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The Effect of Predict-Observe-Explain (POE) Strategy on Students' Conceptual Mastery and Critical Thinking in Learning Vibration and Wave

Dandy Furqani[1*], Selly Feranie [2], Nanang Winarno[1]

[1]International Program on Science Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia
[2]Department of Physics Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia

*Corresponding Author. dandyfurqani@gmail.com

ABSTRACT Scientific learning in schools requires not only students' ability to understand concept, but also critical thinking abilities of the students. However, the current scientific learning process is still focused on only cognitive aspects. Therefore, a teaching model or strategy that is able to support students to understand concept as well as develop students' critical thinking abilities is needed. One of the existing needed strategies is Predict-Observe-Explain (POE). The aim of this research is to identify the effects of Predict-Observe-Explain (POE) strategy on students' conceptual mastery and critical thinking in learning vibration and wave. The method that was used in this research was weak experiment and the design was one-group pretest-posttest. The population of this research was 8th grader students in a junior high school in Bandung. The sample of the research was 18 students. The technique that was used was purposive sampling. The results of the research were: There was enhancement in students' conceptual mastery, indicated by average normalized gain of 0,29; There was enhancement in students' critical thinking abilities from level 1,30 (challenged thinker) to 2,07 (beginning thinker). Students can easily predict, observe and explain waves concept have difficulties on transversal waves and longitudinal waves concepts. For the next research it is recommended that Predict-Observe-Explain (POE) is to be tried on motion, electricity and ecosystem.

Keywords Predict-Observe-Explain (POE), Conceptual Mastery, Critical Thinking Abilities, Vibration and Wave

1. INTRODUCTION

The Indonesian National Curriculum of 2013 stated that learning activities should be focused on students with actively seeking learning patterns and also critical learning (Indonesian Ministry of Education and Culture, 2015). Based on the statement of the Indonesian Ministry of Education and Culture, we can infer that the learning is now emphasized on critical thinking skills of the students. However, according to an interview with a teacher of a middle school in Indonesia, Physics topics such as vibration and wave are considered a tough subject for the students. Vibration and wave, as like as other physics topics, require not only students' knowledge on basic understanding, but also complex thinking, especially to understand the characteristics and types of waves. Therefore, it is necessary to find a more suitable learning model for topics such as vibration and wave.

Critical thinking ability is the ability to think to solve the problem systematically. The purpose of critical thinking is to achieve a deep understanding which is to uncover the meaning behind an event (Johnson, 2010). Critical thinking ability can be sharpened through laboratory activities, discoveries, homework to develop critical thinking skills, and exams designed to build critical thinking skills. Critical thinking skills can be enhanced through group discussions were organized and guided directly by the teacher. High-level questions can encourage deeper critical thinking (Wardatun, Dwiastuti & Karyanto, 2015).

Critical learning emphasizes activities to analyze, interpret, and assess a case or an issue and rationally and logically. Such activities are part of the critical thinking skills. These learning activities require high learning motivation from the students themselves. Motivation to learn can help students develop critical thinking skills because by having the motivation to learn, the students will be more enthusiasm and always feel challenged to keep learning (Ulfah, Asim & Parno, 2014). Critical thinking as part of thinking skills must be possessed by every member in the community because a lot of problems in life that must be done and finished (Wijaya, 2007). Low critical

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thinking skills will lead learners to have difficulty when faced with a concrete problem in everyday life.

The main goal of the school is to improve the students' critical thinking ability (Slavin, 1997). However, in fact, the students in the school did not have the opportunity to develop critical thinking skills so that students' critical thinking abilities tend to be low. According to Pratama (2012), the readiness of students to find the best knowledge from a context, confidence to ask, honesty and objectively seek for the information are still low. In fact, someone who has the readiness to find the best knowledge of a context, confidence to ask, honesty and objectively seeks for the information tends to have the nature of critical thinking. Learning activities that are done at school are less able to develop the critical thinking skills of their students. Learning activities that are designed are still lacking in providing critical thinking activities of students, such as activities to analyze, interpret, assessing a case or an issue and rationally and logically, which have been mentioned above (Ulfah, Asim & Parno, 2014).

Learning is a change indeed through activities, practice, and experience. The paradigm of learning should emphasize on learning itself, is student-centered, should be shifted from "teacher" and "what is to be taught" to the direction of "students" and "what to do". Learning must also create meaningful connections with real life (Hilgard & Brower in Hamalik, 2009).

According to Kibirige, Osodo & Tlala (2014), in order to learn, students have to construct knowledge in the learning process. Therefore, the teacher must be able to provide supportive learning environments. Before the learning process begins, students may have different opinion or knowledge about what they are going to learn. During the learning process, students might be not satisfied with they have learned. They may find or seek an explanation that is more acceptable, understandable and meaningful.

Learning can be done by using the previously existing knowledge for new knowledge. The teacher may let the students accommodate, assimilate or replace the previously existing knowledge with the new one. The accommodation, assimilation or replacement, however, often causes misconception among students. Students' prior knowledge should also be considered to make it more of a meaningful learning experience for the students (Kala, Yaman & Ayas, 2012).

Table 1 One-group pretest and posttest design

O	X	O
Pretest: 24 multiple choice questions and 6 essay items were given. (Dependent Variable)	Treatment: given to the students using Predict-Observe-Explain strategy	Posttest: 24 multiple choice questions and 6 essay items were given. (Dependent Variable)

In regard to science learning, teachers can involve students to make hypotheses, investigate, and analyze data to develop students' thinking (Wardani, 2017). One model of learning that is capable of developing students' thinking optimally is Predict, Observe and Explain (POE) learning model. POE learning models can include ways that can be taken by a teacher to assist students in improving the understanding of the concept and their psychomotor. POE learning model engages students in predicting a phenomenon, observations through demonstrations or experiments, and finally explain the results of the demonstration as well as their hypothesis. By doing this way, acquired knowledge will be preserved in students' memory and increase students' science processing skills (Zulaeha, Darmadi & Werdhiana, 2014). To make an active teaching-learning process, students need to be able to clearly express themselves in written form and verbal form; teachers need to introduce a new teaching strategy like the Predict-Observe-Explain (POE) that can be used in association with demonstrations and hands-on activities that can help to enhance classroom practice by identifying the learner's conception (Hilario, J.S., 2015). POE is also suited to be applied in physics subjects that can mostly be observed in experiments, and help to solve misunderstanding (Nana & Sajidan & Akhyar & Rochsantiningsih, 2014). According to the given statements, Predict-Observe-Explain (POE) should be able to be applied as one of the solutions to solve the problem at school regarding the topic of vibration and wave.

The novelty of this research is, this research measures conceptual mastery and critical thinking also analyses students' ability to predict, observe and explain in POE stages. From the problems, it is seen that the teaching-learning process in the school is still not very effective to bring out students' capacity to its full potential, including in topics such as vibration and waves. Therefore, the aim of this study is to investigate the effect of predict-observe-explain (POE) strategy on students' conceptual mastery and critical thinking in learning vibration and wave.

2. METHOD

2.1 Research Method and Research Design

The method that was used in this study is weak experiment method. Fraenkel, Wallen, and Hyun (2011) stated that this design is weak and do not have built-in control for threats to internal validity. In addition to the independent variable, there are a number of other plausible explanations for any outcomes that occur to find the effect of predict-observe-explain (POE) strategy on students' conceptual mastery and critical thinking in learning vibration and wave topic on 8th-grade secondary school.

Table 2 The percentage of students' gender

Population	Gender	Number of Students	Percentage (%)
8th Grade Students	Male	8	44
	Female	10	56
	Total	18	100

Table 3 Stages of the research

Stage	Activity
Preparation	Formulating the problem and research objectives
	Defining the dependent and independent variables of the research
	Determining the sample and the population of the research
	Conducting a literature review about predict-observe-explain (POE) learning strategy, students' conceptual mastery, students' critical thinking, and vibration and wave topic
	Designing research instruments
	Testing research instrument
	Making a revision of research instrument
Implementation	Specifying group for the research
	Conducting pretest to the sample group
	Giving treatment to sample group
	Conducting posttest to sample group
Completion	Calculating the data
	Analyzing the data
	Making result and conclusion
	Reporting of the research paper

Table 4 Interpretation of indicator of conceptual mastery

Pretest	Posttest	Gain	N-gain	Interpretation
29.17	50.00	20.83	0.29	Low

This research used one group pretest and posttest design. Therefore, in this study, the researcher picked one group, conducted pretest, gave treatment, and then conducted posttest. According to Fraenkel, Wallen, and Hyun (2011), in the pretest and posttest experiment, researcher assigns a single group and measure or observe not only after giving a treatment of some sort but also before. This design is detailed in Table 1.

2.2 Population and Sample

The population in this research was International Junior High School in Bandung which implements the Indonesian National Curriculum of 2013. The population in this research was 8th-grade students. The samples were from a class in eighth grade. The samples consist of 18 students with the ages ranging from 13 to 14 years old. 8 students (44%) of the samples were male students while the other 10 students (56%) are female students.

The sampling technique that was used in this research is Purposive Sampling. According to Fraenkel, Wallen, and Hyun (2011), Purposive Sampling is a sampling, in which researchers do not simply study whoever is available but rather uses their judgment to select a sample they believe, based on prior information, will provide the data they need. There are 18 students from one class that are assigned as samples in this research. The percentage of students' gender is detailed in table 2.

The stages in this research are represented in table 3.

2.3 Research Instrument

The instrument is necessary to be used for gaining data. In this research, the instruments that were used include pretest and posttest. The researcher used pretest and posttest instrument to test the students' conceptual mastery and critical thinking in vibration and wave topic for both the control group and experimental group. The pretest was held before the groups are given treatment, and the posttest was given after the treatment was applied.

Initially, in both pretest and posttest, the students were to be given 50 questions multiple choices tests, consisting of 26 questions to measure students' conceptual mastery and 24 questions to measure students' critical thinking. However, after some considerations and thorough the validation process, the questions were reduced into 24 multiple choices question items for conceptual mastery test and 6 essay question items for critical thinking ability test.

The questions for the students' conceptual mastery are based on Bloom's taxonomy (Anderson et al., 2000), while the questions for the students' critical thinking that are covered by six indicators of students' critical thinking by Ennis.

2.4 Research Procedure

The steps of conducting this research consist of three main stages, which are the preparation stage, the implementation stage and completion stage. Preparation stage includes: (1) formulating the problem and research objectives, (2) defining the dependent and independent variables of the research; (3) determining the sample and the population of the research; (4) conducting literature review about predict-observe-explain (POE) learning strategy, students' conceptual mastery, students' critical thinking and vibration and wave topic; (5) designing research instruments; (6) testing research instrument; and (7) making revision of research instrument. Implementation stage includes (1) specifying a group for the research; (2) conducting pretest to the sample group; (3) giving treatment to sample group; (4) conducting posttest to sample group. Completion stage includes (1) calculating the data; (2) analyzing the data; (3) making result and conclusion; and (4) reporting of the research paper.

3. RESULT AND DISCUSSION

3.1 Analysis of Students' Conceptual Mastery

In analyzing students' conceptual mastery, students' scores gained from the tests are calculated and compared using data from both pretest and posttest. The average N-gain scores are calculated and then interpreted using the criteria based on Hake's. The result is shown in Table 4.

Based on the research, out of 100 score rating, students obtained an average score of pretest of 29.17. In the posttest, students obtained an average score of 50. Using the average scores obtained in the pretest and posttest, a gain of 20.83 is obtained. Furthermore, an average N-gain score of 0.29 is obtained. This value is interpreted as low according to Hake. The result is shown in figure 1.

Based on Figure 1, there is an enhancement in the posttest compared to the pretest. The initial score obtained by the students measured by the pretest is shown to be 29.17 out of 100 score rating. The students were already informed about holding the pretest before and were not taught by the teacher about the concept before to test their prior knowledge. After the implementation of POE strategy, the posttest was held to measure students' conceptual mastery about the concept. The result of score 50 out of 100 score rating was obtained from the posttest.

As shown by the data, there is an enhancement in students' conceptual mastery measured in the pretest and the posttest. There is a gain of 20.83 value obtained by comparing students' prior knowledge in the pretest and students' knowledge after being treated by POE strategy by the posttest. It is seen that the value of N gain is shown to be 0.29. According to Hake (1999), this value means there is a low gain in students' conceptual mastery in learning vibration and wave using POE strategy.

