regency with a total of 25 people. The selection of North Lombok Regency as a research location was based on its best representation of West Nusa Tenggara with local primacy in the form of coral reef ecosystem which has been widely known by foreign countries.

The model development aimed to determine the integration model of local primacy potential into the curriculum in the form of learning tools consisting of a syllabus, lesson plans, textbooks, and assessment instruments. The model development refers to the theory of the social reconstruction curriculum (Hunkins& Ornstein, 2016) which is actualized into three components, namely (a) learning objectives; (b) learning methods consisting of: strategy of organizing learning, learning delivery strategies; and learning management strategies; and (c) learning results or assessment (Gagne et al., 1992; Degeng, 2013).

Model validation intended to test the curriculum products that have been prepared through expert validation test. Model validation was performed by three experts namely, content specialists, resource display experts, and linguists. The validation test instrument was adopted from the non-text book assessment guidebook developed by the Book Center, Ministry of National Education in 2008 combined with the local resourcebased assessment instrument developed by Sukri et al. (2017). Scoring are in the range of 1-4, i.e score 1 = less good, score 2 = good enough, score 3 = good, and score 4 = very good. The final qualification of textbook appraisal was as follows: 3 <s≤4 (Very Good), 2 <s≤3 (Good), 1 <s≤2 (Good Enough), and $s \le 1$ (Less Good), s = score.

RESULTS AND DISCUSSION

Needs Analysis Stage

Based on need analysis, there were found some issues as follows. First, the lack of materials in junior high schools raised local primacy in West Nusa Tenggara, especially about coral reefs. The results of this FGD also found that this research activity was the first to raise the content of local primacy in the form of coral reef ecosystem as the enrichment materials for science lessons in junior high schools. Second, teachers in schools have not been provided with the necessary knowledge; therefore, they needed to be given an understanding in teaching the reef ecosystem learning materials. Third, classroom teaching activities tended to be traditional through lecturing method although some teachers have already applied several interesting teaching methods in the learning process. Therefore, the teachers had to be informed an understanding of appropriate learning methods to teach the reef ecosystem materials. Fourth, supporting equipment and infrastructure in teaching materials of the coral reef ecosystem was adequate. Fifth, the environmental aspect which is very supportive in learning the coral reef ecosystem as it exists around the students.

The need analysis results concluded that it is a necessity to raise the materials of coral reef ecosystem which is the local primacy of West Nusa Tenggara as one of the enrichment materials for a science lesson in junior high school level. These results are supported by the availability of human resources (teachers), equipment and the environment. In addition to these aspects, the integration of coral reef ecosystems into one of the subject matter of junior high schools also pays attention to socio-cultural aspects of society in as suggested by Sukri (2011).

Model Development

FGD results with the curriculum development team and science teachers for junior high school formulated that the model could be done through insertion and adjustment of coral reef materials on Basic Competence (KD) of science especially on biology materials according to the current 2013 curriculum implemented in Indonesia. The next step was to pack the materials of coral reef into a topic compiled into comic learning materials. The following in Table 1 are listed coral material topics, chapters of Basic Competence (KD) and a description of the materials.

 Table 1. Topic sequence, Basic Competence, and Description of the Main Materials Picturized through Comic

Topic	Basic Competence (KD)	Material Description on the Comic
Topic I: Coral Reefs are Liv- ing Thins	Referring to KD 3.2 Classifying living things and objects based on observed characteristics	The iconic figure describes the characteris- tics of coral reefs from physical features, as well as physiological and cellular features based on miscropcopic observations.
Topic II: Coral Reef Diversity and Classification	Referring to KD 3.2 Classifying living things and objects based on observed characteristics	The iconic figure explains the phylum classification of living things, one of which is coral reef based on cellular observations (organelles), living habitats, and other characteristics.
Topic III: Cellular System and Coral Reef Body Structure	Referring to KD 3.6 Identifying organizational systems of life from the cellular level to the organisms and major compositions of cell constitu- ents.	The iconic figure explains the cellular system and body structure of coral reefs.

Topic IV: Inheritance of Na- ture on Coral Reefs	Referring to KD 3.3 Applying the concept of inheritance of nature in the breeding and survival of living things	The iconic figure invites students to analyze various opportunities of traits derived from the reproductive processes undertaken by coral reefs according to Mendel's trait inheri- tance laws.
Topic V: Survival and Con- servation of Coral Reefs	Referring to KD 3.8 Analyzing the occurrence environmental pollution and its impact on the ecosystem Referring to KD 3.9 Analyze climate change and its impact on the ecosystem	The iconic figure explains the causes of damage to coral reef ecosystems caused by environmental pollution and global climate change. The iconic figure then invites stu- dents to analyze the importance of coral reefs and efforts of coral reefs conservation in In- donesia
Topic VI: Coral Reef Biotech- nology	Referring to KD 3.7 Understanding the concept of biotech- nology and its role in human life	The iconic figure invites students to ana- lyze the use of biotechnology principles in tackling various human activities (pollution) that can potentially cause extinction on coral reefs. One of them is environmental biotech- nology (waste-eating bacteria)

The design of the integrated curriculum model of local primacy implemented into learning tools includes syllabus, lesson plan, comic learning materials, and assessment packed into three learning variable components adopted from Reigeluth & Merrill (1978), consisting of (a) learning conditions, (b) learning methods, and (c) learning outcomes. Each component of the learning variable refers to the social reconstruction theory that is considered relevant to the developed model. This is in accordance with the principle of social reconstruction theory because it places an integrated education with the environment, solves social problems, and learns content excavated from environmental potentials around students (Sukardi, 2016).

Learning conditions are factors which influence the effect of using certain methods to improve learning outcomes (Gagne et al, 1992; Degeng, 2013). Furthermore, Degeng (2013) classified the learning conditions into four variables namely learning objectives, characteristics of the subject, constraints, and characteristics of students. The learning conditions in this study focused on two classifications, namely learning objectives and characteristics of the subject. The structure of learning objectives in this development model referred to the structure of the 2013 curriculum which consists of (a) the learning objectives, (b) the core competence, and (c) basic competence. The objectives of the subject study pointed to the principle of constructivism and social reconstruction to build students' understanding of the coral reef biological system from the simplest aspect to the most complex aspects suitable with conceptual orientation objective (Degeng, 2013). The determination of core competence (KI) and basic competence (KD) adopted and modified in the science syllabus for junior high school according to the 2013 curriculum is shown in Table 1.

The learning method covered three components, namely (a) organizing learning strategy, (b) learning delivery strategy, and (c) learning management strategy. The strategy of organizing learning in the developed model points to the content organization by involving more than one concept, procedure, or principle with the aim to unite the entire contents of the field study (Degeng, 2013; Reigeluth & Merrill, 1978). The learning organization included: (1) arranging coral reef materials into 7 chapters (Table 1); (2) presenting the core and basic competence for each chapter; (3) determining the storyline according to the supporting materials and images, and (d) the task or exercise displayed at the end of each topic. The sequences of coral reefs comic materials in sequence starting from the simplest to the most complex materials.

The learning delivery strategy on the developed model highlighted the principles of social reconstruction which emphasizes the existence of collaboration, interaction, communication and direct practice (Sukardi, 2017). Therefore, the learning delivery strategy was actualized in the form of group learning, face-to-face activities in the classroom, field trips to see the real conditions of coral reef ecosystems in the real environment.

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The delivery strategy pointed to the principle of social reconstruction by implementing social reconstruction learning method adopted from Luisa (2007) combined with social reconstruction syntax developed by Sukardi (2017). Learning activities were implemented through several activities: (1) forming heterogeneous learning groups in terms of gender, abilities, and cultures. The formation of heterogeneous groups is expected to establish interaction and cooperation among students (Pitriani et al, 2013); (2) initial knowledge activation; (3) presentation of new knowledge; (4) conducting exercises through problem analysis; (5) conducting research through field trip activities; (6) drawing conclusions; and (7) reflections on the learning process.

Learning outcomes are all impacts serve as a reference for using a method under different conditions (Degeng, 2013). The expected learning outcomes were assessments oriented to the principle of social reconstruction and problemsolving for real problems in a student's life (Hunkins& Ornstein, 2016). The assessment activities include: (a) guidance of field trip activity combined with project-based assessment including planning, data collection, organizing, process, analysis and concluding, and displaying data (Fauziah & Saputro, 2018); and (b) critical analysis reports as the results of field monitoring of coral reef problems.

Product Validation Test Results

The product validation test was done to assess product appearance and language whether it is good and correct according to Indonesia standard rules. The results of the curriculum product validation test are shown in Table 2-4.

Table 2.	The	Content	Validation	Results
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No	Scoring Components	Evaluation Score
1	The correlation between basic competence and materials elaboration	3
2	The harmony between basic competence and materials elaboration	4
3	Material elaboration which describes the coral reef comprehensively for each chapter or topic	3
4	Learning syntax according to the basic competence and main materials	3
5	The validity of the substance according to scientific principles	3
6	The explanation of coral reef materials according to the improvement of stu- dents' cognitive.	4
7	The harmony of comic illustration with the materials in every topic or chapter	4
8	The harmony between the storyline, topic, and basic competence	3
Overa	all rate	3,4*

Note:

* scoring qualification

 $3 \le \le 4$ (very good), $2 \le \le 3$ (good), $1 \le \le 2$ (good enough), $S \le 1$ (less good), S = score

Table 3. The Appearance Validation Results

No	Scoring Components	Evaluation Score
Α	Design of the Topic, Basic Competence, and Syllabus	
1	The design of the topic displaying the coral reef materials comprehensively	4
2	Clarity of the chapter design	4
3	Clarity of the basic competence design	4
4	Clarity of the main material elaboration	4
5	Clarity of the learning syntax in the lesson plans	3
6	Clarity of the syllabus description (learning source, time allocation, learning methods, and evaluation)	4

В	Comic Learning Materials	
7	Clarity of the illustrations in every topic or chapter	3
8	The coherence of displayed coral reef materials	4
9	Clarity of the comic storyline	4
10	Clarity of the information displayed in the comic	4
11	The use of proportional color gradation	4
12	Harmony between pictures, font size, and types used in the comic	4
Overa	1l rate	3,8*

* scoring qualification

 $3 < S \le 4$ (very good), $2 < S \le 3$ (good), $1 < S \le 2$ (quite good), $S \le 1$ (less good), S = score

Based on the content validation results, the eight components' average score was 3.4. As a result, the curriculum products consisting of a syllabus and comic teaching materials were in a very good category. Table 2 shows that three of the eight assessment aspects were in the very good category with a score of 4. All the three assessment aspects included the 2, 6, and 7 assessment related to the suitability of coral reef ecosystems with basic competence, student cognitive levels, and illustrations shown in comics for each topic. This indicated that the coral reef ecosystem materials have been described in the curriculum well. Similar results were obtained by Hartini et al. (2018) which showed that teaching materials integrated with local wisdom had been prepared in accordance with aspects of content validation and appearance.

The appearance validation test results presented in Table 3 showed that the average score was 3.8 and belonged to the very good category. These results indicated that in terms of appearance, the developed curriculum products have met the criteria for all assessment components. Based on Table 3, it is known that out of the 12 components, there are 2 components scored 3, namely the assessment components 5 and 7. This elucidated that overall; the validation test results achieved a high validity score. According to Afriadi et al. (2013), the magnitude of the validity score plays an important role in drawing conclusions. Therefore, the higher the validity, the better the conclusions are drawn (Hartini et al., 2018). The high validation test results are also shown in Table 4 with an average score of 3.4. Thus, the language used was in a very good category.

No	Scoring Components	Evaluation Score
1	Standardized words and sentence	4
2	The accuracy of idiomatic expressions	3
3	Standardized sentence arrangement	3
4	A clear correlation between information and sentences	4
5	Punctuation accuracy	3
Overa	all rate	3,4*

Table 4. The Language Validation Results

*scoring qualification

 $3 < S \le 4$ (very good), $2 < S \le 3$ (good), $1 < S \le 2$ (quite god), $S \le 1$ (less good), S = score

The main purpose of the social reconstruction curriculum is to include students in solving social problems (McNeil, 1981; Stanley, 1981; Hunkins& Ornstein, 2016; Sulthon, 2014). The social reconstruction curriculum emphasizes interaction and substance extracted from the surrounding potentials (White, 2001; Sukardi, 2016; Sulthon, 2014; Mubaroq, 2018). The basic concept of social reconstruction theory is the foundation for the development of science curriculum integrated with local primacy of West Nusa Tenggara, Indonesia. The concept of social reconstruction theory in this research was implemented through the learning materials and learning condition, and assessment activities which held firmly the local wisdom (McNeil, 1981; Stanley, 1981; Hunkins& Ornstein, 2016; Pitriani et al., 2013).