By using students' score from pretest and posttest, the researcher analyzed the data using SPSS ver.20 to determine whether the data is normally distributed or not. The result is detailed in Table 5.

In the table, it is shown from the Shapiro-Wilk test that the significance is less than 0.05. Thus, the data is not normally distributed. In comparison, the significance in the pretest has a value of 0.010 while the posttest has a significance value of 0.35. Since there is only one class used for the sample and the data is compared to its pretest and posttest score, Wilcoxon test is used to determine the difference. The result is described in Table 6.

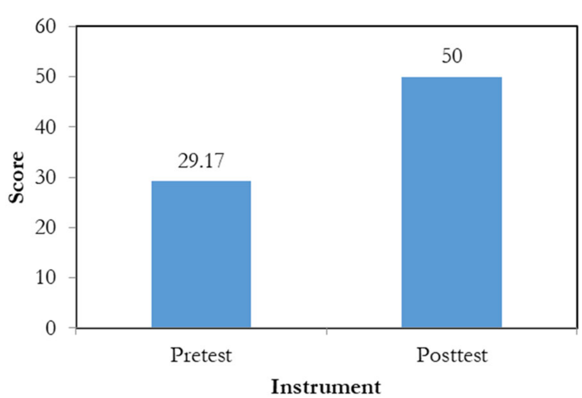

Figure 1 Students' average score on conceptual mastery test

Table 5 Statistical analysis for conceptual mastery test

Instrument	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	.220	18	.021	.855	18	.010
Posttest	.235	18	.010	.888	18	.035

Table 6 Statistical result of wilcoxon non-parametric test

Ty	Posttest - Pretest
Z	-3,742b
Asymp. Sig. (2-tailed)	,000

Table 7 N-gain scores for each aspect of conceptual mastery

Level	Pretest	Posttest	Gain	N-gain	Inter-pretation
C1	30.56	75.93	45.37	0.65	Fair
C2	30.56	47.92	17.36	0.25	Low
C3	27.22	36.11	8.89	0.12	Low

Based on the table, the level of significant value in the test is 0.05. Since the significant value is 0.00, which is less than 0.05, it means there is the difference between students' pretest and students' posttest. The result is supported by Kibirige, Osodo, and Tlala (2014), which found enhancement in students' understanding of the concept. Although, based on the research, different levels of cognitive skills have a different gain. As the cognitive level rise, the more complex the thinking level will be, and less effective Predict-Observe-Explain becomes. Thus, Predict-Observe-Explain shows the linear result, supported by Kala, Yaman, and Ayas (2012).

The enhancement is likely due to students' capability in learning through Predict-Observe-Explain stages. In the predict stage, students were required to gather information with their prior knowledge, assisted with reliable sources. In this stage, students seemed to pass it without much difficulty. In the second stage, which is observed, students had to carefully observe the moving pendulum and slinky which and find any information to be obtained as knowledge. In the third stage, students were required to put the knowledge they obtained into words or any other methods to describe, which also require communication skills and comprehensive understanding.

The enhancement in students' conceptual mastery is also analyzed from the average of for each aspect. In this calculation, each aspect of conceptual mastery (C1, C2, and C3) is calculated using multiple choices test in the pretest and posttest. The data obtained are detailed in Table 7.

Based on Table 7, the C1 level has an N-gain value of 0.65, which is obtained using pretest and posttest. According to Hake, the N-gain value of the C1 level is categorized into fair. However, the C2 level has an N-gain value of 0.25, which is categorized into low. The C3 level has an N-gain value of 0.12, which is categorized into low as well. The data is also shown in figure 2.

From the figure, it is seen that C1 cognitive level has higher N-gain than C2 and C3 cognitive levels. It is then

Table 8 Scoring and interpretation of students' critical thinking ability

Name	Pretest score (average)	Pretest Interpretation	Posttest score (average)	Posttest Interpretation	Gain
Student 1	0.83	Unreflective Thinker	2.33	Beginning Thinker	1.50
Student 2	1.50	Challenged Thinker	2.50	Practicing Thinker	1.00
Student 3	1.33	Challenged Thinker	1.83	Beginning Thinker	0.50
Student 4	0.83	Unreflective Thinker	1.17	Challenged Thinker	0.33
Student 5	1.67	Challenged Thinker	2.50	Practicing Thinker	0.83
Student 6	1.00	Unreflective Thinker	2.33	Beginning Thinker	1.33
Student 7	1.50	Challenged Thinker	2.00	Beginning Thinker	0.50
Student 8	1.50	Challenged Thinker	1.67	Challenged Thinker	0.17
Student 9	1.50	Challenged Thinker	1.83	Beginning Thinker	0.33
Student 10	1.17	Challenged Thinker	1.83	Beginning Thinker	0.67
Student 11	1.33	Challenged Thinker	2.17	Beginning Thinker	0.83
Student 12	0.67	Unreflective Thinker	2.50	Practicing Thinker	1.83
Student 13	1.50	Challenged Thinker	2.50	Practicing Thinker	1.00
Student 14	1.67	Challenged Thinker	2.67	Practicing Thinker	1.00
Student 15	1.67	Challenged Thinker	1.67	Challenged Thinker	0.00
Student 16	1.00	Unreflective Thinker	1.83	Beginning Thinker	0.83
Student 17	1.67	Challenged Thinker	2.33	Beginning Thinker	0.67
Student 18	1.00	Unreflective Thinker	1.67	Challenged Thinker	0.67
Average	**1.30**	**Challenged Thinker**	**2.07**	**Beginning Thinker**	**0.78**

followed by a C2 cognitive level. In comparison, the C3 cognitive level has the least value of N-gain. From the analysis, we see that POE strategy is more effective for the C1 cognitive level (understanding), less effective for the C2 cognitive level (understanding), and least effective for the C3 cognitive level (applying). This happened most likely because C1, C2 and C3 cognitive levels require different thinking levels. According to Clark (2015), the levels can be thought of as degrees of difficulties. That is, the first ones must normally be mastered before the next one can take place. C3 cognitive level requires a higher thinking process than C2 cognitive level, while C2 cognitive level requires a higher thinking process than C1 cognitive level. This result is in accordance with Hilario (2015) that stated that the POE strategy helped students to understand the concept better

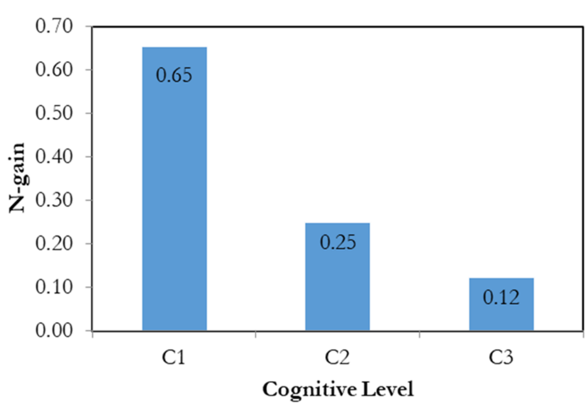

Figure 2 N-gain scores for each aspect of conceptual mastery

3.2 Analysis of Students' Critical Thinking

In analyzing critical thinking ability, the researcher uses rubrics to determine the score, which is then interpreted to determine the development of critical thinking skill. The data obtained is as detailed in Table 8.

Based on Table 8, students obtained a score with an average value of 1.30, which is interpreted as Challenged Thinker according to Paul and Elder. From the posttest, students obtained a score with an average value of 2.07, which is interpreted as Beginning Thinker. These scores are obtained out of 4 score rating using the rubrics. Using the scores, a gain of 0.78, which is an increase of roughly 20% from pretest, is obtained by calculating the score of posttest minus the score of the pretest. The example of students' answers is shown in figure 3, figure 4 and figure 5.

Figure 4 represents the students' answer in the pretest, while figure 5 represents students' answer in the posttest. For the pretest, the representative figure 4.4 obtained score 1, because the answer is correct but the reason is related to the answer according to the rubric for the scoring, which is "The answer is incorrect and the reason is not relevant to the question". Meanwhile, for 4.5 that is presented in the posttest obtained score 4, because the answer is correct that the reason given is acceptable according to the rubric, which is "The question is answered correctly and the reason is significant to the question". Both figures are from the same student. During the pretest, students seemed to have many ideas about the concept of vibration and wave with their prior knowledge. During the posttest, students seemed to have set an idea according to the knowledge they obtained and then applied it to solve the problem.

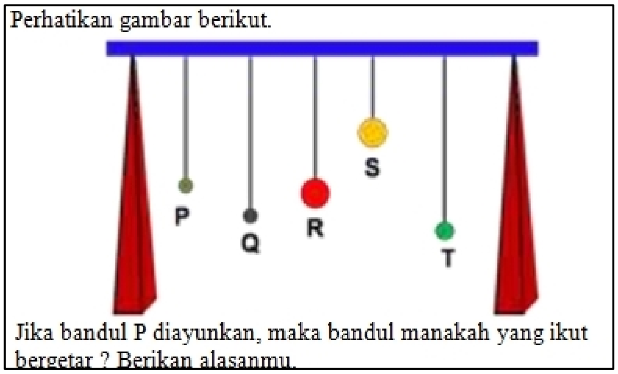

Figure 3 Example of questions used in critical thinking test

Figure 4 Example of students' answer in critical thinking pretest

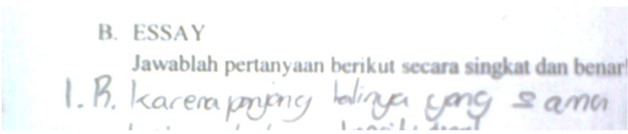

Figure 5 Example of students' answer in critical thinking posttest

The analysis shows that there is a positive result or enhancement of students' critical thinking ability with POE strategy, which is supported by Cholisoh, Fatimah, and Yuniasih (2015) in "Critical Thinking Skills in Integrated Science Learning Viewed from Learning Motivation" that stated that there is a positive effect on the students' critical thinking skills with POE strategy. In table 4.5, there are 17 students that have an increase in thinking level. The increase in critical skills varies from one to two levels. In the pretest, the result shows that students also have a range of critical skill indicated by the scores, with the lowest being 0.67 (Unreflective Thinker) while the highest being 1.67 (Challenged Thinker), which is shown by a number of students. In the posttest, students' critical thinking vary with the lowest being 1.17 (Challenged Thinker) and the highest being 2.67 (Practicing Thinker). We also find that there are two students that did not raise thinking level and stay at Challenged Thinker. In addition, one of the two did not have gain in pretest-posttest comparison.

The enhancement in students' critical thinking is likely to be caused by each stage of POE that corresponds to the aspects of the critical thinking. In Predict stage, students have to make a prediction with their prior knowledge and clarify it with other sources before observing the objects. Once it is set, during observe stage, students have to adjust strategies or tactics to conduct the observation. After the information is obtained, students sum up what they have found during observation and their prior knowledge and make an inference to obtain information. During the process, students are not only required to find the right answer but also to construct the knowledge so that the answer they come with is within the reason they have. Therefore, students should be able to use their further thinking skill to solve the problems during the process.

3.3 Analysis of Students' Capability in Predict-Observe-Explain (POE)

In addition to analyzing the data with the test, the researcher also conducted a test to analyze students' gaining capability in POE using the worksheet. The results are shown in figure 6, figure 7 and figure 8.

In the predicting stage, as represented in figure 6, students seemed to have roughly no difficulty in predicting the definition of waves. As seen in the diagram, there were no students that obtained 0 scores for the concept of waves. Students mostly have a score of 1, which are obtained by 15 students (83%). The rest 3 students (17%) managed to obtain score 2 in predict stage.

The opposite result of predict stage occurred for transversal waves. Most students failed in predicting transversal waves, which is indicated by the fact that 10 students (56%) obtained a score of 0 for predicting transversal waves. 7 students (39%) obtained the score of 1, while 1 student (6%) managed to obtain the score of 2.

As for longitudinal waves, 10 students (56%) failed to predict the concept. 5 students (28%) obtained the score of 1, while 3 students (17%) managed to obtain the score of 2. As seen on the diagram, the result on predict stage shows a roughly similar result for both transversal waves and longitudinal waves. While students seem to have roughly no difficulty on the definition of waves concept, students seem to have difficulty for an advanced concepts like transversal waves and longitudinal waves. The result is in line with Hilario (2015) that found that students can make sensible prediction through POE. This result is also in line with White and Gunstone (2014) that stated that prediction requires extended knowledge of the problem to solve the given problem so that more complex concept like transversal waves and longitudinal waves are more difficult than the definition of waves concept.

In the observed stage, as represented in figure 7, we see that 2 students (11%) failed with the score of 0. Roughly 12 students (67%) obtained the score of 1, while the rest 4 students (22%) managed to obtain the score of 2 for the concept of the definition of waves. As for transversal waves, 12 students (67%) fail with the score of 0, while 6 students (33%) obtained the score of 1, and no students managed to get the score of 2. For longitudinal waves, 11 students (61%) failed with the score of 0, while 3 students (17%) obtained the score of 1, and 22% students managed to get the score of 2.

Based on the diagram, students seem to be able to perform observation about the definition of waves. However, students still have difficulty for transversal waves and longitudinal waves. The result is in line with Hilario (2015) that found that students can make sensible

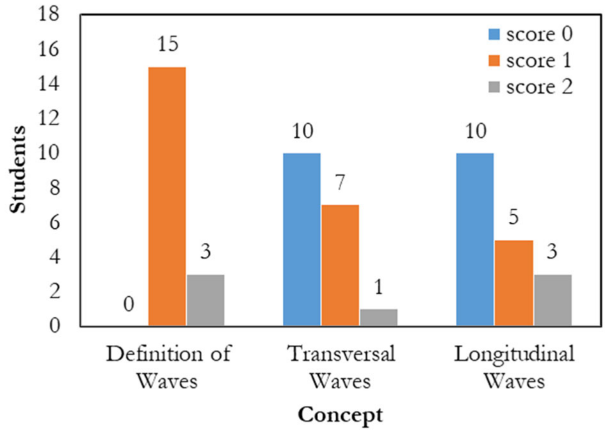

Figure 6 Students' score in predict stage

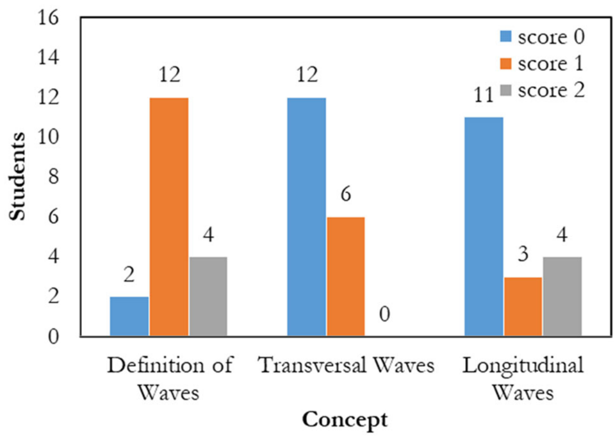

Figure 7 Students' Score in Observe Stage

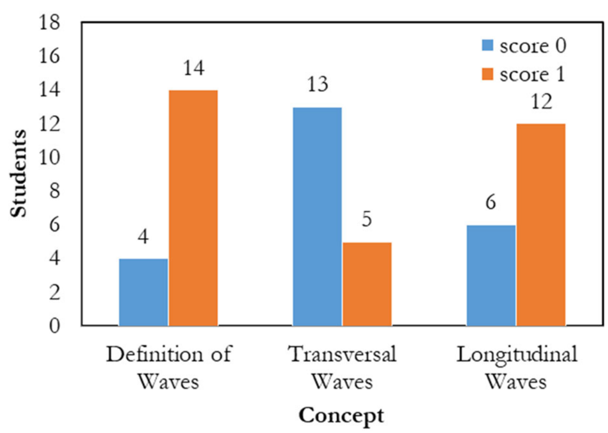

Figure 8 Students' Score in Explain Stage

prediction through POE. This result is also in line with White and Gunstone (2014) that stated that prediction requires extended knowledge of the problem to solve the given problem so that more complex concept like transversal waves and longitudinal waves are more difficult than the definition of waves concept.

In the explain stage, as represented in figure 6, students seemed to be able to perform with not much difficulty. In the concept of the definition of waves, 22% of students failed with the score of 0 while the other 78% of students managed to obtain the score of 1. In the concept of transversal waves, 72% of students failed with the score of 0 while 28% students managed to obtain the score of 1. In the concept of longitudinal waves, 33% of students failed with the score of 0 while the rest 67% students managed to obtain the score of 1.

Based on the diagram, students have quite the grasp of wave and are able to explain it their own way easier than another concept. Students were also able to grasp the concept of longitudinal waves, though not as easy as wave concept. On the other hand, students seem to have difficulty in learning about the transversal wave, unlike waves and longitudinal waves. This result is in line with White and Gunstone (2014) that stated that prediction requires extended knowledge of the problem to solve the given problem so that more complex concept like transversal waves and longitudinal waves are more difficult than the definition of waves concept. The findings show that there is a possibility that students have a misconception in a transversal wave, which is in line with Kala, Yaman, and Ayas (2012), which found that POE can be used for the teacher to find students' misconception in a concept.

4. CONCLUSION

Based on the results on the analysis in the research, it can be concluded that: (1) POE strategy shows enhancement in students' conceptual mastery, indicated by normalized N-gain value 0.29; (2) as for critical thinking skills, POE strategy seems suited to enhance critical thinking ability. Using POE strategy, the result showed that students gain increase in critical thinking from level 1,30 (challenged thinker) to 2,07 (beginning thinker); (3) POE is good to implement the knowledge into students. However, in its implementation, it is not effective as a strategy to implement the whole idea into students as students might face difficulty, especially in some stages. Students can easily predict, observe and explain wave concept, but find it tough for transversal wave concept and longitudinal wave concept; (4) POE is probably not suited for some subjects or topics that require high thinking level. Predict stage should go well when students are learning common knowledge, but might not be the case with rare cases. Observe stage should go well with sensible knowledge, but might not suit abstract knowledge. Explain should go well if students have least required communication ability, else it might cause misunderstanding instead. To put it short, POE also has limitation but can be solved by modifying the stages in POE by adding, removing or replacing one or some stages in POE to suit the subjects/topics. In its implementation, the teacher might want to consider what concept to be taught with POE strategy.

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An Action Research on Enhancing Grade 10 Student Creative Thinking Skills using Argument-driven Inquiry Model in the Topic of Chemical Environment

Pitukpong Kumdang[1]*, Sirinapa Kijkuakul[1], Wipharat C. Chaiyasith[2]

[1]Faculty of Education, Naresuan University, Tha Pho, Mueang Phitsanulok District, Phitsanulok 65000, Thailand
[2]Faculty of Science, Naresuan University, Tha Pho, Mueang Phitsanulok District, Phitsanulok 65000, Thailand

*Corresponding Author. pitukpongk59@email.nu.ac.th

ABSTRACT A goal of the 21st-century education is to enhance students' creative thinking skills as the basis for construction of innovations for developing countries. Generally, previous teaching tradition, teacher-centered approach, are used in many classrooms, however, failed the goal. Therefore, this study aims to promote Grade 10 Thai students' creative thinking by implementing Argument-Driven Inquiry (ADI) through three cycles of action research. There are 31 students participated in the study. The student data are collected using learning journals, artifacts and informal interviews then analyzed with content analysis and method triangulation. The findings indicate that students have a progression in creative thinking. They can develop skills of curiosity, originality, fluency, imagination, elaboration, and flexibility respectively. As a recommendation, it is necessary that teaching for that success needs integrations among chemical environment, geography, and art.

Keywords Creative Thinking Skills, Argument-driven Inquiry, Action Research

1. INTRODUCTION

"Framework for 21st Century Learning" was developed by Partnership for 21st Century Skills (P21) to prepare all students for living in today's and tomorrow's world, for this framework students should have skills of creativity and innovation, critical thinking and problem solving, communication, and collaboration to succeed in work and life in the 21st century world (P21, 2017). Meaningfully, the most important skill is creative thinking that is a basis for construction of innovations for developing countries. Organization for Economic Cooperation and Development (OECD) that implemented the project in the name of "Teaching, assessing and learning creative and critical thinking skills in education", also supported that the creative thinking skills should be aimed at a goal of education for present day and future generations (Stéphan, 2017). Nowadays, creative thinking skills are perceived as a group of six sub-skills including an alternative idea or originality, fluency, flexibility, elaboration, curiosity, and imagination (Greenstein, 2012).

From the pilot study in a special science classroom in Lower North area school of Thailand, most teachers were familiar with the traditional teaching approach, teacher-centered of learning, focused on scientific contents. The school tended to appreciate rote learning for passing examination rather than active learning for using knowledge in real life situations. Evidence was found in grade 10 classroom observations. The teacher appeared to use closed-ended questions which had a single answer or a single method to launch understandings of atomic theory, for example. The students were not promoted to meaningfully deep learning and linking between scientific concepts and things around them (Thompson, 2017). Even though reflection is a critical part of the creative process (Resnick & Mitchel, 2007), the students were not familiar with reflecting themselves after work. As the results, the students had little competency in creative thinking skills. This situation strongly indicated that the traditional teaching approach was blocking the creative thinking skills of students.

One of the effective approaches that possibly promotes creative thinking skills is learning through scientific argumentation approach. Generally, argumentation is known as a social activity of at least two parties, e.g. two

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Table 1 Example of categories and codes.

Categories	Codes	Definitions/levels	Sample
Fluency	Flu1	Level 1: No variety or perspective	S1315: "Energy shortage will happen when the non-renewable energy is low."
	Flu2	Level 2: Some variety but unclearly perspective	S2321: "Renewable energy could be endless.", "Renewable energy is still limited in use."
	Flu3	Level 3: Some variety and clearly describe the perspective	S2317: "The area has a lot of wind or solar would be appropriate, it will help to generate energy"
	Flu4	Level 4: Many varieties and clearly the perspective	S2308: "Chat-trakan district should be suited to renewable energy sources because of the high mountain area, and strong wind."

groups of students, to present the process of constructing a logical explanation that needs theory and empirical evidence to support for making a group decision and accepting or rejecting any claims (Van Eemeren, 1995). In other words, the argumentation seems like convincing other people through credible communication and spoken and written proof (Erduran, 2007; Kuhn & Udell, 2011). Moreover, scientific argumentation represents an attempt to establish the validity of the claims that require reasoning skill (Norris, Philips, & Osborne, 2007) and scientific's conceptions. The scientific argumentation is not shouting to fight each other but it is a dispute involved understanding scientific knowledge, demonstrating personal perspective towards circumstances or claims. The scientific argumentation is also framing students to practice critical thinking and creative thinking skills in order to give appropriate scientific reasons to support the claims (Berland & Reiser, 2011). As mentions above, the process of constructing scientific argumentation possibly promotes the student's creative thinking skills.

Therefore, the researcher aims to implement the effective approach base on scientific argumentation to promote creative thinking skills of grade 10 students in the topic of chemical environment.

2. METHOD

2.1 Participants

Thirty-one students in the 10th-grade classroom, in Phitsanulok province in Thailand, had participated in the study. There were three fifty-minute periods of teaching per week, and they had a lot of learning facilities in the school such as Wi-Fi, laptops, and smartphones. Also, student parents were willing to support all aspects related to student learning, e.g. stationery, technology, and payment.

2.2 Action Research

This study implemented action research as a method to develop own teaching practice within conditions of the 10th-grade classroom. Basically, action research is a spiral process of practices solving a particular problem (Kemmis, McTaggart, & Nixon, 2014). The process consists of 4 steps: 1) plan, 2) action, 3) observation, and 4) reflection (Kemmis, 2009) as Figure 1.

2.3 Argument-Driven Inquiry (ADI) Model

This study used the principles of Argument-Driven Inquiry (ADI) of the previous studies (Sampson & Grooms, 2010; Sampson, Grooms, & Walker, 2011; Sampson & Walker, 2012) that concerned scientific argumentation approach. Generally, ADI is a teaching model emphasizes student-centered learning. It provides students with more opportunities to construct knowledge and scientific explanations through self-inquiry. By teacher facilitation, students learn how to develop an approach for generating data, carrying out an investigation, and simplifying data to answer a problematic issue, as well as reflecting own work and others. In this study, the researcher adaptively implemented the ADI principle as the following steps: 1) to identify tasks base on a problematic issue; 2) to plan and design how to investigate data; 3) to analyze data and develop a tentative argument; 4) to present the tentative argument of each group as a group work; 5) to collaboratively revise that argument and then create final argument; 6) to create group artifacts and individual learning journals; and 7) to revise the final report. This AID model was modified through three cycles of action research, for three weeks.