One implication of the social reconstruction theory in this study was implemented in the content or subject matter that is adopted from the local a.k.a the coral reef ecosystem. According to Suyitno et al. (2015), local wisdom in the school environment needs to be introduced and taught to students in order to produce graduates who are relevant to the needs. In addition, Anggraini (2017) revealed that learning based on local wisdom can enrich the knowledge and character development of the students. Subali et al. (2015) reported that the implementation of teaching design based on local wisdom influenced the character of students as proven by the emergence of 11 positive characters on student performance such as caring toward the environment. The research results of Sugiyo & Purwastuti (2017) showed that the potential of local wisdom in the community can be used as a character education model for elementary school students. The results are in line with Mayne's (2014) opinion that the social reconstruction approach needs to be integrated into teacher training programs as a key component in improving the quality of education.

The implications of the social reconstruction theory in the developed design were also reflected in the learning activities undertaken. Learning activities prioritize the interaction among learners which is the principle of social reconstruction theory (Sulthon, 2014; Mubaroq, 2018). This concrete form of interaction activity is reflected in the learning group activities implemented through the social reconstruction learning model (Luisa, 2007; Sukardi, 2017). The heterogeneous learning group consists of students with different gender and academic ability. Group learning is expected to establish interaction between learners, learners with teachers, and learners with learning environment. The results of previous studies have shown that social interaction influences student learning outcomes and motivation (Fitriastuti, 2013, Hurst et al., 2013; Sari et al, 2013; Mulyaningsih, 2014; Nismawati, 2015; Rahmah, 2016; Murti & Heryanto, 2016). Aside from being positively affects student achievement social interaction is also plays an important role in improving the quality of learning (Jung et al., 2002; Essam & Al-Ammary, 2013). The results of this design are in line with Barakett & Freedman (2001) research suggesting that learning based on the principle of social reconstruction is done to achieve high-level thinking skills through participatory, dialogical, and interactive learning.

Interaction activities are not only carried out in the classroom, but also carried out through field activities. This refers to the principle of social reconstruction theory that the substance or subject matter is extracted from the potential that exists around the student (White, 2001). Furthermore, Sukardi (2016) emphasized that the setting of activities outside the classroom is intended to provide opportunities for students to acquire knowledge and skills through involvement in the real world. The results of various studies show that field trip activities can improve students' academic performance (Amosa et al., 2015), creative and practical thinking (Mahgoub & Alawad, 2014), conceptual understanding (Taneo, 2017), learning experience (Higgins et al., 2012; Nyumba et al., 2018), learning outcomes (Patrick, 2010), knowledge and attitudes toward multicultural (Prokop et al, 2007; Olukayode & Tina, 2013; Neiman & Ades, 2014); and student academic achievement (Estawul et al., 2015).

The third implication of the principle of social reconstruction contained in this design was in the form of assessment. The developed assessments were problem-oriented (Hunkins& Ornstein, 2016) based on the potential around students. This form of assessment was a projectbased assessment which outlined in the critical analysis report on the results of the on-field reef problem. Project-based assessment is one of the authentic assessment models (Fauziah & Saputro, 2018). According to Tai & Yuen (2007), authentic assessment obtained positive results to improve problem-solving skills, teamwork, and increased student knowledge. The results of this design are in accordance with Fook & Sidhu's (2010) suggestions that authentic assessment is more acceptable to students and serves as an alternative to standardized judgments.

Overall, the curriculum design that adopts local primacy generated in this study has been in accordance with the principle of social reconstruction used as a reference in the development of the model. In addition, the results of this study are complementary to previous similar studies in developing local primacy, especially coral reef ecosystems integrated into lessons for secondary school levels.

CONCLUSION

The research results revealed that the integration of coral reef materials can be done through the insertion and adjustment of the main coral reef materials in the Basic Competencies (KD) of science subjects especially in biological materials for junior high school level. The results of this study also indicated that curriculum development adopting local primacy was appropriate based on the principle of social reconstruction as the materials originated from or was explored from the potentials existing around the students.

The resulting curriculum design and products can be used as a blueprint for other areas in curriculum development which raise the potential of the region as the enrichment materials for primary and secondary schools in Indonesia.

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IDENTIFICATION OF METALLOTHIONEIN GENE IN HUMAN PLASMA: A MOLECULAR ANALYSIS OF CADMIUM AND LEAD POLLUTION IN GAS STATION ENVIRONMENT

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ABSTRACT

Metallothionein (MTs) is a protein that binds to metals, cysteine-rich and has low molecular weights. Metallothionein binds metals and has some essential cellular functions, such as transportation, storage, and metal detoxification. When metallic lead (Pb) and cadmium (Cd) are absorbed, it will immediately be bounded by metallothionein and transported by the blood to the liver. Metallothionein gene is encoded by MTs. This study aimed to identify the MTs gene in blood of fuel station workers which can further be used as a vulnerability biomarker of the body as a result of exposure to heavy metals like Pb and Cd in humans. This study was a cross-sectional study, conducted for 8 months and took place in Fuel Stations in the city of Semarang. Samples were fuel station workers who met the study criteria, they sought to fulfill as much as 52 samples. Blood of samples was taken approximately 5 ml and then the MT2 gene was analyzed using Polymerase Chain Reaction (PCR). The data were analyzed descriptively. The results showed that 96% of MT2 gene expression had a resemblance to normal human gene sequences by Blast GenBank. MT2 gene expression did not always reflect the accumulation of lead and cadmium in the blood of fuel station workers. The MT2 gene is likely to have a limitation when used as a biomarker for early detection of the heavy metals exposure in humans to determine the susceptibility of heavy metals exposure.

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Keywords: biomarker, metallothioenian gene, lead, cadmium

INTRODUCTION

The use of a biological marker (biomarker), is needed to detect and monitor the presence of heavy metals in the human body. Additionally, the use of biological markers is able to provide data of heavy metal intensity absorbed by the sample organisms with toxicity and disruption inflicted on biological systems at certain levels. With the study of biomarkers, heavy metal

*Correspondence Address E-mail: noorkusumadewi@yahoo.co.id pollution in humans can be controlled as a preventative action against disease severity.

Metallothionein (MT) is a material that belongs to protein compounds or polypeptide. Metallothionein (MT) is a polypeptide which has many cysteine (Cys) bonds encoded by the gene, has a low molecular weight, and functions as a metal binding peptides (Zatta, 2008). Metallothionein expression indicates exposure to certain metals (Hanson, 2008). The existence of metallothionein has at least two main functions, i.e cleaning free radical materials in the body and detoxifying metals to reach a state of homeostasis (Ryvolova et al., 2011; Sakulsak, 2012; Ruttkay et al., 2013). Induction of metallothionein (MT) expression is involved in metal homeostasis and detoxification (Chen et al., 2014; Wang et al., 2014).

Semarang is one of the metropolitan cities where the number of motor vehicles increases up to 6% per year. The growth of vehicles in this city has a large potential for air pollution which will impact human's health (Mifbakhuddin & Mumpuni, 2010). Increasing the number of motor vehicles will cause a high level of metal pollution which is estimated to derive from motor vehicle exhaust emissions. According to research by Sunoko et al. (2011), Semarang is a city with a high level of lead pollution which is 2.41 μ g / Nm3 at one point in the city of Semarang. According to the ambient air quality standards of Central Java province, based on the Decree of the Governor of Central Java No. 8 of 2001 April 23, the limit of Pb air emissions is $2 \mu g / m3$. Pb impact in human health can be prevented if Pb content in the air does not exceed this quality standard.

Most air pollution comes from motor vehicle exhaust gases. Gas station officers are one of the groups who are vulnerable to exposure to lead (Pb) from motor vehicle exhaust gas because gas stations are places visited by many vehicles. It may also be exposed to cadmium from the air. Cadmium in the air can be carried by different processes into the environment. The main natural sources of cadmium in the air are from mountains, evaporation, soil particles which are carried into the air, and forest fires. Other sources come from human behavior such as vehicle emission and cigarettes. Cadmium (Cd) and lead (Pb) from air entering the body through breathing (derived from cigarette smoke and vehicles).

Accumulation of lead (Pb) in the body can be detected through blood, bones, and hair. The Centers for Disease Control and Prevention in Hanna-Attisha et al. (2016) determined permissible levels of lead in children's blood by 10 μ g / dL, whereas according to WHO (2005) the normal levels in adults' blood averaged 10-25 μ g / dL. If the Pb content is more than 80 μ g / dl, it will be harmful to health. The level of lead in the blood rises within a few hours after exposure and will remain high for several weeks afterward (Gillis et al., 2012; Meikawati & Mumpuni, 2010).

Exposure to heavy metals such as Cd and Pb causes free radicals and oxidative stress, and MRE is the metal response element (MRE)binding transcription factor-1 (MTF-1) factor will be activated and an active MTF-1 bond occurs to the MRE region and initializes the gene transcription. Metallothionein is encoded by the MTs gene. Exposure to heavy metals, oxidative stress, and others can cause MTs gene polymorphism, and it can increase the incidence of aging (Kayaaltı et al., 2011; Ruttkay et al., 2013), damage to placental tissue (Tekin et al., 2012) and autopsy kidney tissues (Kayaaltı & Söylemezoglu, 2010). Kayaaltı et al. (2011) reported that there was a significant relationship between the -5 A / G core promoter SNP in the MT2A gene and Cd, Pb and Zn levels (p = 0.004, p = 0.012and p = 0.002, respectively), but no association was found with Cu level (p = 0.595).

Various types of metal and heavy metal are able to compete on the metallic bond in metallothionein. These circumstances provide an advantage in the distribution mechanism of various types of metal for the body's biological system of organisms. In various studies, it is known that there is a competition among the heavy metals to bind to from metallothionein. Therefore, this study was conducted to determine whether the MT gene can be used as a biomarker for early detection of the heavy metals exposure in humans that indicate susceptibility to heavy metals exposure.

Identification, level measurement and structure characteristics of MTs are important to determine the role of metalloproteins in the body of organisms. Measurement of MT levels in body fluids can be used as a biological indicator of metal exposure in humans. Several studies have reported that examination using enzymelinked immunoassays (ELISA) can be used to measure metallothionein-1 (MT-1) and MT-2 levels in humans and experimental animals (Chen & Song, 2009; Nakazato et al., 2014). Identification, level measurement and structure characteristics of MTs are important to determine the role of metalloproteins in the body of organisms. MT gene identification can be used as early detection of heavy metal exposure in humans or other living things.

METHODS

This study used a cross-sectional design and was conducted over 10 months in the city of Semarang. Plasma samples were examined at the Laboratory of Molecular Biology, Biology Department, Faculty of Mathematics and Science, Universitas Negeri Semarang. The study sample as many as 52 people are all workers of the sample fuel station in Semarang city who were eligible and willing to participate in this study and signed the informed consent. The sampling technique was purposive non-random sampling. Inclusion criteria are men or women aged 15-55 years old, willing to become respondent until the research is completed. Exclusion criteria are: suffering from diabetes mellitus, acute renal failure or chronic renal failure, heart failure/arrhythmias cardiac, liver disease chronic/acute lung tumors or other malignancies, degenerative diseases, discontinue therapy, GI disease, pregnancy or lactation, and hormonal contraception, HIV/AIDS.

MT-2 gene identification was performed through several steps such as DNA isolation and extraction, electrophoresis, PCR and sequencing. DNA isolation of MT-2 gene using QIA amp blood DNA mini-kit (Qiagen, Hilden, Germany) referred to the method recommended by the manufacturer. The obtained DNA stored at -20 ° C for polymerase chain reaction (PCR) analysis. The amplification of the MT-2 gene using the PCR with MT-2A: Forward 5' CGC CTG GAG CCG CAA GTG AC-3 'and Reverse: 5'-TCC TGG GCA CCA TCT GCC TA-3'.DNA amplification in PCR method using master mix kappa with a cocktail total of 50 ul reaction mixture containing 200 µMofdNTPs, 10 pmol each of Forward (F) and Reverse (R) primers, 1 U Hot Star Taq DNA polymerase (Qiagen), 1 XPCR buffer (Qiagen) and 100 ng genomic DNA. The PCR cycling conditions consisted of an initial denaturation step at 95°C for 5 min, followed by 35 cycles of 94°C for 1 min, 60°C for 1 min, 72°C for 1 min, and a nal extension step at 72°C for 10 min. The PCR produced was 241 bp. The PCR products were separated on a 2% agarose gel electrophoresis, visualized by ethidium bromide staining under an ultraviolet illuminator. A good PCR product followed by sequencing stage The good PCR product continued with the sequencing stage. DNA sequencing was carried out to determine the nucleotide sequence in the MT-2 gene region. Sequencing is carried out at PT. Indonesia Science Genetics, St. Duri Raya No. 5D West Jakarta, 11510, Indonesia. The sequencing method used in this study was the Sanger method.

Sequencing result data in the form of ABI files of MT-2 were edited manually using the BioEdit version 7.0.9 program. The sequence editing results were included in the NCBI BLAST (Basic Local Alignment Search Tool). Sample sequences were compared with Gen-Bank MT-2 of Human Homo Sapiens is Lead and cadmium levels were measured using Atomic Absorption Spectrophotometry (AAS) with wavelengths of 283.3 nm and 540nm.