2.4 Research Instruments and Data Collection

The student data were collected using the artifacts, informal interviews and learning journals. Each week of the ADI implementation, the students were assigned to create an artifact, i.e. a poster, a model and a painting, to solve environmental issues. Before the students would create the artifact, they were challenged to inquire

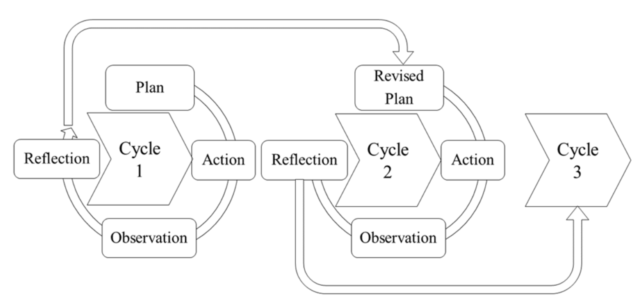

Figure 1 Research process of action research

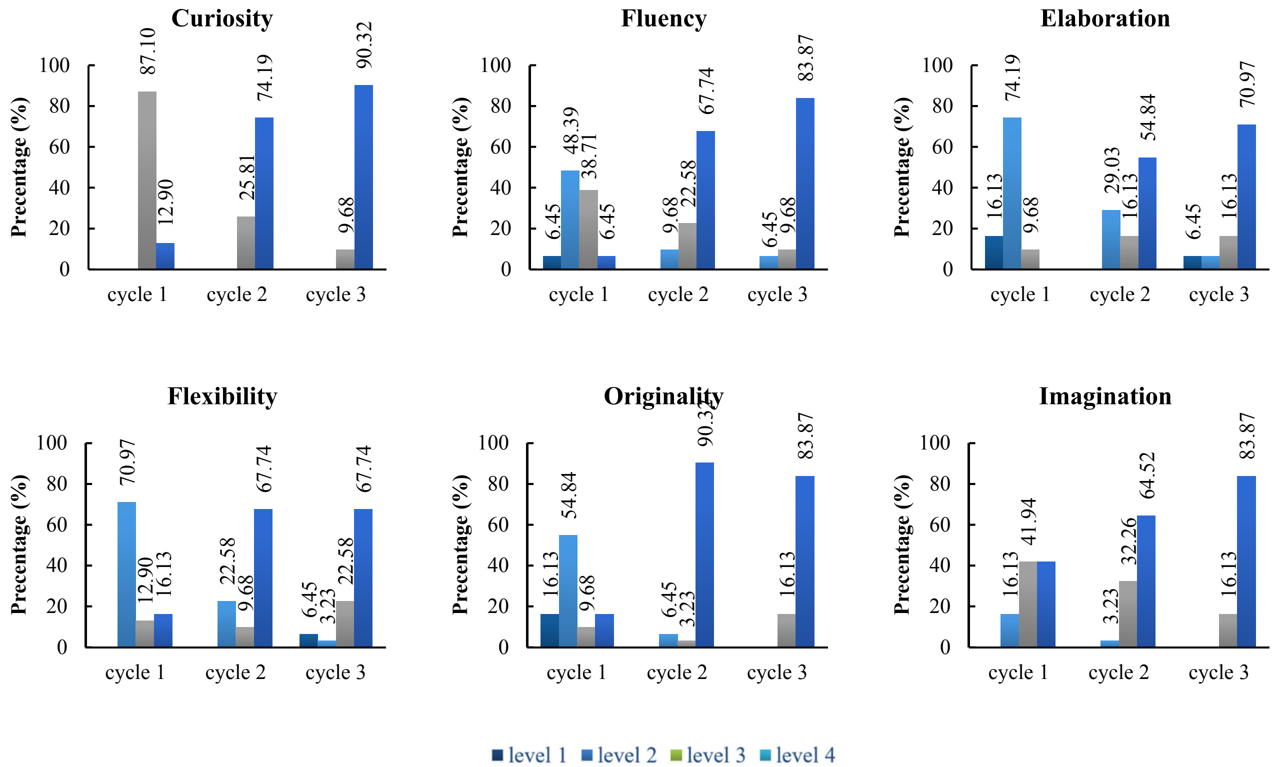

Figure 2. Students' creative thinking skills

knowledge and data in the account to the steps of the ADI model. During class, the researcher, as a participant observer, checked and reflected the students' inquiry through informal interviews. They also were asked to illustrate what they learned in the learning journal.

2.5 Data analysis

This study analyzed the student data using content analysis method. It is the way to search for the truth by making inference about non-definite features of the content through definite features of the fact. The method is used to gain replicable and valid results from the data regarding its content (Krippendorff, 2013). Table 1 shows examples of data categories and codes constructed by the analysis of the learning journals and artifacts. This study also used method triangulation for trustworthiness. Consequently, the student creative thinking skills would be arranged into 4 levels as definitions in Table 1. In addition, the skill was identified as six sub-skills including originality, fluency, flexibility, elaboration, curiosity, and imagination. The results will be shown in the next section.

3. RESULT AND DISCUSSION

The findings of the study revealed that adaptively implementation of ADI model in the chemical environment topic was more effective in improving the students' creative thinking skills. Figure 2 provides information about the percentage of students who developed creative thinking skills in each level of progression from cycle 1 to cycle 3.

As an overview in cycle 1, most students (41.94%) illustrated their progression in the imagination at level 4. In the classroom observation, when the students were asked to create the final argument, they acted like an environmentalist who designed and created a poster to encourage people to use renewable energy. A group of students, for example, showed their imagination through the created poster (figure 3). Their perspective on the situation of increasing temperature in the world is presented by the picture of a fried-earth egg that is being heated. This requests that people need to think about

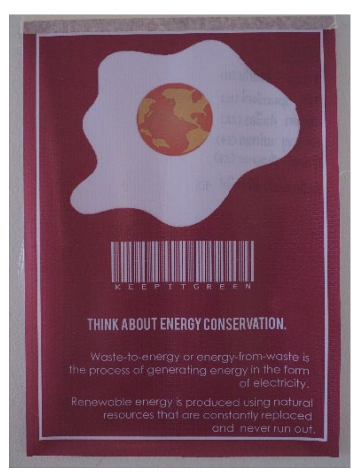

Figure 3 Example of the poster.

energy conservation and suggests that people should turn to use renewable energy. This result is in line with Thompson's study (2017) which indicated that the "real-world" situations which are meaningful problems in ADI model can promote student's imagination.

In addition, some students (more than 12%) were equally found to achieve in three sub-skills, flexibility, originality and curiosity, but only one student (6.45%) had development in the sub-skill of fluency. There had no student achieving in the sub-skill of elaboration. It was possible that this less achievement appeared because the students were familiar with the traditional teaching approach yet. So, when they were challenged with a problematic issue, they were confused and felt that self-inquiry was hard to practice. Examples from the students' questions in informal interviews indicated that some students had no ideas how to inquire knowledge: "what should I do before starting the investigation?" (S01) and "How should I set the objective to explore?" (S02). Moreover, the previous study supported that development of elaboration skill depended on students' achievement in the skill of originality and competency in self-reflection. If students had no high achievement in the originality and could not reflect themselves, they seemed to have less ability in the elaboration (Greenstein, 2012).

Figure 4 An example of the model.

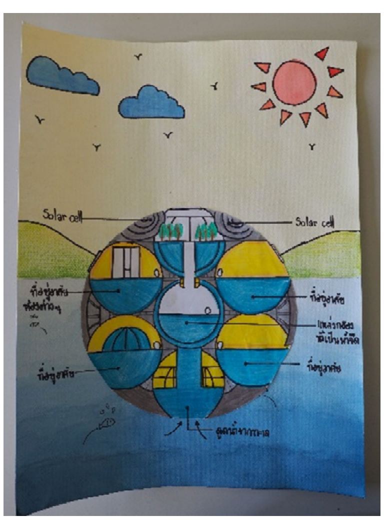

Figure 5 An example of painting.

Cycle 2, all six sub-skills were increased dramatically. Most students had highly achieved in level 4 of the originality (90.32%), curiosity (74.19%), flexibility (67.74%), fluency (67.74%), imagination (64.52%) and elaboration (57.84%). The students' learning journal revealed their progression that they could identify problematic tasks into complexed questions as follows: "What are types of renewable energy?", "Which area in Phitsanulok province could be built as a power factory from renewable energy?", and "Why do I use that area?" (S03). Also, the student's model (figure 4) was another evidence of the increase of originality, imagination, flexibility, and fluency. As the study of Resnick & Mitchel (2007, p.3) showed that "create" is at the root of creative thinking. If we want the student to develop their creative thinking skills, we need to provide them with more opportunities to create. There, they developed the final arguments to create the model that showed the possibility of building the power factory in the area.

Cycle 3, when looking at the graphs as a whole, development of the students' creative thinking skills is continued on the way of implementing the ADI model. This study found that the students had significantly changed in the development of curiosity (90.32%). From the students' learning journals, most students could create complexed questions to guide self-solution of problematic tasks. In classroom observation, the students often appeared to discuss with their group and others. Perhaps these performances led them to have more development of curiosity than what they used to do in cycle 1 and 2.

In addition, more than eighty percentages of students also had development in the sub-skills of fluency, originality, and imagination. As evidence from classroom observation, the students were challenged to create their residences for living in the two-degree warmer world. Such a result, the students illustrated the originality and imagination through the painting (figure 5). They presented a high technology capsule as their residences which can change seawater to be drinking water and produce food by themselves.

After three cycles of action research, this study found that most students had higher development in self-reflection. This meaningful reflection causes them to have rapid progression in the development of the elaboration which is consisted of creative thinking skills. For example, a student (S03) strongly supported that "…our reflections enabled me to improve myself and I would use this strategy for my future work.". This critical reflection shows the design or strategies can help the student improve their creative thinking skill (Resnick & Mitchel, 2007). It is also in line with the study of Awang & Ramly (2008) which stated that: "Creative skills must be practiced until the thought patterns in our minds become comfortable with these creative lateral thinking techniques. We can create these creative grooves in our mind so these techniques will be utilized. This also can help students produce better, more satisfying and more creative." Additionally, if the students are provided the opportunities to continuously create an artifact together through self-reflection, this strategy could help the student to improve their all sub-skills of creative thinking skills.

4. CONCLUSION

Implementation of the modified ADI model in Thailand developed the students' all sub-skills of creative thinking including curiosity, originality, fluency, imagination, flexibility, and elaboration respectively. The curiosity had the most progression in the context of the chemical environment, and this curiosity is the basis of learning other sub-skills. After some consideration on the ADI model, this study suggested that the priority of teaching is challenging students to identify tasks in the account to problematic issues. This would promote the students' curiosity. Also, teachers need to encourage students to reflect themselves in every activity of the ADI model. This would help students to further other sub-skills. In addition, implementation of the ADI model need time so much, so this would be better if teachers could integrate the topic of the chemical environment with other subjects, e.g. geography and art.

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Using Science, Technology, Society, and Environment (STSE) Approach to Improve the Scientific Literacy of Grade 11 Students in Plant Growth and Development

Kultida Chanapimuk[1*], Sureeporn Sawangmek[1], Pranee Nangngam[2]

[1]Faculty of Education, Naresuan University, Tha Pho, Meueang Phitsanulok District, Phitsanulok 65000, Thailand
[2]Faculty of Science, Naresuan University, Tha Pho, Meueang Phitsanulok District, Phitsanulok 65000, Thailand

*Corresponding Author. kultidach59@email.nu.ac.th

ABSTRACT The environmental issues surrounding agrochemical products facing people today include serious health and ecological problems. Scientific literacy is necessary for students to understand scientific knowledge and get ready for the future world. Therefore, this action research aims to promote scientific literacy, in the area of plant growth by using the Science, Technology, Society and Environment (STSE) approach that consists of 4 steps: 1) motivation; 2) exploration; 3) brainstorming; and 4) decision making. The participants are 35 special program students in grade 11. The PISA-like test and worksheets were used to collect data. Content analysis and triangulation were used to indicate the development of scientific literacy. The findings show that the students have better scientific literacy and higher competencies in explaining phenomena scientifically, evaluating and designing scientific inquiry and interpreting data and evidence scientifically. This study suggests that student collaboration is essential to improve the scientific literacy of students.