RESULTS AND DISCUSSION

The sampling took place at the gas station situated on West, East, and South Semarang. The total of fuel station workers that became the samples was 15 people from East Semarang, 17 people from West Semarang, and 20 people from South Semarang. Thus, the total sample was 52 people.

The average lead levels of gas station workers in Semarang was 8.8 mg/dl. Based on WHO (2005), normal blood lead levels in adults are 10-25 mg/dl. This results indicated that the blood lead level of gas station workers was low. While the average of cadmium level was 0.14 mg/L means that it was still below the normal blood cadmium level of 0.42mg/L.

Isolation and Purification of DNA

MTs gene DNA in the blood of gas station workers was isolated using Qiagen DNAeasy human Mini Kit. The results of 2% agarose gel electrophoresis showed the presence of DNA bands. It indicated that the MT2A gene had been isolated seen from the presence of two intact bands of 241bp DNA. The quantity of DNA that had been isolated was measured by spectrophotometric methods. The measurement results of the DNA quantity which was obtained from the ratio A 260/280 was about 1.86-2.01. It showed that the sample had a high purity against protein contaminants.

The results of DNA isolation and purification was continued with PCR and electrophoresis to obtain the DNA strands figure. The DNA strands figure of one of the workers is presented in Figure 1.



Figure 1. The Fuel Workers' Isolation and Purification of Blood DNA

The Results of MT-2A Gene Sequencing

A total of 6 samples as the representative to be sequenced was sent to the laboratory of PT. Indonesia Science Genetics, St. Duri Raya No. 5D West Jakarta, 11510, Indonesia.

Sequencing examination was done to determine the metallothionein gene sequence on the fuel station workers. Then, it compared with genes that already confirmed from the National Center for Biotechnology Information (NCBI Bethesda, MS, USA).

DNA sequencing is the process or technique to determine the nucleotide-based sequence in a DNA molecule. DNA sequencing can be used to determine the identity and function of a gene or other DNA fragments by comparing the samples sequences with other DNA sequences which are already known. Sequencing methods are useful to identify a gene mutation and can compare homologous genes between species. In 1977, the sequencing method was developed in America, spearheaded by Maxam and Gilbert and 1974 in England by Sanger. There are two sequencing methods; Maxam-Gilbert and Sanger.

Sequencing results were obtained in the form of electropherogram. On the electropherogram, there were several curves in four different colors. The blue color indicates the cytosine (C), black for guanine (G), green for adenine (A) and red for Thymine (T). The electropherogram is read based on the colors that make up the highest top. If there is a curve, then it is assumed that in this position, there is a pair of homozygotes allele. If there are two top of curves which have relatively the same height, it is assumed that there was a pair of heterozygous alleles.

These results indicated that the MTs encoding gene from the blood of gas station officers was not successfully isolated. Figure 2 shows the sequence of MT2A encoding genes that had been isolated. The size of the gene obtained could not be ascertained exactly. Alignment analysis of DNA fragment sequence between forward and reverse using the BioEdit computer program had not been able to bring together the ends of the fragment sequence (data not shown).

FORWARD



REVERSE



Figure 2. The MT2A Gene Elektroforegram of Fuel Workers

Based on the results of BLAST analysis, the nucleotide variant in MT-2A gene that was compared with GenBank Acc Number GQ154088.1 was not found. The nucleotide sequences contained in the 388 and 608 base sequence (Figure 2).

Semarang is one of the metropolitan cities where the average number of motorized vehicles increases by 67 vehicles, reaching growth of 5-9% per year. The growth of motorized vehicles has the potential to increase air pollution which will impact the health. (Mifbakhuddin & Mumpuni, 2010). Hadi (2007) stated that the vehicles growth in Semarang reached 6% per year and the 77% was dominated by private vehicles and motorbikes, while cars were only 19%. Thus, the transportation sector becomes greenhouse gas emissions sources and contributes up to 25%. In addition to air pollution, transportation activities produce noise, dust, vibration which can decrease the quality of health and work productivity. The more crowded of vehicles which use gasoline fuel will increase lead levels in the air. In a site of the Semarang area, the lead levels in the air up to 2.41 μ g/Nm3, this indicates that the level of vehicle traffic at that site is high too (Sunoko et al., 2011).

Lead (Pb) exposure from the environment enters the human body through the respiratory and digestive tract. The danger caused by air depends on the particles size. Particles smaller than 10 mg can be swallowed to the lungs, and larger particles settle in the upper airways (Hartini, 2010). Most of the inhaled lead will enter the lungs blood vessels. Lead absorption through the airways is influenced by three processes which consist of deposition, mucociliary cleansing, and alveolar cleansing. Deposition occurs in the nasopharynx, tracheobronchial and alveolar ducts. Particles which are smaller than 10 μ m can be retained in the lungs, while larger particles settle in the upper airway (Neal & Guillarte, 2012).

Low levels of lead exposure that persist for a long time will cause bad effects to the health, such as hypertension, anemia, decreasing of ability brain and could inhibit red blood cell (erythrocytes) formation (Mifbakhuddin & Mumpuni, 2010).

In this study, the obstacle was the difficulty in determining the annealing optimum temperature to make the primer sticks perfectly so that DNA could be amplified. Therefore, optimization temperature was done by trying some temperatures ranging from 51°C to 55°C to obtain the annealing optimum temperature at 53 °C. Moreover, the best PCR reagent composition to thicken the amplification DNA strand might also be an obstacle.

The size of the DNA fragment which obtained from the amplification process using a specific primer cannot be ascertained. Therefore, it was necessary to analyze DNA fragments which had been amplified by sequencing, then the sequences were further analyzed by bioinformatics. In this DNA amplification, discovered was the best DNA strand with the half of cocktail reaction. The good DNA amplification results continued to the next stage, namely DNA sequencing through the help of the Genetica science service agency in Jakarta.

The sequencing results in the form of ABI file were edited using Bio edit of 7.0.9 software. Editing was needed to eliminate unnecessary bases by comparing the sequence with the chromatogram. The results were then compared in Clustal W. The edited sequence was inserted in the NCBI BLAST to found out samples sequence homology with closest species from GenBank collection.

The BLAST results showed the homology values of 96% on MT-2A gene with GenBank Acc Number GQ154088.1. Nucleotide differences between MT-2A were illustrated by the nucleotide sequence from BLAST alignment results. So, the MT-2A gene of the fuel station workers was similar to Gen Bank, which is normally MT-2A gene sequences without exposure. The resemblance was about 96% or approaching close to 100%. Thus MT-2A gene cannot be used as a biomarker for early detection to know the existence of the vulnerability on heavy metals exposure of Pb and Cd.

The results of the amino acid alignment showed similarities in the amino acid structure of MT-2A genes between samples with others in Genbank. These results explained that even at the nucleotide level, there was a mutation (transition or transversion), yet the mutations on nucleotides that did not cause any change of amino acid. Therefore, it did not change the function of the oxidase I cytochrome gene (Zein & Prawiradilaga, 2013). Zhang et al. (2010) added that other characteristics of mtDNA found in the bases content percentage.

In humans, MTs was encoded by a group of genes located on 16q13 chromosome consists of ten functional isoform MT. The encoded protein was divided into four groups: MT1, MT2, MT3 and MT4 protein (Krześlak et al., 2014; Mehus et al., 2014). Humans' MT isoforms have tissue-specific expression patterns. MTs expression increases in the response of variety inducers such as metals, interleukins, interferons, tumor necrosis factor alpha and glucocorticoid hormones (Subramanian et al., 2016; Dziegiel et al., 2016; Maret, 2011). MT could resist stress due to metal exposure by non-specific binding through metal exchange reactions in protein binding sites (Niederwanger et al., 2017). Moreover, high constitutive expression levels can also contribute to the tolerance of heat and cold shock by MTs genes (Gonçalves et al., 2016; Pedrini-Martha et al.,

2016; Baurand et al., 2016; Salice et al., 2017).

The analysis results of DNA fragment sequence with the BLAST program indicated that the isolated MT2A gene was still uncertain. This was shown by the score obtained which was less than 150. The level of homogeneity was measured by scores (bits) and E value. If the score value (bits) was higher, the level of homology was also higher. Otherwise, if E value was lower, the gene was more similar with those in the Gene Bank. Similarity indicates the homology of a gene or protein. Nucleotide alignment results elucidate that the sequence of metallothionein coding genes has a similarity of 25% with encoding genes sequences. Two genes from DNA fragments are homologous if 70% of the nucleotide or 25% of the amino acids sequence are identical, with a minimum sequence length is 100 (Claverie & Notredame, 2003). Thus the MT2A gene isolation results showed that MT2A gene was not found because there were no similarities with Gene Bank.

This isolation failure might be caused by several things, such as laboratory equipment contamination, reagent and primary contamination, isolation protocols which were less obeyed, and the use of PCR cycles which have not been matched. Nevertheless, another possibility was that the low level of lead and cadmium in blood; thus, it did not induce the appearance of the metallothionein gene, because of a limited ability to induce metallothionein synthesis. Klaassen et al. (2009) stated that exposure of heavy metal cadmium will induce metallothionein when the concentration is above the threshold. Gas stations officers are likely to be exposed to lead and cadmium metals, causing various biological dysfunctions because cadmium affects some biological processes. If workers are exposed to lead and cadmium with concentrations below the threshold, symptoms of long-term cadmium accumulation may begin to appear gradually and must be monitored carefully. Therefore, there are still efforts to use the transcription level of the blood metallothionein gene (mRNA) as a metal exposure biomarker that has been applied for almost two decades (Miura, 2009). Furthermore, Ryvolova et al. (2011) said that due to the increase in metal binding capacity, it was suggested to use MT as a biomarker for environmental and biological monitoring of metal exposure. The sensitivity of the MTs gene expression regulation by heavy metals exposure makes it possible to use the MTs gene transcription quantification as a biomarker to evaluate heavy metal pollution (Wang et al., 2014).

CONCLUSION

Based on the molecular analysis, it concluded that the MTs gene cannot be used as early detection of susceptibility to heavy metals lead and cadmium exposure in the blood of gas station workers. Further research through RNA examination is required to see the expression of MTs genes.

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THE INFLUENCE OF SCIENTIFIC INDEPENDENCE TOWARDS STUDENTS' CONTENT ANALYSIS AND SCIENCE PROCESS SKILLS ON CELL METABOLISM TOPIC

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ABSTRACT

Students commonly judge that cell metabolism topic is arduous since they only listen to their teacher and memorizing concept without a deep comprehension. Other than that, a direct explanation could not enhance the students' science process skills. Thus, this research intended to analyze the differences of the content-analysis and science process skills between the students experiencing a learning that oriented to scientific independence (experimental class) and those joining a direct learning (control class). The materials taught in both classes were cell metabolism. This study employed the quantitative of the quasi-experimental method. The research object was the students learning Biology. The students joining a scientific independence-based class were able to answer questions requiring analytical thinking. The relationship of the students' scientific independence towards the content analysis and science process skills was seen on the test. Based upon the statistical data analysis, the correlation significance was 0,038<0,05. Therefore, it concluded that there was a very significant correlation between the students' scientific independence towards the content analysis and science process skills.

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Keywords: independence, scientific, content analysis, science process skills

INTRODUCTION

Prior studies have found out the root of the problem underlying the fact that more than 50% students of two Madrasah Aliyah (high school level); MA Nudia and MA Darul Ulum in Semarang City, could not answer properly the biology questions requiring analytical thinking. On the run test, the students answered just in brief without attaching a detailed discussion. In fact, the cell metabolism topic is importantly understood since it is one of the topics of national and university entrance examination. Hence, they should comprehend the concept in order to be able to

*Correspondence Address E-mail: nunuk_arya@yahoo.com give satisfying answers. Once a student offers a detailed answer, it shows s/he understands the materials well; yet it did not happen. It revealed that they found it difficult to answer the questions of cell metabolism. Furthermore, this was worsened by the teachers who generally applied the direct learning method and gave assignments beyond the students' analysis skill development. The cell metabolism topic covers respiration and photosynthesis discussion which are complex and abstract concepts. The less comprehension a student has, the bigger the chance of a misconception happens (Andrews et al., 2012).

Moreover, in performing the scientific works, the students tended to be fully dependent on the teachers. These proved that during the classroom learning, the students were lack of independence and the teachers have not taught them to be.

The scientific independence covers the activity of experimenting, collecting data, and drawing up a conclusion. The teachers' unawareness to teach it resulted in the students' lack of understanding the way of using laboratory tools, practicum procedures, their self-safety, and maintaining laboratory tools. As a result, early data collection found that most students had the low-level skills in observing, proposing hypotheses, planning a program, interpreting data and graph, predicting and applying concepts, also, communicating. These findings were supported by the analysis results of the 2016 National Examination which stated that 48% of students of the two schools incorrectly answered the questions.

Based on the analysis of the previous study, one of the problematic concepts faced by XII IPA 4 was cell metabolism. The students found it difficult since it has complex basic competence including (1) the process and function of enzymes in cell metabolism, catabolism process and carbohydrate anabolism, also, the relation of carbohydrate and fat metabolism process. The following is the graphic illustrating the students' test results on several topics of XII IPA.