Keywords Science, Technology, Society and Environment Approach, Scientific Literacy, Plant Growth, and Development

1. INTRODUCTION

In the twenty-first century, science and technology progressed greatly. While uses of scientific knowledge have been of great benefit to humankind, it also led to negative effects on society and the environment. For the example, harmful raw materials, which used in food and drink production process, have caused many people unhealthy. Some of the environmental issues cause of chemical products using. Accordingly, many countries prepare their citizens by including scientific knowledge in the school curriculum and enabling people to adapt to the future world (Organization for Economic Co-operation and Development; OECD, 2016a). Therefore, young people should be able to use science to identify and solve problems in the real world because scientific knowledge is the base of development in the modern nation. Scientific literacy is one of the necessary components of education that drives society (Ogunkola, 2013). Not only teachers teach the student to use scientific knowledge to explain phenomena, but also should guide students to apply related knowledge and draw appropriate conclusions based on scientific evidence. The opportunity to use science in everyday life comes from appreciating scientific processes (Klainin, Datesri, & Pramodnee, 2008). Moreover, the environmental issues in Thailand include the use of chemicals caused by development technology which requires people to understand technology and its possibility to impact on the environment. This is the reason why students should be prepared to develop their scientific literacy.

However, the result from the program for international education systems assessment (PISA) in 2015 indicated that Thai students' scored were 421 points in science literacy which far lower than the average of OECD countries (OECD, 2016b). It shows that Thai students lack scientific literacy competencies. Such competencies include the explanation of phenomena, the evaluation, and design of scientific inquiry and the interpretation of data. They can use their basic scientific knowledge to give some explanation of familiar situations such as they may encounter in the classroom, but they cannot integrate their knowledge to real-world situations (The Institute for the

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Promotion of Teaching Science and Technology, 2017). This result is similar to the observations of the researcher's monitoring in a high school biology class, where the students could not draw a diagram of a plant structure after observing it under a microscope. Students are unable to draw in the proportion of a diagram from what they observed. These observations show that they have low scientific inquiry skill and rarely able to interpret the information from observation. Many students could explain the nature of the plant tissue, but they could not explain with evidence why monocotyledonous plants have differences in structure. This result indicates that students lack the ability to provide evidence to support their explanations. From these observations, it is apparent that the students in this study need to improve their scientific literacy.

Science, technology, society, and environment (STSE) approach focuses on using the result of science and technology that affects society and the environment in the science lesson. It can be used for improving the students' ability to apply their scientific knowledge in order to comprehend the relationship between what they learn in the classroom and what occurs in their daily life and also make meaningful scientific learning (Pedretti et al., 2008; Pedretti & Nazir, 2011). In addition, students have the opportunity to practice asking scientifically valid questions, designing experiments, exploring, analyzing and interpreting data to find solutions to solve the problem. Students also need to recognize the social and physical environment through the socio-scientific context (Pedretti & Nazir, 2011). In another research, STSE process was used to promote students' scientific literacy in ecosystem topics (Gresch, Hasselhorn, & Bogeholz, 2015).

In this study which used the STSE approach modified from Lau (2013) could improve students' ability to develop their scientific literacy. This approach consists of 4 steps; 1) motivation, encourage students to be aware of important environmental issues and contexts. In the context of this study, plant growth was examined in the context of chemical pollutants; 2) exploration, students were encouraged to examine this issue and to find possible solutions; 3) brainstorming, brainstorming was used to collect information and ideas, then interpret the information; 4) decision making, students had to decide the best solution of the class from presentation and discussion.

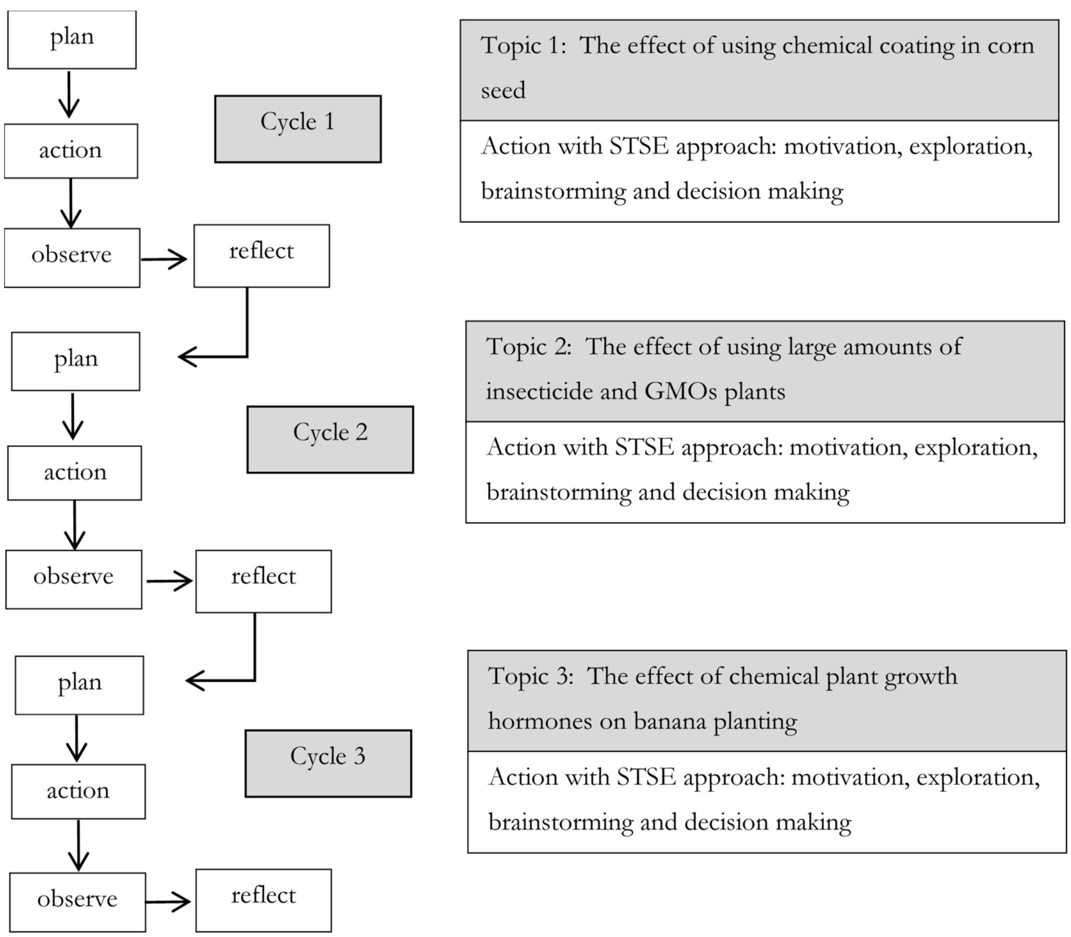


Figure 1 A research methodology

Specifically, the research question in this study was "How the impact of the Science, Technology, Society, and Environment approach affect to improve the scientific literacy of grade 11 students in the topic of plant growth and development"

2. METHOD

2.1 Methodology

This research design is based on the concepts of action research. The developmental model used in this study refers to Kemmis & McTaggart (2014). There are four main phases in a cycle of action research including Plan-Act-Observe-Reflect (PAOR). This study includes three cycles which have different topics that each cycle lasted 4 hours. The research methodology as shown in Figure 1.

2.2 Science, Technology, Society and Environment approach

The Science, Technology, Society, and Environment approach was adopted in this study from Lau (2013). This process consists of four steps: motivation, exploration, brainstorming, decision making. The detail of STSE approach in this study was described as following.

First, the step is motivation, the teacher presented an environmental issue and context to the class. Then, each group of students was asked to determine what scientific questions they would ask in the same environmental issues which different environmental issues in each learning cycle following by 1) The effect of using chemical coating in corn seed; 2) The effect of using large amounts of insecticide and GMOs plants; 3) The effect of chemical plant growth hormones on banana planting. The second step is exploration, the participants work in a collaborative group in order to design a method for exploration, collecting information, searching for evidence and analyzing data to answer the questions that they asked in the previous step. The third step is brainstorming, the members of each group shared possible solutions and choose the best way to solve the problem according to the data collected and interpreted. Then, they prepared to present their solution. The presentation could be a poster presentation, diagram, brochures, PowerPoint, etc. The final step of the approach is decision making. All the groups present a solution and discuss the pros and cons of the solution. After each group has finished their presentation, the students will decide which is the best solution overall.

2.3 Participants

The research explored in this study involved Grade 11 students of Phitsanulok province in northern Thailand. The samples comprised 35 students (31 boys and 4 girls) in a special program in the Sciences and Mathematics.

2.4 Data Collection

The instruments used for data collecting were the PISA-like test and student worksheets. The PISA-like test has 12 items consisting of multiple choices, complex multiple choices and open-ended questions in order to assess scientific literacy before and after the learning activities with STSE. The quality of the test to its validity by using Index of Consistency (IOC) from three experts. The experts consisted of a professor from a faculty of agriculture natural resources and environment, a professor from a faculty of science education and a biology specialist teacher from the school where collected the data. The Index of Consistency of 12 items in the test was between 0.67 - 1. It demonstrated that the test consistent with content. Student worksheets were used to collect information about student scientific literacy during learning activities in each cycle total of three cycles. By dividing students into eight group, each group has to collaborate to complete student worksheet. Then, submit to a researcher at the end of each cycle.

2.5 Data analysis

The data was collected from two instruments: 1) assessing the PISA-like tests by using criteria similar to the PISA 2015 framework (OECD, 2016a); 2) assessing the

Table 1 Scientific competencies description

Scientific competencies	Sub-competencies
Explaining phenomena scientifically (6 points)	- Indicate, use and make some representations for explanation - describe scientific knowledge in terms of its potential implications for society
Evaluating and designing scientific inquiry (15 points)	- Ask scientific questions - Distinguish questions to be explored - Offer a way of exploration - Estimate the way of exploration - Describe and estimate how scientists ensure the credibility of data
Interpreting data and evidence scientifically (15 points)	- Convert data to a different representation (e.g. chart, diagram, etc.) - Analyze, interpret and draw conclusions from the gathered data - Identify the supposition, evidence, and reasoning based on scientific knowledge - Distinguish between scientific evidence, justification, and other considerations - Estimate scientific justification and evidence from different sources

Note. Adapted from "PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematics, Financial Literacy, and Collaborative Problem Solving," by OECD, 2016, p. 24-25.

Table 2 The percentage of scores in each competency and scientific literacy level of students

	Percentage of scores in each competency								Level of scientific literacy
	explaining phenomena scientifically (C1)		evaluating and designing a scientific inquiry (C2)		interpreting data and evidence scientifically (C3)		total scores		
	Score	%	Score	%	Score	%	Score	%	
Pre-test	3.34	55.71	8.63	57.50	9.18	61.22	21.15	57.90	3
Cycle 1	3.75	62.50	8.75	58.33	9.75	65.00	22.25	60.78	3
Cycle 2	5.25	87.50	11.75	78.33	11.50	76.67	28.50	80.06	5
Cycle 3	5.38	89.58	13.25	88.33	13.50	90.00	32.13	87.65	6
Post-test	5.36	89.29	12.05	80.36	12.18	81.22	29.59	84.19	5

student worksheets by given mark scientific competencies and sub-competencies that students demonstrated during the cycles. The scientific competencies are component of scientific literacy to indicate that students are able to handle with science-related issues (see Table 1). The rubric score comprises as follow; 0- exhibit no competencies; 1- exhibit low competencies; 2- exhibit more good competencies; 3- exhibit good competencies with content analysis. Then, the results of both instruments were evaluated with basic statistics include of Percentage and Mean, then categorized them to scientific literacy levels developed from PISA 2015 framework into 7 levels as following; level 6 (87.5-100%); level 5 (75-87.4%); level 4 (62-74.5%); level 3 (50.5-63%); level 2 (37.5-50%); level 1b (25.5-37%); level 1a (12.5-26%), (OECD, 2016). Next, scientific competencies were compared between three phases including before, during and after study with the STSE approach. Finally, the result's trustworthiness was established by using method triangulation that compares the results from the PISA-like test and student worksheets.

3. RESULT AND DISCUSSION

The analysis and discussion of the results will be presented as percentages of the scientific competencies and the level of scientific literacy from the PISA-like test and the student worksheets. The results are clarified in Table 2.