Figure 1. The Students' Test Results on Several Natural Science Topics

On the basis of the prior study's findings, the research problem of this study was; what are the differences of the students' content analysis and science process skills between those who joined the scientific independence-based learning and those who experienced the direct learning?

Hsu et al. (2009), Ozgelen (2012), Susilowati & Anam (2017) stated that the measurable aspect of content-analysis skills is the process of identifying problem performed by making use of the gained concepts in a certain problem in order to quickly finish the problem. Students' logic underlies their critical thinking of elaborating, detailing, and analyzing information used to comprehend new knowledge. The skill of analyzing information is the process of dividing and structuring information into smaller parts to recognize its pattern, connection, and various cause-effect of a complex scenario. Moreover, the students' thinking skill is very related to the learning devices employed during the scientific works (Boleng et al., 2018; Mapeala & Siew, 2015; Rabin, 2011; Yao et al., 2016).

The analysis of several published research on the strategies to develop students' analytical thinking revealed that it strongly correlates to the scientific works during the learning process. This means that if the students' scientific works have not been improved, it will contribute to the students' low content analysis skills. This research aimed at analyzing the differences in content analysis and science process skills between the students attending the scientific independencebased learning and those experiencing the direct learning. The science process skills are essentially developed to gain new knowledge and lead the students to independently discover facts and concepts (Seraphin et al., 2013; Michel & Neumann 2016; Susilowati & Anam, 2017).

Learning biology requires a systematic comprehension of biological processes (Seniwati, 2015). The biology learning process should be emphasized on performing practicum in order to lead students to build their own knowledge (Chang et al., 2011). Referring to Jackson et al. (2008), a practicum is done to encourage them in learning science since it provides an experimental process through science process skills. Nyoman et al. (2014) stated that practicum activities are important steps in discovering concepts.

A concept, according to Saylor & Alexander (1966) and Michel & Neumann (2016) is facts, data, perceptions, classifications, designs, and problem-solving emerging from human's experience and thought structured in ideas, principles, conclusions, plannings, and solutions. Concept mastery is essentially owned by a student to strengthen the existed concepts, or even discover new concepts. Students' concept mastery is not limited to getting to know a concept but connecting it to another in various difficult situations to solve problems.

Scientific work is a way of solving problems through a series of systematic and chronologic activity (Bang, 2017; Lodge, 2017). Students develop curiosity, honesty, creativity, perseverance, and accuracy in collecting, processing, communicating data, and drawing up conclusions during scientific experiments. By emphasizing learning on scientific works, they would be able to analytically communicate the discovered knowledge. Lestari et al. (2018) explained that analytical thinking is a process of solving a problem by applying the gained concepts. Furthermore, Azarpira et al. (2012) and Nuangchalerm & Thammasena, (2009) revealed that students' problem-solving skills could be examined by analyzing their answer to the examination questions. The questions developing high-level thinking skills could not be separated from science process skills which consist of observation, classification, prediction, measurement, drawing up conclusions, and communicating. The observation and measurement skills are the basis of thinking skills (Buchert, 2014; Mioduser & Betzer, 2008; Wouters et al., 2011). This research intended to analyze the differences between the content-analysis and science process skills between the students experiencing a learning-oriented to scientific independence (experimental class) and those joining a direct learning (control class).

METHODS

This study employed the quantitative of the quasi-experimental method. The quasiexperiment is suitable to analyze the cause and effect correlation by involving two groups; experimental and control. The research objects were the students learning Biology on cell metabolism topic in both the experimental and control group at Madrasah AliyahNudia Semarang. The independent variables were c The dependent variables were the students' content analysis and science process skills. The research design is presented in Table 2.

Table 1. The Research Design

Group	Pretest	Independent Variable	Posttest
Е	Y1	Х	Y2
Κ	Y1	-	Y2

The quasi-experimental design used the randomized group of pre- and post-test. The sample was chosen by employing the purposive sampling. Purposive sampling is a non-random sampling technique in which researchers determine particular characteristics that suit the research objectives so that the research problems are answered. This research chose 20 respondents consisting of 13 female and 7 male students. Suharsimi (2010) explained that the purposive sampling is suitable for taking sample based on the intention instead of strata, random, or cluster. In line with this, Sugiyono (2012) stated that the purposive sampling technique chooses the sample in regards to several considerations, which means that every object from the chosen population is intentionally taken in accordance with the objectives and considerations, which in this case were (1) similar teacher's characteristics; (2) relatively the same time allotment for teaching; and (3) students' low content analysis.

The normality and homogeneity test results determined group 1 as the experimental groups (E) which implemented the scientific independence-based learning with inquiry model and group 2 as the control group (K) which applied the direct learning. The test results indicated that the analyzed data were homogeneous, thus, a parametric test was possible to carry out. The students' ability in analyzing the material content of cell metabolism topic was assessed based upon the content analysis criteria adopted from Bloom and measured relying on their answers on the tests. There were 30 questions provided. The action verbs adopted for the tests were 'assess', 'compare', 'differentiate', 'sort', and 'determine'. The data collection technique of this research appears in Table 2.

Table 2. The Data Analysis Techniques

The Observed Aspects	Techniques	Instruments
Content analysis and science process skills	T - test	Questions
Learning improve- ment	N-gain	Questions
The correlation between content analysis and sci- ence process skills	Correlation	Questions
The students' response to scien- tific independence- based learning with inquiry model	Descriptive- qualitative analysis	Questionnaires
The teachers' per- formance on scien- tific independence- based learning with inquiry model	Descriptive- qualitative analysis	Questionnaires

The individual's mastery learning was measured using the following formula;

$$\frac{(1 x PS) + (1 x ES) + (2 x PrS) + (2 x PoS)}{6}$$

Where PS= Portfolio Score; ES= Exercise Score; PrS= Pre-test Score; PoS= Post-test Score. While in determining the classical mastery learning, the below formula was employed;

$$P = \frac{\sum ni}{\sum n} \times 100\%$$

Where P (classical mastery learning); $\sum ni$ (the number of students passed the individual mastery learning) (nilai \geq 75); and $\sum n$ (total number of students).

The data of the students' science process skills were analyzed using the descriptive qualitative method. The given formula was employed to analyze the obtained score:

Activity level = $\frac{\text{number of obtained score}}{\text{maximum number of score}} \times 100\%$

The researchers adopted the Arikunto & Cepi's (2009) assessment criteria, which are as folows: (1)81% - 100% (very good); 61% - 80% (good); 41% - 60% (sufficient); 21% - 40% (poor); and <21% (bad).

The data of the students' answer on the shared questionnaires on the learning activities were examined descriptively. The percentage was calculated using the following equation:

$$P = \frac{f}{N} \times 100\%$$

Where; f =frequency; N =number of students; and P = percentage. In addition, the teachers' performance was evaluated by knowing the descriptive qualitative percentage computed using the below equation:

$$Performance \ level = \frac{number \ of \ obtained \ score}{maximum \ number \ of \ score} \times 100 \%$$

RESULTS AND DISCUSSION

The learning outcomes obtained from both the experimental and control group were informed in Table 3.

Table 3. The Analysis of Students' Learning Outcomes from both the Experimental and Control Group

		After learning		
Group	Pre-test average	Post- test average	Classi- cal mastery learning (%)	N-Gain average
Control	51	71	45 %	0,41
Experi- mental	52	82	90 %	0,64

Initially, the pre-test score average of the experimental and control class differed only by 1 number. However, after the different treatments were given, the gap enlarged to 11 number. The minimum of classical mastery learning on cell metabolism topic was \geq 75. The number of students achieving the classical mastery learning in the experimental and control group appears in Figure 2.



Figure 2. The Number of Students who Achieved and Unachieved the Classical Mastery Learning

In this study, the classical mastery learning was obtained from the assessment results of the portfolio, worksheet, and post-test score. There were 20 students in the experimental class. There were 18 students achieved the mastery learning while the other 2 did not. On the other side, only 9 students achieved the mastery learning in the control class. In measuring how big the students' improvement was in analyzing content, an Ngain test was performed. The test results in the control class showed that 8 students categorized as low, 11 students categorized as intermediate, and 1 student categorized as high. Meanwhile, the experimental class had 15 students in the intermediate category and 5 students in the high category.

Each student's science process skills were evaluated through his/her scientific works during the learning process and the portfolio. The assessment of students' science process skills in the experimental class is presented in Figure 3.



Figure 3. The Students' Science Process Skills in the Experimental Class

Referring to Figure 2, the percentage of the science process skill aspects obtained by the students in the experimental class was 95% for the observing, 95% for the proposing hypotheses, 85% for utilizing tools and materials during the experiment, 70% for analyzing the experiment results, and 80% for communicating the experiment results. These results indicated that the students already possessed scientific independence. Moreover, they responded positively to the learning implemented in this research.



Figure 4. The Students' Science Process Skills in the Control Class

The results of the correlation analysis of the students' content analysis skills and process skills are listed in Table 4.

Table 4. The Correlation Coefficient of the Students' Independence with Content Analysis andProcess Skills

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.333ª	6	.038
Likelihood Ratio	16.912	6	.010
Linear-by-Linear			.119
Association	2.424	1	
N of Valid Cases	20		

a. 14 cells (100.0%) have expected count less than 5. The minimum expected count is .40.

The *chi-square* analysis obtained a *chi-square* value of 13,333 with a significance of 0.038 since the significance value was 0.038 < 0.05, then a significant relationship between the students' independence with the content analysis skills existed.

In this study, The students' analytical thinking skills were witnessed to improve during the practicum activities; therefore, they were capable of understanding the cell metabolism topic. This is in line with Abrahams & Millar (2008) that students could develop their thinking skills through scientific works. Moreover, Bancong & Song (2018) stated that experimental learning applied in Indonesia fully intends to improve the analytical thinking skills. In addition, Schuster et al. (2018) elucidated that efficient science learning will be achieved if students master the concepts. However, previous studies revealed that the students found it difficult to learn cell metabolism materials. Thus, this study measured the students' concept mastery by examining their mastery learning.

Roberts (2016) explained that valid and reliable questions would achieve the target level of comprehension. As stated above, this research analyzed the content, hence, the test validity became the major issue to obtain the apparent data of the students' content analysis. The students' content analysis skills were known by their answers to the tests. Prior to that, the test of validity, reliability, differentiators, and difficulty level have been examined. There were 30 valid questions of 35, which means that those 30 questions could properly assess the intended aspects and reveal the data of the studied variable. The valid questions contained the cell metabolism materials in accordance with the basic competence and indicators.

It found that the level of content analysis from the two groups was different, based on the post-test results of both the experimental and control group. The post-test results analysis showed that the students of the experimental groups have better content analysis skills compared to those in the control group. The content analysis skills were determined by the number of students achieving the classical mastery learning. Besides, there was also a different response outcome proposed by the students and teacher. 90% of the students in the experimental class declared that they were able to study the cell metabolism topic, while only 60% of the students in the control class declared that they were able to study the cell metabolism topic.

Rees et al. (2013), Hairida (2016), and Buck et al. (2008) said that inquiry learning could improve students' science process skills. Similarly, it revealed in this study that the students'science process skills differed from those learning using the inquiry model and those studying using the direct learning model. The experimental class oriented not only to apply scientific methods but also scientific independence. Experience gained by the students through self-made worksheets has resulted in their ability in utilizing tools and materials, and scientific independence. Meanwhile, the students' dependency on the teacher found in the control class had strengthened that it would only alienate them to scientific independence. There was a positive correlation between the content analysis and science process skills, as seen from the result of the regression correlation where Sig. = 0.038or > 0,05, therefore, it said that the better the content analysis skills, the higher the science process skills. Therefore, it has been proven that content mastery is the key to favorable science process skills (Zion, 2008), as stated also by Awalliyah et al. (2015) that a student's high science process skills are determined by his/ her level of concept mastery. Moreover, Noviani et al. (2017) explained that students' ability in answering questions relies on their critical thinking skills developed through scientific works during the learning process.

After the learning, the students in both groups were asked to give feedback on the applied strategies. The responses were collected by choosing the provided choices on closed questionnaires. The students in the experimental class mostly stated that they were able to learn the materials easily, which contrasted a bit with the control class. Furthermore, the students in the control class said that they were unable to arrange the self-made worksheet. This was caused by the different level of concept mastery in both groups. The findings are parallel with Misbah et al. (2018) elucidated that the students' performance during the practicum process strongly relies on their understanding of the worksheet. The students of the experimental group's responses had a significant impact on their achievement seen the analysis of test score, content analysis skills, and science process skills. Other than that, the teacher's performance was also evaluated.

The same teacher taught in both the experimental and control group but applied different learning strategies. This research had been carried out for a semester or six-month learning. The uncovered differences were in proposing hypotheses, directing the students to use the lab tools and materials, and supervising the students in interpreting the scientific work outcomes. The observers explained that these differences occurred since the teacher required a longer time in the control class and the students lacked these three aspects. Generally, the teacher scored well in both groups. A well-performed teacher has to overcome the students' learning problems (Japkowicz & Matwin, 2017). Nevertheless, in the experimental group, the teacher sometimes too much assisted the students while the learning orientation was scientific independence. This was probably because the teacher was used to provide any learning need (Koskinen et al. 2018).