An increasing of students' competencies before and after learning was shown in table 2 which were measured by the PISA-like test. In the pre-test, students indicated their highest level of development in C3, at 61.22%. After the students studied through STSE approach, the percentage of total scores at the post-test was higher than in the pre-test, at 84.19% and 57.90% respectively. The best-developed competency was C1 at 89.29% in post-test. Consistent with the result, teaching with STSE had been able to improve the competencies of scientific literacy after learning.

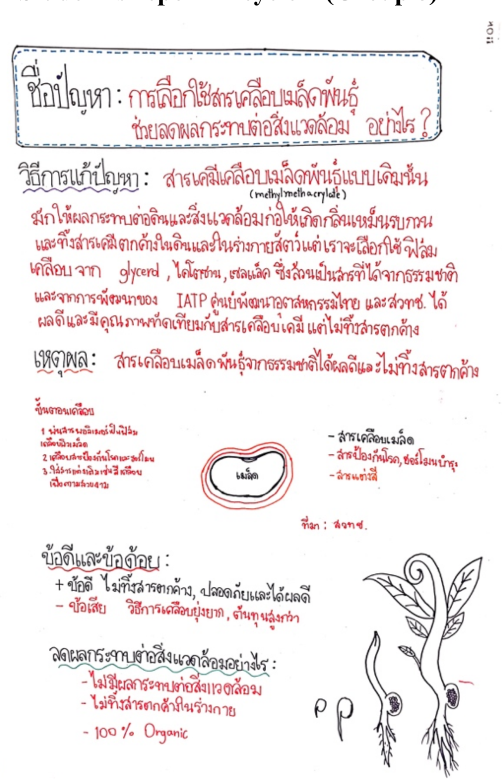
An improvement of students' competencies was demonstrated in Table 2 which were assessed by student worksheets during the learning activity. From this table, the percentage of student competency scores continually raised from cycle 1 to 3, at 60.78% and 87.65% respectively. Especially, C3 was significantly increased to 90% in cycle 3, while C1 slightly increased to 89.58%. It can be seen from Table 2 that the students increased their competencies in scientific literacy when they learned with STSE for three cycles. From these results evaluating by PISA-like test and student worksheets indicated that student improved their scientific competencies of scientific literacy though STSE approach. The results of this competencies as descript below.

In an aspect of C1, the students' competencies were evaluated by students given explanations in class. In cycle 1, the students explained the chemical using in corn seed's solution. Their findings can be presented with a simple solution for explaining how a new chemical that they use was useful. As group 1 commented in their report: *"Using polyethylene glycol 600 is good for the environment because it is low toxic, can protect the seed and low absorb into a human."* (Group 1, Cycle 1). This comment has shown that student created a poor explanation without scientific knowledge. In cycle 2, students' explaining competency significantly improves from cycle 1 as shown in Table 2. The students were able to draw a representation from the presented problem and explaining to the others in class after they had the additional time for brainstorming with members of their group. Their illustrations and findings can be presented with possible benefits of their solution to society as a whole, which their evaluation of the advantages of the GMOs plant issue according to the potential solutions. Group 1 commented in their report: *"The benefits of using physostigmine instead of glyphosate products are that they are water-soluble chemicals that are safe for the environment and plants. The weakness of this solution is that it can lead to acidic soil. This problem can be solved by adding lime (CaO) to the soil."* (Group 1, Cycle 2). In cycle 3, the students had a good progression of explaining competency. As group 7 reported in a worksheet: *"Using Effective Microorganisms makes soil degradation and soil has more oxygens. It activates microbial resistant for soil and plant will be growth by nitrogen fixation.* Providing the chances for students to present their finding and brainstorming with their member group though STSE approach would promote the ability to explain the phenomena. According to Ladachart & Yuenyoung (2016) which stated that building the opportunity for students to discuss their explanations was developed the ability to explain phenomena competently. Furthermore, Hidayanti, Pochintaniawati, & Agustin (2018) also proved that brainstorming can attribute the student to give an accurate explanation and estimation possible way to solve the problem.

In an aspect of C2, it can be seen in the students' work that they could improve their competency during the exploratory process in which they began to organize and evaluate possible ways to solve the presented problem. They would need to consider the problem and appropriate questions that would need to be answered to solve the given problem. From there, they can decide what exploratory steps to take. In cycle 1, most of the students had poorly designed their own literature review before finding the solution. The knowledge that they want to know was slightly comprehensive with the topic. As group 6 commented in a worksheet: *"We start to review about biochemical that safe for environment and human. Then, we will find what chemical is used in the seed coat? and what is the effect when we use in the plant?"* As the comment in the worksheet, it can be seen that the students' competency is developed. Consequently, teacher motivated students by using environment issue about GMOs plant and encourage them to give questions about the issue. In cycle 2, teacher guided by questions for specific designing led to the improvement of students' competency from cycle 1. The following quotation reveals the students designed in their worksheet: *"We think the knowledge that should review to answer our question is what chemical that non-toxic. Organophosphate is safe, so we should search what does it work? and how it uses in the plant?"* In cycle 3, the students had good development of evaluating and designing competency. They could search and review appropriate literature on the subject. For example, they could collect data by reviewing the literature about plant growth and some experiments from existing research papers. In the comment written of group 8' s worksheet: *"The knowledge that is necessary to exploration included 1) ethylene was planted hormone that associated with fruit senescence, 2) fruit ripening was the process of changing methionine to ethylene that could lead to a sweet flavor in ripe fruit, 3) acetaldehyde could inhibit the synthesis of ethylene by bonding with the protein function group that could delay the fruit ripening..."* (Group 8, Cycle 3). Training the students through the exploration step leads the students encouraging scientific literacy. In line with Ladachart & Yuenyoung (2016) which stated that students who are trained in the scientific procedure (i.e. Identify question, scientific inquiry, appraise ways of investigation) tended to draw on their own understanding and exploratory methods. Moreover, Eliyawati, Sunarya, & Mudzakir (2017) said that the issues or situation in society that occur around the students can give a response them, attempt to find solutions and pay attention to explanation carefully.

In an aspect of C3, the students had the opportunity to transform large amounts of complicated information into a form that is easier to understand and present it in class.

Student's report in cycle 1 (Group 8)



Student's report in cycle 3 (Group 8)

Figure 2 an example of scoring for competencies in scientific literacy of students in cycle 1 and 3

They presented their findings based on the scientific evidence, discussed other findings and considered choosing the best alternative solution of the class. Students' work is presented in Figure 2. Practicing the students to transform and discuss based on the scientific evidence leads the students developing the competency of interpreting data and evidence scientifically. According to Ladachart & Yuenyoung (2016) who state that: the teacher should train students to modify the data by turning it into a graph or other form of representation. Moreover, Gresch, Hasselhorn, & Bogeholz (2015) indicated that the decision-making process could be enhanced or justified because students had the chance to identify the scientific evidence and use it to distinguish the claims of others in the class and consider choosing the best solution through the process of argumentation.

Figure 2 shows cycle 1 and 3 from Group 8's worksheets. The initial and final representations of Group 8 included information on the explored problem. The students examine the positive and negative implications in the situation for the environment and society. Additionally, Students could associate the following solutions to solve the problem and how this solution may help the environment and society. Moreover, they can create a simple model to explain their solution based on group findings through the process of STSE. In cycle 1, students created a simple representation by using investigated documents to be a short word. They did not represent the data as a diagram, etc. Rather, the competency of the interpretation of data and evidence significantly improved from cycle 1. For the evidence as shown in Figure 2, the students generated an appropriate representation that was shown by their own understanding and linked scientific knowledge to explain how the solution worked as diagram about changing of substances in banana when it ripens.

For overall results, students' scientific literacy improved during the learning cycle because they had opportunities to draw their scientific exploration, analyze investigated data and construct their scientific explanation through three cycles of STSE approach. The researcher would conclude that learning though STSE could promote scientific literacy of students, according to the increase of scientific literacy during STSE activity in three cycles and the enhancing after learning score in post-test.

Similar to the level of scientific literacy developing in each cycle, the level of scientific literacy increased progressively from level 3 in cycle 1 to level 6 in cycle 3. In the same way, the scientific literacy level of students in post-test (level 5) was higher than in pre-test (level 3). However, the percentage of total scores in cycle 3 was higher than post-test, at 87.65% and 84.19% respectively. This is because the students collaborated with others in their group through the process of exploration and brainstorming. Thus, the process of group work included chances to assist students in exchanging complicated information from different sources, which promoted group work where friends verified the information. The researcher suggests that group collaboration will promote the students' scientific literacy. It is in line with a previous study of Rosario (2009) which stated that: *"…focus-group discussion will lead students to prefer the freedom given to them to choose their activities rather than simply accept prepared activities provided by the teacher…"*.

Based on a result of scientific literacy developing during the study from students' worksheets and a result of the pre-test and post-test from the PISA-like test, it shows that the scientific literacy level of both was increased. This indicates that student scientific literacy progressed because of the process of STSE though environmental topics related to society for relevant science learning. It is in line with Yoruk (2010) who stated that: "The STSE teaching approach promotes students in recognizing their own skill and enables them to learn more meaningfully than by traditional teaching".

4. CONCLUSION

Based on the results and discussion the STSE approach is supportive of the conclusion that STSE is able to improve the scientific literacy of students which applied their knowledge in the topic of plant growth and development. They understand the effect of the issues and why they might solve these issues and find solutions through the process of STSE. Most of the students could design an experiment and find a solution to environmental issues. They are also able to consider the effect of the solution on the environment and society as a whole. These results also suggest that student collaboration is essential to fully develop student scientific literacy.

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Interactive E-Module Development through Chemistry Magazine on Kvisoft Flipbook Maker Application for Chemistry Learning in Second Semester at Second Grade Senior High School

Roza Linda[1]*, Herdini[1], Ika Sulistya S[1], Teja Pratama Putra[1]

[1]Program Studi Pendidikan Kimia, Jurusan Pendidikan Matematika dan IPA, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Riau, Pekanbaru, Indonesia

*Corresponding Author. roza.linda@lecturer.unri.ac.id

ABSTRACT This research is an innovative development on teaching materials in order to intensify the movement of "Satu Guru Satu Buku (SAGUSABU)" and to prepare skillful media users on mastering Information and Communication Technologies (ICT). The resulting prototype is an interactive e-module named Chemistry Magazine which have two editions: ionic equilibrium and pH of buffer solution and solubility equilibrium. Applying research and development study design with Plomp model, assessment and suggestion by validator team on material substance aspect, instructional design, display (visual communication) and software utilization using validation sheet are in valid category. Percentage of legality score by media validator is 91.70% for ionic equilibrium and pH of buffer solution edition; and 94.18% for solubility equilibrium edition, whereas by material validator is 93.75% and 94.45% on each. Users response score rate through questionnaire for teachers and students on ionic equilibrium edition and pH of buffer solution edition are 87.08% and 88.45%; meanwhile 94,25% and 91,43% are obtained from solubility equilibrium edition.

Keywords Interactive e-Module, Chemistry Magazine, Kvisoft Flipbook Maker, Buffer, Solubility, Plomp Model

1. INTRODUCTION

Having a good teaching material is an essential point on acquiring chemistry, it can facilitate both teachers and students while in the learning process (Direktorat Pembinaan SMA, 2008). Teaching materials are the resources a teacher uses to deliver instruction. Each teacher requires a range of tools to draw upon in order to assist and support student learning. These materials play a large role in making knowledge accessible to a learner and can encourage a student to engage with knowledge in different ways. Since 2016, Ministry of Education and Culture has been promoted the motion called "Satu Guru Satu Buku (SAGUSABU) in order to improve teachers capability in producing paperwork. One of the examples is a module. Andi Zulkarnain, et al (2015) stated that a module is a learning tool that contains the materials, methods, limitations, and steps used systematically and appealing to achieve the expected competence according to the complexity level (Direktorat Pembinaan SMA, 2008).

Printed modules teaching material can be modified into a filled glossary magazines form, as has been done by Wulandari, Azrita, & Hendri (2016). This breakthrough appear due to learners are accustomed to technological advances and it can be observed that learners have a better understanding on android system technology rather than the teacher itself (Syahrowardi & Permana, 2016). This is in line with the aim of our national education which stated that chemistry learning is expected to deliver participants who are capable of using Information and Communication Technologies (ICT).