CONCLUSION

The students' content analysis and science process skills of the experimental group (scientific independence-based learning with inquiry model) and control group (direct learning model) differed quite remarkably. The differences found in their test scores and answers to the questions requiring content analysis skills. Other than that, the students in the experimental group were more skillful in performing scientific works. In addition, there was a correlation between the content analysis and science process skills based on the correlation where Sig. = 0,038 or < 0,05. The better the content analysis skills, the higher the science process skills.

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THE EFFECT OF MULTIPLE REPRESENTATION-BASED LEARNING (MRL) TO INCREASE STUDENTS' UNDERSTANDING OF CHEMICAL BONDING CONCEPTS

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ABSTRACT

This study was conducted to determine the effectiveness of multiple representation-based learning (MRL) model compared to discovery learning (DL) model and problem based learning (PBL) model in terms of students' initial abilities. The factorial design was used in this study. The selection of samples in this study was done through a random sampling technique. Three X classes of the same school was chosen. The three classes applied different learning model. The first class employed the MRL, the second class used the DL model, and the last class adopted the PBL model. Overall, the number of samples involved in the study was 117 students. The results of the study showed that the conceptual understanding of students learning using MRL was significantly different from the students using discovery learning. This finding showed that MRL is the most effective model for increasing the conceptual understanding of students with "low" and "moderate" initial ability compared to PBL and DL.

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Keywords: multiple representations, conceptual understanding, chemical bonding, initial ability, effectiveness

INTRODUCTION

Chemistry is a science that seeks answers to what, why, and how of natural phenomena in relation to substances, covering structures, compositions, properties, dynamics, kinetics and energetics, which involve skills and reasoning (Chang & Overby, 2011; Huddle & Pillay, 1996). Therefore, studying chemistry should begin with solving daily life problems (Bodner & Herron, 2002; Jaber & BouJaoude, 2012; Gkitzia et al., 2011). Learning through problem solving in real life by applying knowledge of chemistry, partici-

*Correspondence Address E-mail: sunyono.1965@fkip.unila.ac.id pants were expected to develop an understanding of meaningful chemistry concepts (Yuanita & Ibrahim, 2015).

Problem-solving skills to develop meaningful chemistry knowledge could be accomplished with the ability to carry out interpretation and transformation among the three levels of chemistry phenomena (macro, sub-micro and symbolic) through visual, verbal, symbolic, or action representation. The key point in solving the chemistry problems is to develop the ability to represent chemistry phenomena at the submicroscopic level (Davidowizth et al., 2010). Previous studies have shown that students have difficulty in solving chemistry problems during examinations
due to their inability to visualize the structures and processes that occur at the submicroscopic level and the inability to correlate them with the phenomenon on other chemistry levels (Sunyono & Sudjarwo, 2018; Davidowizth et al., 2010).

In reality, current chemistry learning is limited to two levels of representation including the macroscopic and symbolic level (Jaber & BouJaoude, 2012; Yuanita & Ibrahim, 2015). Unfortunately, students integrate sub-microscopic and macroscopic or symbolic phenomena by themselves. Students try to understand the phenomena through the figures and diagrams in textbooks without teachers' facilitation. Therefore, chemistry learning must be directed to the improvement of students' multiple representations, either verbally or visually, in order to develop the students' representational capabilities so that the ability to associate chemistry phenomena can be increased.

The discovery learning (DL) and problembased learning (PBL) model have been widely used by teachers either in elementary or high schools. In DL, students are encouraged to learn concepts and principles through their own active involvement and to use thinking skills to solve problems independently (Prasad, 2011). Discovery learning is a teaching strategy that can help students discover and learn scientific concepts by themselves through their active participation in the learning process (Kim, 2013). However, in this discovery process, students accept guidance from the teacher so that students' focus is improved and the learning process as well as goals is achieved completely. Students also play an active role in the learning process by answering various questions and solving problems to find a concept. On the other hand, in learning, teachers only give a few examples to students, provide guidance to students in finding ideas in these examples, and finally draw conclusions to describe the ideas that have been taught to students. (Jacobsen et al., 2008). Learning with DL can guide students to develop the ability to carry out independent discoveries in the future (Carin, 1993; Vitoševic et al., 2014). The application of DL can contribute significantly to students' thinking abilities (Fuad et al., 2017).

Previous studies revealed that the DL model could help students learn in depth. The DL model is more meaningful because it employs individual associations as the core of understanding (Kim, 2013). Janssen et al. (2014) concluded that DL is more effective than conventional learning. In addition, the application of DL model in chemistry learning increases students' achievement and facilitates students to reduce the level of difficulties in understanding a concept (In'am & Hajar, 2017). In contrast to DL model, PBL model is a student-centered learning model in which students define their own key issues based on chemical bonding concepts for real-world problems through collaborative learning activities, also, direct students under the guidance of a teacher (Savoie & Andrew, 1994). Focusing on real-life problems and exploring relevant information allow students to develop their flexible knowledge and meaningful problem-solving skills (Abubakar & Arshad, 2015). PBL consists of the seven (7) following steps: problem identification, knowledge exploration, hypothesis creation, key issue identification, independent study, re-evaluation, the application of new knowledge towards problem-solving, evaluation, and reflection (Prasad, 2011).

Previous studies showed that learning using PBL can improve students' conceptual understanding. Rodríguez & Fernández-Batanero (2017) stated that PBL is one of the learning models that can motivate students to learn chemistry. The research of Kelly & Finlayson (2007) concluded that chemistry learning using PBL model could provide an excellent scope of learning for the development of skills, understanding of chemistry concepts, and laboratory experiment processes. Jones et al. (2013), in their research, found that many elements of the PBL model provide students with internal motivation. The opportunity to motivate students is important because learning using PBL model can influence students' perception of the concept being studied. The motivational opportunity available in PBL is a real asset to students' motivation. Abubakar & Arshad (2015) concluded that students who learn using PBL have been able to develop a deeper understanding and acquire effective problem-solving skills as well as more effective and focus on independent information processing.

Referring to Indonesian national education curriculum, the most suitable science learning is the student-centered approach such as the DL and PBL model. Both learning models focus on learning that prioritize problem-solving through a variety of innovative approaches initiated by teachers. The differences between DL and PBL are implied in the above description. Through the DL and PBL models, students can solve problems in a structured and systematic way so that an accurate and quick problem-solving solution is achieved. In addition, with a structured and systematic problem-solving strategy, students are trained to identify, analyze, and evaluate the problems carefully so that they may develop their critical reasoning to work on problems (De Cock, 2012; Kim, 2013; Rodríguez & Fernández-Batanero, 2017).

Several studies on multiple representationbased learning showed that MRL has been able to improve students' higher-level thinking skills (Davidowizth et al., 2010; Jaber & BouJaoude, 2012; Yuanita & Ibrahim, 2015). Nevertheless, the effectiveness of MRL model needs to be investigated further in chemistry learning by comparing to the PBL and DL model that have been widely known by teachers. Therefore, this study aimed to evaluate the effectiveness of the MRL model compared to the DL and PBL models. Both the DL and PBL learning model have cooperative and collaborative characteristics, while the MRL model has cooperative, collaborative and imaginative characteristics (Yuanita & Ibrahim, 2015). Thus, the question this research poses was "how effective is the MRL model compared to the PBL and DL model in terms of students' initial ability?"

METHODS

In this study, a factorial design was used to compare the increase of students' conceptual understanding through the three different learning models including MRL, DL, and PBL model in terms of students' initial ability (high, moderate, and low).

The random sampling was carried out so that three X classes of the same school were obtained. The first class acted as an experimental class which applied the MRL model while the other two classes were control classes, the control class A used the DL model and the control class B employed the PBL model. The research design is illustrated in Table 1 below.

Group	Subject	Pre- test	Treatment	Post- test
Experimental (MRL Model)	R1	01	Х	O2
Control A (DL Model)	R2	01	C1	O2
Control B (PBL Model)	R3	01	C2	O2

 Table 1. The Research Design

Description:

- O1 and O2 = Pre-tests and post-tests were administered to measure students' concept mastery (the test results were distinguished based on the students' initial ability of low, medium and high)
- X = The implementation of learning by using an MRL model
- C1 and C2 = Learning implementation by using the DL and PBL models.
- MRL Model = Multiple Representation-Based Learning Model
- DL Model = Discovery Learning Model PBL Model = Problem Based Learning Model

Before the learning implementation, the students in each class were grouped based on their initial abilities. Students' initial abilities were determined through the teachers' assessment data from previous learning. Each class consisted of 13 students with low, medium and high initial abilities, respectively. Pretest and posttest were carried out in each class to obtain the N-gain of students' understanding.

Instruments in the form of learning achievement tests were utilized to measure the level of students' understanding of the chemical bonding concepts. The questions on the achievement test were tested for validity and reliability. The validity and reliability of the test instruments were carried out through trials to 20 students. The validity and reliability of the test instrument were calculated using the SPSS 17.0 program. The validity computation resulted in the validity correlation coefficient (Corrected Item-Total Correlation) > 0.30. Meanwhile, the reliability calculation obtained a value of r_{11} of 0.92 or greater than r_{table} . Thus, the questions used to measure students' understanding of concepts owned high validity and reliability. This test consisted of 30 items with five options. The Pre-test and post-test with same questions were administered to the experimental class and control classes. The students gained 1 score for a correct answer and 0 for an incorrect answer. The concept mastery data was determined by the N-gain scores (Hake, 2002). The N-gain score was grouped based on the students' initial ability. The data were analyzed using analysis of variance (ANOVA) followed by a Tukey test at the 5% level. The analysis was performed using ANOVA factorial design. The hypotheses tested

R1 = Students in the experimental class used the MRL model of learning (selected randomly) with a total of 39 students.

in this analysis were: (1) H_01 : there was no difference in the N-gain of the chemical bonding concept understanding among groups of students based on the different learning models; (2) H_02 : there was no difference in the N-gain of the chemical bonding concept understanding among groups of students based on the differences in initial ability; and (3) H_03 : there was no significant interaction between the learning models and the initial ability of students in chemical bonding concept understanding.

RESULTS AND DISCUSSION

The findings showed that students' concept mastery was higher in MRL model than students' concept mastery in the DL and PBL model. The findings in Figure 1 demonstrated that the results of the pretest and post-test displayed the N-gain average of students' concept mastery in the experimental class and the control classes. Generally, the N-Gain average of students' concept mastery in chemistry learning using the MRL model was higher than the N-Gain average of the DL and PBL model at all levels of student ability. By using the N-Gain criteria, the general average value of the N-Gain obtained by students who learned using the MRL model categorized as "high" for all students with a high and medium initial ability, while for students with a low initial ability, the acquired N-Gain categorized as "medium". In general, the N-Gain average in the "moderate" category was also found in the DL and PBL class for all levels of the students' initial ability.



Figure 1. The Experimental Class (MRL model) and Control Classes (DL and PBL model) concept Mastery based on the N-Gain Averages Reviewed from the Initial Ability of Students (High, Moderate, and Low)

The subsequent analysis was accomplished using a statistical analysis to determine the difference in the students' concept mastery among the three learning models in terms of students' initial ability. The ANOVA statistical analysis results for the N-gain of the three learning models are shown in Table 2.

Table 2. The Analysis Results of Variance (ANO-VA) on the N-Gain of Students' Chemical Bonding Concept Mastery based on Initial Ability Factors and Learning Models.

Source	F	Sig.
Learning Models	545.151	.000
Initial Ability	0.919	.402
Interaction: Models*Initial ability	0.418	.795

There were significant differences among the N-gain averages as a result of using the various learning models; MRL, DL, and PBL. Thus, a post hoc test (multiple comparisons) using the Tukey test was needed. There was no significant N-gain difference among the students who had different initial abilities (high, medium, and low). Hence, it was unecessary to perform a further test. In addition, there was no significant interaction between the effects of the learning models and the students' level of initial ability (high, medium, and low), so, it was not necessary to conduct a further test. The post hoc analysis results of the learning model effects were achieved through a Tukey test (Table 3).

Table 3. The Tukey Test Results of the ThreeLearning Models' Effects

Learning Model	Mean Difference	sig.(p)
MRL – DL	0,0575	.299
MRL – PBL	0,1278*	.004
DL – MRL	-0,0575	.299
DL – PBL	0,0703	.167
PBL – MRL	-0,1278*	.004
PBL – DL	-0,0703	.167

Based on Table 3, it is clear that one pair of MRL – PBL had a significant difference in the Ngain average of chemistry concept mastery, while the two other pairs (MRL – DL and DL – PBL) had no significant difference in the N-gain average. Thus, it could say that the significant differences in the N-gain average only occurred in the implementation of learning that used the MRL and PBL model. These results indicated that the MRL model had no difference with the DL model in improving the mastery of chemical bonding concepts. However, the MRL model cannot be equated with the PBL model; hence, it was necessary to perform a further test to determine the difference in the N-gain average of the concept mastery from the two different learning models (MRL and PBL) with regards to the initial ability of the same students.

A statistical test to examine the differences in the average of the two different samples was administered by using a T-test. The tested hypothesis (Ho) was "there were no differences in the N-gain average of the chemistry concept mastery between the students learning with the MRL model and those learning with the PBL model with the same initial ability level". The t-test results analysis of the N-gain average for students' concept mastery is summarized in Table 4.

Table 4 shows that the N-gain averages were significantly different for the concept mastery of students at the medium and low initial ability level in the MRL and PBL model. On the other hand, there was no difference in the N-gain average of the high initial ability between the students using the MRL and PBL models. This result suggested that the learning process using the MRL model improved the students' concept mastery compared to the learning process using the PBL model for students with "medium" and "low" initial ability.

Table 4. The T-test Results of the N-gain averageon Students' Concept Mastery from the ThreeLearning Models of the Same Initial Ability.

Pair	Ν	Df	t	р
MRL High> <pbl high<="" td=""><td>13</td><td>12</td><td>1,193</td><td>0,256</td></pbl>	13	12	1,193	0,256
MRL Medium >< PBL Medium	13	12	2,563	0,025
MRL Low> <pbl low<="" td=""><td>13</td><td>12</td><td>1,917</td><td>0,031</td></pbl>	13	12	1,917	0,031

This study revealed that chemistry learning using the MRL model was more effective than using the PBL model yet had no difference with learning using the DL model in improving concept mastery and problem-solving skills on chemical bonding topic especially for those with moderate and low initial ability. This comparison indicated that the MRL model is the most recommended suitable model among the three models of learning applied to provide learning on chemical bonding. The results suggested that learning with various representations could stimulate the students to be actively engaged to solve chemical problems especially to interpret and transform macro, sub-micron, and symbolic phenomena. Through the exercises of various learning models, the students acquired easier ways to understand the chemistry concepts deeply (Rodríguez & Fernández-Batanero, 2017) and stronger ability to perform meaningful reasoning of chemical phenomena (Coll, 2008; Sunyono & Sudjarwo, 2018).

Based on the observations in the classroom, increasing students' concept mastery using the MRL model was supported by the use of high learning activities. This process also appeared in the teaching activities using the DL model but not the PBL model. In the MRL model, the teacher played a role as a facilitator and mediator in the learning activities. This model consistently indicated that learning has provided the opportunity for students to explore knowledge in discovering chemistry concepts to solve problems. This achievement was supported by the high activity of the students through the learning. These results showed that learning with MRL was carried out attractively, collaboratively, and cooperatively so that the students had more experience in solving the chemistry problems. The same results occurred through the DL model. The observation results revealed that both learning models were capable of making students become highly active in their exploration of knowledge. This finding is consistent with the report by In'am & Hajar (2017) that the implementation of learning using the DL model with a scientific approach can be accomplished to improve student learning activities to improve students' understanding of a concept. Furthermore, Vitošević et al. (2014) in their research revealed that DL procedures explore higher order thinking about real life issues and situations. Learning with the DL model can generate the interest and motivation of the students. This relation is in line with the previous statement that the DL model could generate chemical bonding concept mastery that is not significantly different from the MRL model because both models equally provide simplified learning materials by using sufficient media to reduce the level of difficulty in learning. Teaching through discovery learning by using mobile technologies could increase students' curiosity and interest in science as well as students' scientific knowledge (Kim, 2013).

MRL model is an effective learning model to optimize students' imagination capability; as a result, the students' ability to think and reason in solving problems is increased (Yuanita & Ibrahim, 2015). In the exploration activities during the learning process in the MRL model, the students were given the opportunity to broaden and deepen their knowledge by searching information through the internet or textbooks, observing

demonstration or animation activities, analyzing sub-micro visual images, and building concepts through reasoning in an effort to improve mastery of their concepts. The use of information technology (such as web pages/weblogs) in the MRL model could stimulate students' interest in searching for information. Through the learning process, the student-student and student-teacher interaction were very common. This condition was not much different from the learning under the DL model. Thus, it can be said that learning with the MRL model can be equated with the DL model yet was more effective than the PBL model. The ineffectiveness of the PBL model compared to the MRL model was due to the lower level of activity and motivation of the students. Based on the data during the observation, most of the students had a low ability to formulate an actual problem. This difference in the problem formulation phase was one of the causes that made learning with the MRL model more effective, where learning did not use computer-based media. The results of this study seem to be in line with Jaber & BouJaoude (2012) who stated that computers can be used as a tool to aid students to gain the ability to visualize the systems and processes at the molecular level. Relevant to this result, although PBL has been known as a model to improve student learning achievement, the lack of media usage in the learning has caused the results to be less favorable.

The learning process using the MRL model was suitable for students with medium and low initial ability. The increase in the chemical bonding concept mastery of students with medium and low initial ability in the MRL class was higher than that of students with the same initial ability in the class using the PBL model. Meanwhile, for students with a high initial ability, the increase in concept mastery for those using the MRL model was insignificantly different compared to that of students using the PBL model. These results explained that the MRL model was very suitable for students with a medium and low initial ability, especially in improving chemical bonding concept mastery.

The previous studies suggested that students with different initial ability have the same chance to increase their concept mastery through the MRL model. Carroll's theory (Joyce & Weil, 2003) stated that learning achievement is not solely influenced by previous academic ability but is also influenced by the quality of learning, the learning environment, talent, and available time. The right learning strategy to improve low and middle achievement academic ability to be equivalent to students with high academic abilities is a cooperative, collaborative and imaginative learning strategy. This idea was suggested by Slavin (2006) that cooperative learning can motivate students to support and help one another in mastering learning materials. De Cock (2012) stated that teachers need to provide convenience in the problem-solving process by providing opportunities for students to find or apply their own ideas and students will use different problem-solving strategies, depending on the representation format in which the problem is stated. Based on the above description, it can be said that the MRL model, which is characterized by being collaborative, cooperative, and imaginative, will be consistent with Carroll and Slavin's perspective.

The results of this research also reinforced the research conducted by De Cock (2012) which found that grouping the students based on initial capabilities in the learning of all subjects provide the same positive effect on learning outcomes, except in social studies where the effect may be negative. Similarly, Kingir et al. (2012) reported that the Science Writing Heuristic (SWH) approach, by involving the submicroscopic and symbolic phenomena in the learning of the chemical transformation and mixtures topics, significantly influences student learning performance and achievement. Thus, the results of this study align and complement the findings of previous research. The findings indicated that the MRL model appears to be more applicable to learning the concept of chemical bonding than the DL and PBL models, especially for students with low and medium initial abilities.

The findings of this study implicated for learning chemistry in schools, considering that chemical materials always involve macro, submicron, and symbolic phenomena, so, learning with multiple representations is very important. Through this MRL model, we provide advice to focus on the bonds formed between two atoms. Presentation of chemical bonds (including hydrogen bonds and Van der Waals bonds) using a model of interaction between two atoms in a gas state, including using an animation model to correlate macro phenomena (e.g. reactions between Na and Cl₂), sub-micron (electron handover movements), and symbolic (complete presentation of chemical reactions that occur). In this study, it should be noted that the students' ability to distinguish between ionic, covalent, hydrogen bonds, and Van der Waals based on length, energy, and other important characteristics (such as directivity). Although all chemical bonds can be presented at the sub-micron scale (such as bond strength, bond energy, etc.), the students must obtain a qualitative understanding of the chemical strength of the bond and its characteristics. Therefore, learning with the MRL model is able to provide the demand for learning the concept of chemical bonds as suggested above.

In addition, when compared with DL and PBL models, learning with the MRL model will be better able to examine the questions about why ions formed in the solution form ionic lattices? Is it because the solution is a solution of an ionic compound? In this case, learning must focus on the electric interactions between ions. However, we suggested that in introducing the concept of ionic bonding, it begins with the introduction of chemistry without the need to focus on ion formation. Learning begins by giving a little understanding of chemistry by considering discrete neutral atoms. At the beginning of this learning, it is better to start with a macroscopic approach, namely by demonstrating the formation of ionic solids with neutralization and evaporation (e.g. NaCl) and/or by precipitation (e.g. FeCl₃). Furthermore, learning is done by using animations to explain sub-micro phenomena, such as the release of one electron from Na and into the Na⁺ ion, and the capture of the electron by the Cl atom and becoming the Cl-ion. The final step is to explain the occurrence of symbolic ionic bonds by writing down the ionic reaction equation that occurs. Likewise, in learning about hydrogen bond concepts and so on, it is necessary to consider a macro, sub-micron, and symbolic scale approach. Learning chemistry by considering macro, submicron, and symbolic phenomena will be able to increase students' reasoning power (Devetak et al., 2009; Jaber & BouJaoude, 2012; Yuanita & Ibrahim, 2015) and the conceptual knowledge gained will be more profound and maintained long enough in students' brains (Yakmaci-Guzel & Adadan, 2013).

CONCLUSION

Based on the analysis and interpretation of the research results, the researcher concluded that the MRL model was capable of improving students' concept mastery of chemical bonding yet had no difference from the DL model. The MRL model was more effective than the PBL model in increasing chemical bonding concept mastery, and the MRL model was very suitable for chemical learning for the students with medium and low initial ability compared to the PBL and DL model.

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THE DEVELOPMENT OF TWO-TIER MULTIPLE CHOICE TEST TO ASSESS STUDENTS' CONCEPTUAL UNDERSTANDING ABOUT LIGHT AND OPTICAL INSTRUMENTS

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ABSTRACT

This study aimed to develop a two-tier multiple choice test about the concept of "light and optical instruments" in the 8th grade of the Indonesian science curriculum. The test development procedure had three general steps: (1) defining the content area of the test; (2) identification on students' conceptions; and (3) developing the two-tier multiple choice test. The final version of two-tier multiple choice test consisted of 25 items question. This test was administered to 95 junior high school students. The students had completed a unit on light and optical instruments. The reliability of the test was 0.76. Based on the data analysis, twenty-two alternative conceptions were identified. The results of the study showed that the two-tier multiple choice test was effective in determining the students' misconceptions and also it might be used as an alternative to the traditional multiple choice test. In conclusion, two-tier multiple choice test could be used to assess students' conceptual understanding as well as students' misconceptions on light and optical instruments concept.

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Keywords: two-tier multiple choice test, conceptual understanding, misconceptions, light and optical instruments

INTRODUCTION

Conceptual understanding in science learning has been the main concern of the researchers in the science education field. Students' conceptual understanding could not be easily observed or measured. Teachers have to investigate students' understanding before and after instruction. In order to measure students' conceptual understanding of several concepts in a science subject, various diagnostic tools have been developed and used such as open-ended tests, interviews, and multiple choice tests. Tho-

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se are found to be the ones commonly employed in science education research (Gurel et al., 2015).

Multiple choice tests have been employed for measuring students' understanding of concepts since they allow a large number of students to be sampled in a provided amount of time as compared to time-consuming interviews. These tests are easy to administer and score; moreover, the results obtained are also easily processed and analyzed (Petersonn et al., 1989; Tan et al., 2008; Tan & Treagust, 1999). However, multiple-choice questions may not always indicate students' understanding or detect students' misunderstanding for a certain concept (Adodo, 2013). The use of a two-tier diagnostic test (Treagust, 1988) has examined a better way to evaluate students' conceptions.

A two-tier diagnostic test was first developed with items precisely designed to identify auxiliary conceptions and misunderstandings in a defined content area of science. Since that time, a number of two-tier tests have been developed and reported in the literature (Treagust & Chandrasegaran, 2007). Two-tier diagnostic tests have been considered as an effective assessment tool to establish students' conceptual understanding (Treagust, 1988; Odom & Barrow, 1995; Chen et al., 2002; Lin, 2004; Cengiz, 2009; Sesli & Kara, 2012; Adadan & Savasci, 2012).

One of the factors affecting students' conceptual understanding is misconceptions. Misconceptions occur if a student's understanding of a concept differs from the scientific concept (Nakhleh, 1992). Misconceptions are stable cognitive structures to change, affect students' conceptual understanding, and must be overcome so that students learn scientific concepts effectively (Hammer, 1996). Misconceptions have become a part in the science education area. Previous researchers have done lots of studies to investigate the students' misconceptions, particularly in light and optical instruments concept.

Light and optical instruments is an important science concept included in the curriculum of many countries (Jones & Zollman, 2014). Although everyday experience with light and optical instruments concept, understanding of this concept turn out to be difficult for students. According to Ling (2017), light is a complex concept in science learning. Due to the complexity of the concept and difficulty of the subject, students have a various misunderstanding and hence have developed misconceptions about light and optical instruments concept. According to the national curriculum in Indonesia, light and optical instruments concept are taught at the 8th-grade student in junior high school (Krisno, 2008). This concept is expanded and taught in the upper grade in senior high school. If the students' misconceptions about light and optical instruments concept are not corrected, students will carry these misconceptions to the upper grades. Dealing with this issue, the development of two-tier multiple choice test for evaluating students' conceptual understanding of light and optical instrument may lead to more meaningful learning. Therefore, the purpose of this study was to develop a two-tier multiple choice test to assess students' conceptual understanding, as well as to explore students' misconceptions of light and optical instruments concept.