Chemistry Magazine is a teaching material in the form of interactive e-module. It can be accessed easily by students using computers and various types of gadgets anywhere and anytime. This module can be created using flipbook applications namely Kvisoft Flipbook Maker (Syamsurizal & Chairani, 2015). This kind of practicality can enrich digital products such as texts, images, audio, videos, animations, flash and links (www.kvisoft.com, 2015).

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Two of the hardest discussion, based on student's difficulty; one is about ionic equilibrium and pH of buffer solution, and the other is solubility equilibrium; are considered as the proper material for e-module content. Those subjects require a thorough understanding of theory and analysis to solve the problems, as well as proficient in calculations because the basic concepts related to solubility are described in terms of mathematical equations.

Based on the explanation above, the research was conducted on the development of interactive e-module Chemistry Magazine by utilizing Kvisoft Flipbook Maker Application for chemistry learning on a second-grade senior high school in the course of the second semester.

2. METHOD

The research is held in Chemistry Education Study Program, Faculty of Teachers Training and Education, Riau University with trials in SMA Negeri 8 Pekanbaru, SMA Negeri 12 Pekanbaru and SMA Negeri 2 Bangkinang Kota. Interactive e-module Chemistry Magazine by utilizing Kvisoft Flipbook Maker application for chemistry learning on a second-grade senior high school in the course of the second semester is adopted from Plomp development model. Consisting of initial investigation phase, design phase, realization/construction phase, validation, trials, and revision phase, and implementation phase (Rochmad, 2012). The implementation phase is not done because the purpose of the research is limited to obtain output in the form of valid product based on material substance aspect, instructional design, display (visual communication) and software utilization.

Data gathering related to user's validity and responses to interactive e-module Chemistry Magazine was obtained in validation phase, experiment and improvement using research instrument in the form of validation sheet prepared by one media validator and two material validators along with rubrics and user response questionnaires by teachers and students.

The data collected is then analyzed by specific analytical techniques. Analysis of validity using the formulation by Rohmad, Suhandini, & Sriyanto (2013). The data collected is then analyzed by specific analytical techniques. Analysis of validity using the formulation by Rohmad, Suhandini, & Sriyanto (2013).

$$P = (n/N) \times 100\%$$

Explanation:

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

The percentages obtained are then converted to qualitative values with the validity criteria in Table 1. The user response analysis is measured by the Likert four-choice scale with scoring guidelines in Table 2. The formula used in calculating the percentage of user response scores using the formulation by Yamasari (2010):

$$R = (f/n) \times 100\%$$

Explanation:

R = Percentage of respondents score (%)
f = Number of scores obtained
n = Maximum score

The percentages obtained are then converted to qualitative values with the validity criteria in Table 3.

Table 1 Validity criteria

Percentage score (%)	Validity criteria
75.00-100	Valid
50.00-74.99	Valid Enough
25.00-49.99	Less Valid
0.00-24.99	Not Valid

Table 2 User response scoring guidelines

Statement of attitudes	Score
Agree (S)	4
Quite Agree (CS)	3
Less Agree (KS)	2
Disagree (TS)	1

Table 3 Criteria for user response

Percentage (%)	Criteria for user response
75.00-100	Very Good
50.00-74.99	Good
25.00-49.99	Less Good
0.00-24.99	Not Good

3. RESULT AND DISCUSSION

This research development produces interactive e-module Chemistry Magazine products for ionic equilibrium and pH of buffer solution and solubility equilibrium materials. This product can be accessed via electronic media such as a computer, laptop, Android, iPhone, iPad, and other technology both online and offline. Teachers and students can use the interactive e-module Chemistry Magazine during the learning process in the classroom and as self-teaching materials even not in lesson time. Here is the exposure of results and discussion of each development phase that has been done. Research stages using the Plomp model include the initial investigative phase, design phase, realization/construction phase, validation, trial, and revision phase, and the implementation phase. The explanation of the results of each stage of development, as follows:

3.1 The Initial Investigation Phase

Front End Analysis, Information and data obtained from the analysis of the front end is a little source of learning that also can generate interest and motivation of the learners, and it can help the learners to connect with the material that has been learned in daily life. The teaching materials commonly used in the learning process is printed text materials in the form of textbooks, student worksheet, and copied task and digital resources in the form of powerpoint text (PPT). Analysis of the front end to some relevant literature, obtained the information that the chemistry subject is expected can bring the students to fill the 21st century ability, one of that is, skilled in using media, technology, information and communications (ICT) (Kementerian Pendidikan dan Kebudayaan, 2016) and in the framework of teacher competence development in producing a paper which is intensified through movement of "Satu Guru Satu Buku (SAGUSABU)" by Directorate of Teacher and Education Personnel of Ministry of Education and Culture since 2016.

Student's Analysis, Characteristics of learners adjust with the design of the development product that has made. The results of the analysis of students showed that students at the second class of senior high school are in the range age of 16-17 years. Based on Piaget's cognitive development theory, on this age, the learners approach the maximum intellectual efficiency, but due to lack of experience thereby limiting their knowledge and skills to exploit what is known. Many things that can be learned through experience, but learners sometimes have difficulty in understanding of the abstract concepts (Piaget, 2001).

The result of the questionnaire is 100%, the learner stated that the existence of the learning resource is considered important. As many as 85.54% of students find difficulties in learning chemistry subject, in this case, it's because less of the learning resources that can help the learners to an understanding about the subject, therefore the existence of learning resources in this interactive e-module Chemistry Magazine is expected can help the learners in the learning process. It is also supported by the facilities for interactive e-module Chemistry Magazine that is 81.92% of students have PC or gadget to operate of interactive e-module Chemistry Magazine.

Material's Analysis, The results of interviews with chemistry teachers found that the material of ionic equilibrium and pH of buffer solution there are three main points; the nature of the buffer solution, the pH of the buffer solution and the function of the buffer solution in the body of living beings and in daily life. Sub-material properties of buffer solutions are sub-material theories that require an understanding of the concepts that the learners must really understand because these sub-materials are the first sub-matter of the ion equilibrium material and the pH of the solution, as well as for the functions of sub-material buffer solution in the body of living beings and in daily life. The calculation of pH sub-material of the buffer solution is a calculation material involving some of the precursor material such as stoichiometry and acid-base. While in the material of solubility equilibrium, learners learn about the definition of solubility, the yield of the solubility product (Ksp), forecasting the formation of precipitate from mixing the ions with opposite charge, the influence of the same ion on the solubility of ionic solids in water, the factors that

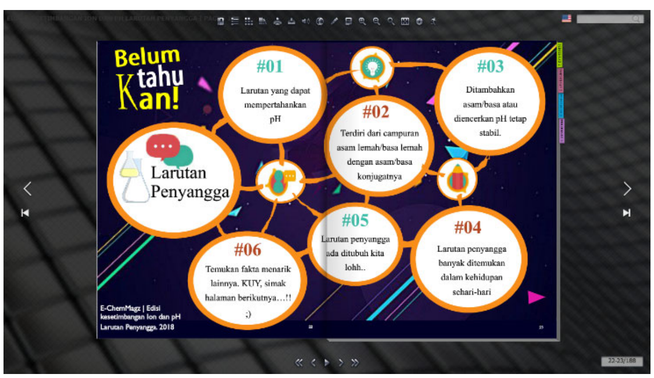

Figure 1 Examples of products in ionic equilibrium and pH of buffer solutions editions on material design part

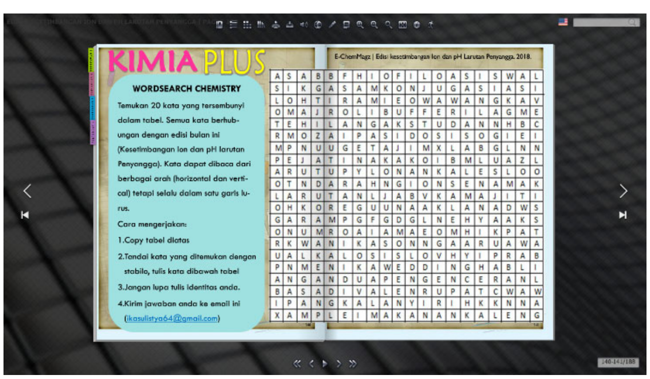

Figure 2 Examples of products in ionic equilibrium and pH of buffer solutions editions on magazine part

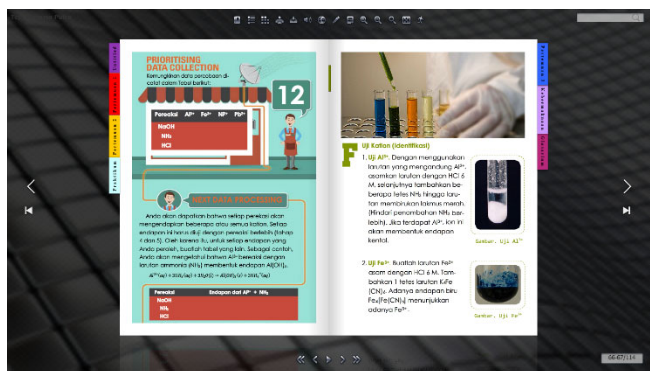

Figure 3 Examples of products in solubility equilibrium editions on material design part

Figure 4 Examples of products in solubility equilibrium editions on magazine part

affect the solubility, and selective precipitation (Watoni, 2014).

Competency Analysis, The ionic equilibrium, and pH of the buffer solution is one of the chemical learning materials found in the basic competence of 3.12 and 4.12 in the syllabus of chemical subjects of senior high school (Kementerian Pendidikan dan Kebudayaan, 2016). While the solubility equilibrium material is found in the basic competencies of 3.14 and 4.14. The results of the syllabus analysis will be obtained indicators of learning achievement and learning objectives to be achieved by learners.

3.2 Design Phase

The design phase is designed to design the initial product that will be developed in outline. The results of the design stage are; (1) the blueprint of interactive e-module Chemistry Magazine, (2) grid sheet validation of material experts and media experts and (3) design of user response questionnaires by teachers and students. The blueprint of interactive e-module Chemistry Magazine load e-module content according to Direktorat Tenaga Kependidikan (2018), that is; 1) Cover page, 2) Preface, 3) Table of contents, 4) Position map, 5) Description of content, 6) Benefits, 7) Instructions for use, 8) Concept maps, 9) Learning; which includes a) learning objectives, b) material description; composed of apperception, learning material, sample questions, formative tests; in the form of crossword and multiple choice puzzles, summaries, assignments, follow-up, magazine content; in the form of scientific articles, tips, galleries, and profile figures, 10) Evaluation, 11) Answer keys, 12) Glossary and 13) Bibliography.

3.3 Realization or Construction Phase

The results obtained in this phase are; (1) the prototype as the realization of the design result of interactive e-module Chemistry Magazine which is in accordance with the results of the analysis that has been carried out, the characteristics and structure of an interactive e-module, magazine content, and components of ICT-based teaching materials assessment, (2) the validation sheet of material experts and media experts refers to the guidance of developing ICT-based teaching materials by the Direktorat Pembinaan SMA (2010) and (3) user response questionnaires constructed in such a way as to the needs of the study.

3.4 Validation, Trial and Revision Phase

Validation aims to derive valuations and suggestions from a validator team consisting of a media validator and two material validators. Validation is done until the product developed in category valid. Some examples of products in ionic equilibrium and pH of buffer solutions editions can be seen in Figure 1 and Figure 2. As for the solubility, equilibrium can be seen in Figure 3 and Figure 4.

For the validation of the ionic equilibrium and the pH of the buffer, solution edition can be seen in Figure 5 and Figure 6. As for the result of validation of the equilibrium solubility edition can be seen in Figure 7 and Figure 8.

Overall, the validation results show very good criteria, which means that the e-module Chemistry Magazine that has been developed has met the requirements set by the Direktorat Pembinaan SMA (2010) in the guide to the development of ICT-Based teaching materials that covering substance aspect, instructional design, display (communication visual) and software utilization.