METHODS

This study was a mixed method with incorporating both quantitative and qualitative methods. The Two-Tier Mulitple Choice Test (TTMCT) was developed in three stages adopting procedures by Treagust's (1988, 1995). The procedure was divided into three stages as shown in Figure 1. Stage 1 was defining the content area of the study. Stage 2 was the identification of students' conceptions from previous literature and students' responses. Stage 3 was several steps in the designing of the test items and the validation of the final version of the two-tier multiple choice test.

The first stage was defining the content area. Based on the science textbooks, the content area of light and optical concept were identified. The concept can be defined into five concepts boundaries the content area of the properties of light, the formation of images in mirrors and lenses, the formation of images in lenses, optical instruments, and the human eye. The content area was encapsulated in concept maps. Then, the relationship between the concept maps was checked. The concept maps were validated by two expert science teachers and three science lecturers. Table 1 shows the distribution of the content area of light and optical instruments concept in the TTMCT.

Table 1. The Content Area of Two-Tier MultipleChoice Tests

Content Area	Items			
The properties of light	Q1, Q2, Q3, Q4, Q5			
The formation of images in mirrors and lenses	Q6, Q7, Q8, Q9, Q12, Q13			
Optical instruments	Q18, Q20, Q21, Q22			
Human eyes	Q10, Q11, Q19, Q23, Q24			
Human eye disorders	Q14, Q15, Q16, Q17, Q25			

The second stage was the identification of students' conceptions. The students described and explained the light and optical instruments concept using multiple levels of representations. The students' conceptions were identified using semi-structured and free response questions. These questions were administered to 40 students in grade 8th junior high school, which are chosen by using purposive random sampling. For more information and deeper perspective of students' conceptions, semi-structured interviews were conducted. The interviews endured 20 to 30 minutes. Finally, the students' conceptions were identified by structured protocols.

The third stage was the development of two-tier multiple choice test. This stage focused on developing the two-tier multiple choice test. Based on the specification grid, 25 items two-tier multiple choice tests were developed. Each item of the instrument consists of two sections. In a TTMCT, the first tier asked students to choose about some specific concept related with light and optical instruments concept; and the second tier questioned students about the reason or explanation for choice in the first tier. There were four choices for both tiers. The instrument of the first version was validated by three science lecturer and two science teachers. Then, the final draft of TTMCT was developed. The final version of TTMCT consisted of 25 items question. The example of the TTMCT items can be seen in Figure 2.



Figure 1. The Flowchart of Instrument Development Based on Treagust (1988,1955)

RESULTS AND DISCUSSION

In order to validate the two-tier multiple choice test (TTMCT), a pilot study was conducted. The final version of the TTMCT was administered to 95 students in grade 9th Junior High School. All of them had studied light and optical instruments in grade 8th. The fundamental purpose of the pilot study was to evaluate the effectiveness of the TTMCT regarding its content coverage and language appropriateness. Based on the pilot test, it was identified that the students needed about 80 minutes to complete the TTMCT which consisted of 25 items question related to the concept of light and optical instruments. Item 1, 2, 3, 4, and 5 concerned with the properties of light. The formation of images in mirrors and lenses represented in item 6, 7, 8, 9, 12, and 13. Item 18, 20, 21, and 22 involved the concept of optical instruments. The concept of the human eye was demonstrated in item 10, 11, 19, 23, and 24. Finally, the concept of eye disorders was available in item 14, 15, 16, 17, and 25. Details indicator of items in TTMCT can be seen in Table 2.

Торіс	Indicator of question	Item
The properties of light	Definition of light	Q1
	The relationship between light and vision	Q2
	Monochromatic and polychromatic light	Q3
	Light refraction	Q4
	Light as a transversal wave	Q5
The formation of an image in	Image formation in a plane mirror	Q6
mirrors and lenses	The law of reflection	Q7
	The relation between incident and reflection ray	Q8
	Image formation between two plane mirror	Q9
	Image formation in a concave mirror	Q12
	Analyzing the focus of the concave mirror	Q13
Optical instruments	The image formation in the convex lens	Q18
	The parts of microscope	Q20
	The image formation of eye and camera	Q21
	Similarities of human eye and camera	Q22
Human eye	Part of the human eye (retina)	Q10
	Part of the human eye (eye lens)	Q11
	Definition of human eye accommodation	Q19
	The relationship between presbyopia and eye lens	Q23
	Part of the human eye (aqueous humor)	Q24
Eye disorders	Eye disorders (myopia)	Q14
	The eyeglasses for myopia	Q15
	Eye disorders (hypermetropia)	Q16
	The characteristic of nearsighted eyes	Q17
	The solution for myopia	Q25

Table 2. Distribution of Items to the Contexts on the TTMCT

Two experienced science teachers and three science lecturers validated the questions' content. The validator was provided with a task description and a concept outline to evaluate the validity of the instruments. The validator commented that the content of the instruments included almost 95% of the syllabus and suitable to be used. The language used in the TTMCT was easily understood by the students. The reliability test is essential to examine the consistency of the items measured using the instruments. The reliability of the TTMCT was 0.76. Hence, it can be concluded that the items in the TTMCT were reliable in assessing the understanding of light and optical instruments concept.

In a traditional multiple choice test with four possible choices, the chance of predicting the correct answer is 25 percent. Nevertheless, in a TTMCT, the chance of predicting is 6.25 percent. By lessening the predicting chance from 25 percent to 6.25 percent, the arithmetic means of the students might decrease. Treagust (1988) stated that the development of the two-tier diagnostic test to reveal students' conceptions. The first tier of each item test is a multiple choice question dealing with proportional statements, and the second tier of each item is a composed of multiple choice set of reasons for the first tier's answer. The set of reasons includes students' scientific answer and possible misconceptions. A student's answer to an item was declared correct if the student selected both the correct answer and reason. Items of the TTMCT were evaluated for both correct and incorrect response combinations chosen by the students. Figure 2 shows the example of the response combinations picked by the students for item number 1 and number 2 dealing with the properties of light.

 What is the definition of light? A. Light is an electromagnetic wave B. Light is a mechanical wave C. Light travels unlimited distance D. Light is a longitudinal wave Reason:			e 2. W th ey B um C t t E E E c c c	 We can see the fish in the aquarium. The fact about the relationship between light and the ability of the eye to see objects is A. The eye can see objects because the object can absorb the received light B. The eye can see objects because the object reflected light, so that light enters the eye C. The eye can see objects because the object refracted light, so that light enters the eye D. The eye can see objects because the eye nerve can see objects, so the ability of the eye to see the object has no relationship with light <u>Reason:</u> a. Eyes can see even without light b. Eyes can see even without light b. Eyes can see objects c. Light coming from a light source directly entert to our eyes d. If there is no light to reflect at an object, no object can be seen 			fact about bility of the object can the objects he eye the object he object he eye eye nerves e eye to see ight an see ectly enters ect, no
Item	Answer Option	a	Rea	ason Opti	on	Blank	Total
	A	23.16	56.84*	3.16	0.00	0.00	83.16
	В	1.05	4.21	2.11	0.00	0.00	7.37
O 1	C	1,05	3,16	1,05	0,00	0,00	5,26
~	D	2,11	2,11	0,00	0,00	0,00	4,21
	blank	0,00	0,00	0,00	0,00	0,00	0,00
	А	3,16	1,05	2,11	0,00	0,00	6,32
	В	12,63	8,42	12,63	35,79*	0,00	69,47
Q2	С	4,21	2,11	4,21	3,16	0,00	13,68
	D	2,11	3,16	2,11	3,16	0,00	10,53

Note : Figure in bold and with an asterik indicates the correct answer. texts in italics indicate a major alternative conception (>15%).

Figure 2. The Example of TTMCT Item and Percentage of Students Selecting Each Response Combination for Item Number 1 and Number 2 Dealing with the Properties of the Light

The Analysis of Alternative Conceptions Using Two-tier Multiple Choice Test

Alternative conceptions are considered significant and conventional if they were found in more than 10% of the students' sample (Peterson, 1986; Tan et al., 2005). Table 3 shows the summarize of significant common alternative conceptions of students in light and optical instruments concept using two-tier multiple choice tests. Twenty-two alternative conceptions were identified and grouped under the headings of 'the properties of light', 'the formation of the image in mirrors and lenses', 'optical instruments', 'human eye', and 'eye disorders'.

Table 3. The Students' Alternative Conceptions from the Administration of TTMCT

Alternative Conceptions	Choice Combination	Percentage
The Properties of Light		
Light is an electromagnetic wave and has an infinite speed	Q1 (A-a)	23%
White light bulb is the type of monochromatic light and can be broken down into other colors through the process of light diffraction	Q3 (A-a)	28%
White light bulb is the type of monochromatic light and can be broken down into other colors through the process of light dispersion	Q3 (B-c)	39%
Light can refract towards the normal when light ray directly refracted by the rarer medium	Q4 (B-c)	25%

The Formation of an Image in Mirrors and Lenses		
The height of an image is the same as the height of the object, while the distance of an image is two times the distance from the object	Q6 (B-a)	17%
The distance of the object affects the magnitude of the incidence angle and reflection angle	Q7 (B-b)	17%
The magnification of an image is the result of the height of the object with the height of the image	Q12 (A-a)	25%
The magnification of an image is the result of the height of the object with the distance of the image	Q12 (A-b)	16%
Optical Instruments		
In a convex lens, if the object position in closer to the lens then characteristic image are virtual, upright and enlarge	Q18 (A-a)	21%
Microscope consists of two convex lenses, the ocular lens (near the object) and the objective lens (near the eye)	Q20 (A-a)	26%
The similarities between human eyes and camera are both of them have concave-convex lens	Q21 (B-d)	17%
The lens in a camera has function to controls the accommodating power that same function with iris in the human eve	Q22 (C-a)	24%
Human Eye		
Human Eye The eye lens is a part of the eye which serves as an image catcher	Q10 (B-b)	19%
Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing.	Q10 (B-b) Q10 (B-c)	19% 22%
Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing. The pupil is a part of the human eye that has function to focuses the light onto the retina	Q10 (B-b) Q10 (B-c) Q11 (C-a)	19% 22% 18%
Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing. The pupil is a part of the human eye that has function to focuses the light onto the retina Eye accommodating happen when the object is far, the lens of the eye is flat- tened; while when the object is close, the muscle in the eye relaxing and the lens of the eye is bulging	Q10 (B-b) Q10 (B-c) Q11 (C-a) Q19 (D-b)	19% 22% 18%
 Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing. The pupil is a part of the human eye that has function to focuses the light onto the retina Eye accommodating happen when the object is far, the lens of the eye is flattened; while when the object is close, the muscle in the eye relaxing and the lens of the eye is bulging Presbyopia caused by the cornea is not working properly 	Q10 (B-b) Q10 (B-c) Q11 (C-a) Q19 (D-b) Q23 (B-a)	19% 22% 18% 18%
 Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing. The pupil is a part of the human eye that has function to focuses the light onto the retina Eye accommodating happen when the object is far, the lens of the eye is flattened; while when the object is close, the muscle in the eye relaxing and the lens of the eye is bulging Presbyopia caused by the cornea is not working properly Presbyopia caused by the pupil is not working properly 	Q10 (B-b) Q10 (B-c) Q11 (C-a) Q19 (D-b) Q23 (B-a) Q23 (C-a)	19% 22% 18% 18% 18%
Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing. The pupil is a part of the human eye that has function to focuses the light onto the retina Eye accommodating happen when the object is far, the lens of the eye is flat- tened; while when the object is close, the muscle in the eye relaxing and the lens of the eye is bulging Presbyopia caused by the cornea is not working properly Presbyopia caused by the pupil is not working properly The aqueous humor is located in the iris	Q10 (B-b) Q10 (B-c) Q11 (C-a) Q19 (D-b) Q23 (B-a) Q23 (C-a) Q24 (A-d)	19% 22% 18% 18% 18% 18% 21%
Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing. The pupil is a part of the human eye that has function to focuses the light onto the retina Eye accommodating happen when the object is far, the lens of the eye is flattened; while when the object is close, the muscle in the eye relaxing and the lens of the eye is bulging Presbyopia caused by the cornea is not working properly Presbyopia caused by the pupil is not working properly The aqueous humor is located in the iris Eye Disorders	Q10 (B-b) Q10 (B-c) Q11 (C-a) Q19 (D-b) Q23 (B-a) Q23 (C-a) Q24 (A-d)	19% 22% 18% 18% 18% 18% 21%
Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing. The pupil is a part of the human eye that has function to focuses the light onto the retina Eye accommodating happen when the object is far, the lens of the eye is flattened; while when the object is close, the muscle in the eye relaxing and the lens of the eye is bulging Presbyopia caused by the cornea is not working properly Presbyopia caused by the pupil is not working properly The aqueous humor is located in the iris Eye Disorders Myopia can help using positive eyeglasses	Q10 (B-b) Q10 (B-c) Q11 (C-a) Q19 (D-b) Q23 (B-a) Q23 (C-a) Q24 (A-d) Q15 (B-a)	19% 22% 18% 18% 18% 18% 21% 16%
Human Eye The eye lens is a part of the eye which serves as an image catcher The eye lens is a part of the eye that refracts the light so that it can give the impression of seeing. The pupil is a part of the human eye that has function to focuses the light onto the retina Eye accommodating happen when the object is far, the lens of the eye is flattened; while when the object is close, the muscle in the eye relaxing and the lens of the eye is bulging Presbyopia caused by the cornea is not working properly Presbyopia caused by the pupil is not working properly The aqueous humor is located in the iris Eye Disorders Myopia can help using positive eyeglasses The characteristic of nearsighted (hypermetropia) is formed image behind the retina and caused by the shape of the eyeball is too convex	Q10 (B-b) Q10 (B-c) Q11 (C-a) Q19 (D-b) Q23 (B-a) Q23 (C-a) Q24 (A-d) Q15 (B-a) Q17 (D-b)	19% 22% 18% 18% 18% 18% 21% 16% 18%

The finding from Table 3 illustrates that students hold misconceptions of light and optical instruments concept. Based on the data analysis, twenty-two alternative conceptions were identified. These alternative conceptions in light and optical instruments concept were arisen because of the difficulty and complexity of the concept, daily life experiences, textbooks, language used, and teachers' misconceptions. Students come to school with different knowledge about this concept based on their daily experiences.

In light and optical instruments concept, Indonesian students have been provided an example of the properties of light based on their daily experiences. For instance, in Table 3 showed that 23% of the students held the misconceptions about "light is an electromagnetic wave and has infinite speed." Based on this conception, the students think that light is an electromagnetic wave and has infinite speed because they taught that the sun is shining every second. The fact is the light needs 8 minutes 20 seconds to reach on the earth from the sun.

Another example of misconception was eye accommodation process. Based on the analysis, 23% of the students held the misconceptions about "eye accommodation happens when the object is far, the lens of the eye is flattened; while when the object is close, the muscles in the eyes are relaxing and the lens of the eye are bulging." Students in Indonesia are difficult to explain the process of the eye's accommodation. Eyes accommodation is a reflex action as a response to focusing on a near object, then looking at a faraway object and vice versa. This process is achieved through the changing of the eye lens. The process of the eyes accommodation is too abstract for students and tends to cause the misconceptions.

To determine the students' understanding in light and optical instruments concept using TTMCT instrument, the first tier asks a student to choose about some specific concept, and the second tier asks the student about the reason or explanation for choice in the first tier. The scoring method of TTMCT considered each item to be correctly answered if a student's choice of either the first tier (content knowledge) or the second tier (reason for the first tier) were both correct. Table 4 shows analysis of the percentage correct answer and correct reason of the TTMCT.

Table 4. The Percentage of Correct Answer-Correct Reason from the Administration of the TTMCT

Tonic	Indicator of Question	Item -	Total		
тори	indicator of Question		Ν	Percentage	
The properties of light	Definition of light	1	54	57%	
	The relationship between light and vision	2	34	36%	
	Monochromatic and polychromatic light	3	3	3%	
	Light refraction	4	13	14%	
	Light as a transversal wave	5	6	6%	
The formation of image	Image formation in a plane mirror	6	24	25%	
on mirrors and lenses	The law of reflection	7	45	47%	
	Relation between incident and reflection ray	8	14	15%	
	Image formation between two plane mirror	9	24	25%	
	Image formation in a concave mirror	12	16	17%	
	Analyzing the focus of the concave mirror	13	29	29%	
Optical instruments	The image formation in the convex lens	18	13	14%	
	The parts of microscope	20	41	43%	
	The image formation of eye and camera	21	9	9%	
	Similarities of human eye and camera	22	17	18%	
Human eye	Part of the human eye (retina)	10	20	21%	
	Part of the human eye (eye lens)	11	25	26%	
	Definition of human eye accommodation	19	22	23%	
	The relationship between presbyopia and eye lens	23	14	15%	
	Part of the human eye (aqueous humor)	24	12	13%	
Eye disorders	Eye disorders (myopia)	14	28	29%	
	The eyeglasses for myopia	15	9	9%	
	Eye disorders (hypermetropia)	16	31	33%	
	The characteristic of nearsighted eyes	17	24	25%	
	The solution for myopia	25	5	5%	

Science curriculum in Indonesia stated that the assessment directed to measure students' conceptual understanding (Widiyatmoko & Shimizu, 2018). The TTMCT in this research addressed conceptual understanding in five topics: (1) The properties of light (definition of light, relationship between light and vision, monochromatic and polychromatic light, light refraction and light as a transversal wave); (2) The formation of image in mirrors and lenses (the image formation in a plane mirror, the law of reflection and refraction, and image formation in a mirror); (3) Optical instruments (the image formation in the convex lens, the image formation of microscope, and similarities of human eye and camera); (4) Human eye (the parts of human eye and the accommodation of human eye); (5) Eye disorders (the type of eye disorders and the solution for each eye disorders).

To show students' conceptual comprehension of the properties of light, students were expected to understand the definition of light, the relationship between light and vision, monochromatic and polychromatic light, light refraction, and light as a transversal wave. As seen from Table 4, 57% of the students have grasped the defini-

tion of light while 36% of the students showed an understanding of relationship between light and vision, and only 3% of the students understood the concept of monochromatic and polychromatic light. Moreover, 14% of the students showed an understanding of light refraction, and 6% of the students showed understanding of light as a transversal wave. Based on Table 1, the lowest percentage of the properties of the light was monochromatic, polychromatic, and light as a transversal wave. The factors that impeded understanding of this concept are light is abstract for the students, and the characteristic of light (its speed, wavelength, color, etc.) are beyond the perception of students' senses. Furthermore, many terms in light topic like reflection, refraction, and dispersion are difficult for students.

To know students' conceptual understanding of the image formation on mirrors and lenses, the students were expected to understand the image formation in a plane mirror, the law of refraction and reflection, and image formation in a mirror. Stand on Table 4, 25% of the students comprehended the image formation in a plane mirror, 47% of the students showed an understanding of the law of reflection, 15% of the students indicated an understanding of relation between incident and reflection ray, 25% of the students got the image formation in between two plane mirror, 17% of the students showed an understanding of image formation in a concave mirror, and 29% of the students showed an understanding of analyzing focus of the concave mirror. The image formation on mirrors and lenses are difficult for students due to several reasons. First, they were confused about the law of reflection (incident angle and reflection angle). Second, the students found it difficult to determine real image and virtual image. Third, the students did not have any experience with the number of images which generated from two plane mirrors, and fourth, they considered it difficult to measure image distance, object distance, focal length and image magnification.

To show the students' conceptual understanding of the optical instruments, they were expected to understand the image formation in the convex lens, the parts of microscope, and similarities of human eye and camera. As appeared in Table 4, 14% of the students showed an understanding of the image formation in the convex lens, 43% students indicated an understanding of the parts of microscope, 9% of the students showed an understanding of the image formation of human eye and camera, and 18% of the students revealed an understanding of the similarities of human eye and camera. The optical instruments topic were difficult for students because it was difficult to explain the similarities between human eye and camera about the process of image formation. Moreover, they found it hard to explain the similarities between parts of human eye and camera; further, the students hardly used microscope in order to find the image ude to their lack of knowledge about the parts of microscope.

To reveal the students' conceptual understanding of the human eye, they were expected to understand the parts and function of human eye. On the basis of Table 4, 21% of the students explained an understanding of the retina as a part of human eye, 26% of the students showed an understanding of the eye lens as a part of human eve, 23% of the students showed an understanding of the definition of accommodation human eye, 15% students indicated an understanding of the relationship between presbyopia and eye lens, and 13% of the students showed an understanding of the aqueous humor as a part of human eye. Human eyes topic was difficult for the students because they faced difficulties to mention the parts of the human eye and its function, the complex concept of how image formation process in the human eye, and the process of eye accommodation as those are too abstract.

To know the students' conceptual understanding of the eye disorders, they were expected to comprehend the type of eye disorders and the solutions. Based on the above Table 4, 29% of the students understood of the eye disorder myopia, 9% of the students grasped the eyeglasses for myopia, 33% of the students comprehended eye disorders of hypermetropia, 25% of the students showed an understanding of the characteristic of nearsighted eyes, and 5% of the students showed an understanding of the solution for myopia. Eye disorders topic was hard for the students as myopia, presbyopia, and hypermetropia are difficult to explain and they felt it difficult to visualize the process on how convex lens and concave lens can help someone who has eye disorders.

The analysis results elucidated that the students' conceptual understanding of light and optical instruments were low. The percentage of the indicator achievement in light and optical instruments concept below 50%. The highest percentage in Table 4 is 57% of the students showed an understanding of the definition of light. On the other hand, the lowest percentage is 3% of the students showed an understanding of monochromatic and polychromatic light. These results were indicating that a number of students did not know the correct answer and hold misconcep-

tions about light and optical instruments concept. Two-tier multiple choice test in this study can assess students' conceptual understanding as well as analyzing students' misconceptions.

Two-tier tests have been used by previous researchers to identify students' misconceptions in science learning (Treagust & Haslam, 1986; Treagust, 1988; Adodo, 2013; Kanli, 2015; Yusrizal & Halim, 2017), and particularly in light and optical instruments concept (Chen et al., 2002; Chu et al., 2009; Haagen-Schützenhöfer & Hopf, 2014). A two-tier diagnostic test, as Treagust (1988) reported, was first developed with items specifically designed to identify alternative conceptions and misunderstandings in clearly defined content areas of science. Since that time, a number of two-tier tests have been developed and reported in the literature (Treagust & Chandrasegaran, 2007).

The use of two-tier multiple choice tests allows teachers to achieve students' conceptual understanding, and also to explore students' reasoning behind these ideas (Tsai & Chou, 2002). Moreover, it facilitates the assessment of misconceptions of a larger sample of students in an effective way in science education research (Voska &Heikkinen, 2000). Misconceptions are stable, unscientific conceptions that obstacle the real learning of individuals Peşman & Eryılmaz (2010) and Hammer (1996) listed the properties of misconceptions as follows: (1) strong and stable cognitive structures; (2) Differ from scientific conception; (3) Affecting how students understand scientific explanations; and (4) Must be overcome, avoided and eliminated to achieve the scientific conceptions.

Research in overcoming students' misconceptions involves three main steps, namely developing diagnostic test instruments, analyzing the causes of misconceptions, and remediation of misconceptions (Allen, 2014). Misconceptions are difficult to replace with new, correct understandings; they consistently influence the effectiveness of further learning (Özmen, 2004; Tan et al., 2008). This condition happens because of misconceptions was difficult to change (Widarti et al., 2016). Students' misconceptions interfere with students' learning of scientific concepts (Sreypouv & Shimizu, 2017). Overcoming students' misconceptions require teaching methods which provide chances for students to reveal their pre-concepts and dissatisfaction with their concepts, particularly in light and optical instruments concept. According to Indonesian's national curriculum, the beginning of eighth grade in junior high school is the stage prior to receiving formal instruction about light and optical instruments concept, and this concept is expanded and taught in the upper grade in senior high school. If the students' misconceptions about light and optical instruments concept are not corrected, students will carry these misconceptions to the upper grades.

The previous literature indicated that there are various advantages of using two-tier multiple choice tests. Chen et al. (2002) found that the twotier multiple choice test provided a reliable and valid pencil-and-paper, easy to score instruments for the teacher to evaluate students' idea better. Furthermore, this test has been used to evaluate students' misconceptions (Treagust, 1988) and very useful as the instruments that provide the teachers with students' understanding of particular science concept (Treagust & Chandrasegaran, 2007). The test is more readily administered and scored than the other method (Tan & Treagust, 1999, Adadan & Savasci, 2012). The TTMCT is relatively convenient for students to respond and more practical and valuable for teachers to use regarding reducing guesswork, allowing for large-scale administration and offering insight students' reasoning (Adadan & Savasci, 2012).

The complexity and difficulty of the light and optical instruments concept can cause the students' misconceptions. In the learning process, students will try to link the new knowledge to their cognitive structures. If the students have misconceptions, these will interfere with their learning and they will difficult to connect new knowledge with their existing knowledge. Because of this condition, students will difficult to achieve conceptual understanding in a learning process. Thus, the teacher should guide prerequisite concepts for the students as the bridging between students prior knowledge and the understanding of the concept being learning (Tsui & Treagust, 2010).

CONCLUSION

Based on this study, TTMCT is comfortably used to assess students' conceptual understanding as well as students' misconceptions on light and optical instruments concept. The TTMCT could help teachers to enhance students' knowledge level and prevent students' misconceptions. Thus, TTMCT help to improve teaching- learning process in the science classroom. This study exhibits several limitations. One of the limitations is that it lacks generalizability. Since the study involving a small number of participants, the findings from this study may not be generalized to the other contexts.

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