The trial aims to derive user-side assessments and suggestions of teachers and students of interactive e-module Chemistry Magazine. Scores of respondents of ionic equilibrium and pH of buffer solution edition were obtained from teachers questionnaire sheet of 87.08% and 88.45% of students questionnaires. As for the solubility equilibrium edition, a percentage of 94.25% was obtained from the teachers and 91.43% from students. Based on Table 4, the 75% -100% range is in the very good category, it can be concluded that the developed interactive e-

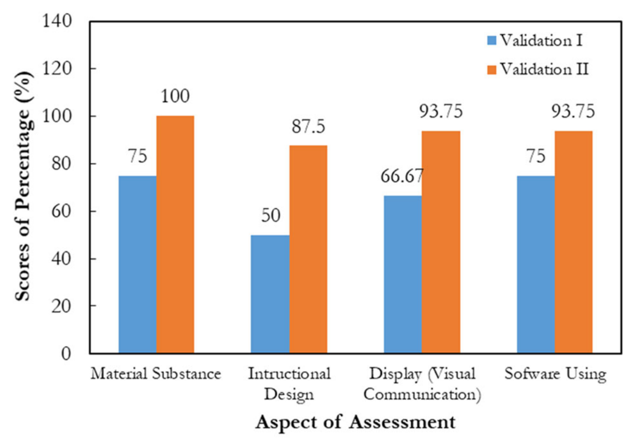

Figure 5 Comparison diagrams validation I and II by media experts the ionic equilibrium and the ph of the buffer solution edition

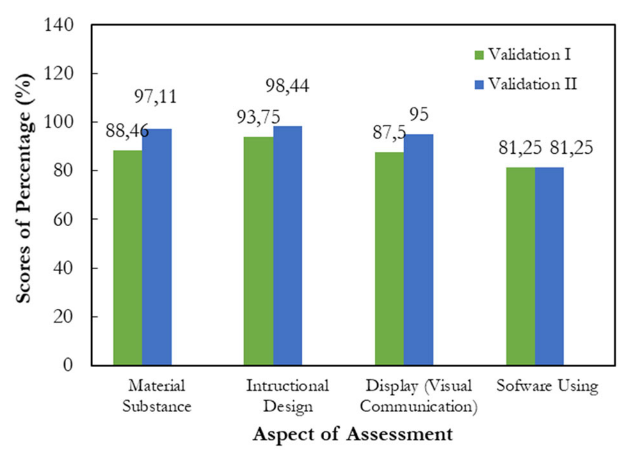

Figure 6 Comparison diagrams validation I and II by materials experts in the ionic equilibrium and the ph of the buffer solution edition

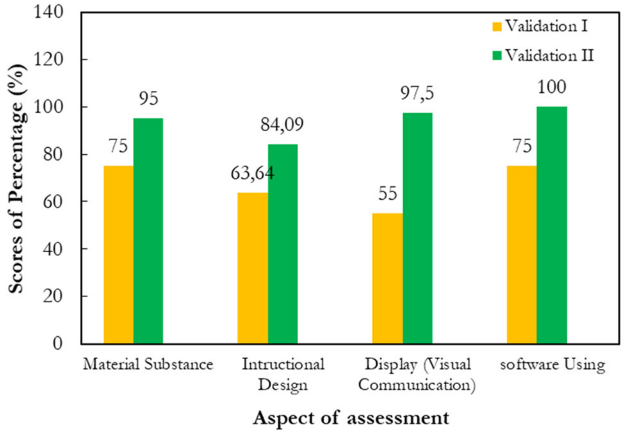

Figure 7 Comparison diagrams validation I and II by media experts in the equilibrium solubility

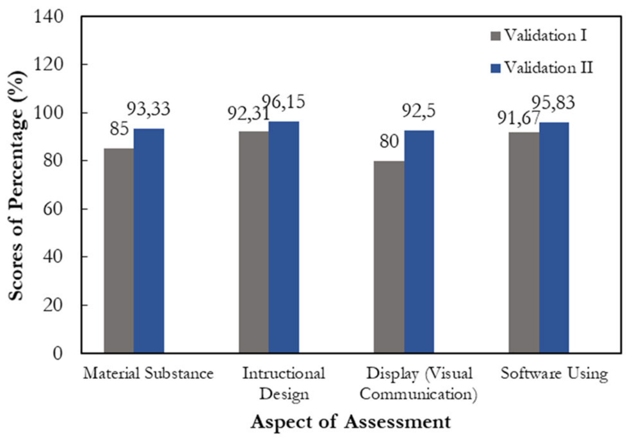

Figure 8 Comparison diagrams validation I and II by materials experts in the equilibrium solubility

module Chemistry Magazine is considered positive by the respondents and can be used in the learning process.

4. CONCLUSION

This research was conducted until the phase of validation, trial, and revision, which produced a learning product in the form of ICT-based teaching materials. The phases of the research that have been carried out involve investigating the target users of the product, designing, constructing and evaluating by experts to regarding the wetness of the material and the use of the media in the learning process.

The results of the research on the development of interactive e-module Chemistry Magazine of ionic equilibrium and pH of buffer solution edition and solubility equilibrium edition are valid by material validator with *a* score of 93.75% and 94.45%. While the media validator obtained a score of 91.70% and 94.18%. The interactive e-module Chemistry Magazine is also rated very well by students and teachers with a percentage of 88.45% and 87.70% in ionic equilibrium and pH of buffer solution edition. While on *an* edition of solubility equilibrium obtained by percentage of 91,43% by teachers and 94,25% by students.

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The Effect of STEAM-based Learning on Students' Concept Mastery and Creativity in Learning Light and Optics

Gita Ayu Wandari[1], Agus Fany Chandra Wijaya[2], Rika Rafikah Agustin[1]*

[1]International Program on Science Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Indonesia

[2]Departement of Physics Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Indonesia

*Corresponding Author. rikarafikah@upi.edu

ABSTRACT The integrated knowledge should be implemented to face the 21st-century era. Beside the integrated knowledge, mastery the concept and creativity also must be involved in order to enhance the quality of education. Thus, this research was aimed to investigate the effect of STEAM-Based Learning on Students' Concept Mastery and Creativity in learning Light and Optics. The method that used was a mixed method with convergent parallel design. The population in this research was 8th-grade students in private junior high school in West Bandung and the sample was one class of 8th grade. The school implemented Indonesian Curriculum 2013 in the teaching-learning process. The sampling techniques were convenience sampling. The number of participants in this research was 27 students. The quantitative data in this research was obtained through an objective test. The objective test was made based on Bloom's Taxonomy revision by Anderson. The qualitative data was obtained through the creativity rubric adopted from Creative Product Semantic Scale (CPSS) developed by O'Quinn and Bessemer. The dimension that was in creativity is novelty, resolution, and elaboration and synthesis. According to the research, students' concept mastery improved as much as 0.78 with category high improvement after the implementation of STEAM-Based Learning. For students' creativity achievement, in every dimension gained different result: 1) Novelty is categorized into good with 75.6%, 2) Resolution is categorized into good with 77.8%, and 3) Elaboration and synthesis are categorized into enough with 65.3 %. Overall, students' concept mastery and creativity in the implementation of STEAM-Based Learning in learning light and optic is categorized as good.

Keywords STEAM-Based Learning, Students' Concept Mastery, Students' Creativity, Light and Optics

1. INTRODUCTION

The new paradigm of the 21st Century science education explores a wide range of possibilities that can foster students' interest in science and creative convergent thinking. In Indonesia, education is supported by the National Curriculum of 2013. The purpose of using National Curriculum 2013 is to prepare Indonesian to be a creative, productive, innovative, affective, and also give a contribution to the environment, country, and the world. STEAM (science, technology, engineering, art, and mathematics) education has been implemented to enhance scientific literacy to use the integrated knowledge in the newly revised Korean science education curriculum (Kong & Huo, 2014). Recently STEAM education has emerged to develop human resource with creativity in mind and see and understand human society in the future. STEAM education is defined as education in which the students' understanding and interest in related subjects such as science, technology, engineering, etc., foster of conversions of thinking and problem solving based on science and technology (Baek & Yoon, 2016). Hence, the purpose of National Curriculum 2103 of Indonesia and STEAM has the similarity which is to make the student be creative and implement the knowledge in daily life.

Learning activities cannot be separated from the mastery concept. Ability in mastering the material can be seen from the mastery concept. Mastery concept is the students' ability to understand the meaning of learning and apply it in their daily life (Shidiq, Rochintaniawati, & Sanjaya, 2017). Mastery concept is very important, Anderson and Krathwohl (2001) state that mastery concept can improve their intellectual skills and help them solve the problem they face and lead them to meaningful learning.

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Concept Mastery should be completed by creativity and other skills to enhance the quality of students. Deep understanding of a concept is highly needed to maximize the students' creativity. Creativity has long been recognized as a powerful force in shaping human society progress and knowledge (Henriksen, Mishra, & Fisser, 2016). Creativity and innovation concern to the process of creating and applying new knowledge (Gurteen, 1998).

Concept mastery not only should be completed with the creativity but also should be related or implemented in daily life. Light and optics is something that used in daily life. It is an essential concept that student is difficult to understand. Light and optics concept is a complex area for students and if it is not connected even implemented to daily life the student may not grasp the concept easily. The concept of light and optics is a relay on daily life such as camera, microscope, telescope, etc. The concept of the optic can be developed to make a valuable product in the future. This concept consists of science and mathematical explanation. Besides, it also could be integrated with technology, engineering, and art to produce a better product. Light and optics topic also in line with STEAM and National Curriculum 2013 of Indonesia because the topic makes the student be a creative one to make something useful in daily life.

Thus, the present study proposed the research to see the effect of STEAM-Based Learning on Students' Concept Mastery and Students' Creativity in Learning Light and Optics. This research will analyze two variables they are students' concept mastery and students' creativity towards STEAM-Based Learning.

2. METHOD

The research method used in this research is the Mixed Method. According to Creswell (2012) stated that mixed method is a type of research design which collects, analyzes, and mixes both quantitative and qualitative methods in a single study or series of studies to understand research problem. The quantitative data focuses on students' concept mastery that is measured by an objective test in form multiple choices test while the qualitative analysis focuses on students' creativity that is measured by the rubric of CPSS developed by O'Quin and Bessemer (2006). There are several sub aspects in CPSS rubric. After the students finish their project, the researcher gives a score to the project done by the student and find the average of the score. All data are analyzed separately based on the indicator and compared to obtain better understanding and interpretation regarding the effect of STEAM-Based Learning on students' concept mastery and creativity in learning light and optics. Then, the researcher finds the gain to see the improvement of a student using STEAM Based Learning. Besides, the researcher relates the result of the concept mastery and creativity and find the relation of both variables.

The location of this research was in Private Junior High School in Bandung. The school was using Indonesian Curriculum 2013 in the teaching-learning process. *Bahasa Indonesia* was the daily language used. The population in this research are 8th students in Private Junior High School. The researcher took one class in eight grades as the sample consist of 27 students.

The sampling technique was convenience sampling technique. Fraenkel, Wallen, and Hyun (2013) stated that convenience technique is used because there is a group of individuals who (conveniently) are available for study (Fraenkel, Wallen, & Hyun, 2013). the research problem and question rather than only a method (Creswell, 2012).

Based on the research method which has been adjusted to the research objective, therefore the research design which was implemented in this research is the convergent parallel design. The rationale for this design is to complete the understanding of research problem result from collecting both quantitative and qualitative data at the same time (Creswell, 2012). Besides researcher chose one class to make the researcher easier to conduct the research. The school has 3 classes of 8 grade. The researcher selected one class of 27 students because compare to the other classes, it was the available class and the amount of the student is not too much.

In this research, the concept of Light and Optics is limited by Core Competence No. 3 and Basic Competence No 3.12 and 4.12 that are attached in *Kurikulum 2013*. The focus of subtopics that will be investigated by students such as (1) Light properties, (2) The image formation of lenses, and (3) Telescope.

There are two types of instruments used in this research. There are objective test and rubric. **First**, an objective test based on Bloom's Revised Edition was used to measure students' concept mastery before and after implementing STEAM-Based Learning. It consists of Pre-test and Post-test. A pre-test is conducted to find the prior knowledge, while the post-test is conducted to identify whether the cognitive mastery is increasing or not. The cognitive level that will be tested in this objective test is C4 (analyzing), C5 (evaluating), and C6 (Creating).

Concept mastery test consists of forty-one questions before judgment by experts. It is used to measure students' concept mastery. After judging by the expert the objective is only twenty questions as a representative for each learning indicators. Then, the test was distributed to students in grade 8 as a test. The next step after conducting the test, the result is analyzed the objective test using ANATES software to measure the validity, reliability, difficulty level, discriminating power and distractor. **Second,** Creative Product Semantic Scale (CPSS) developed by Besemer and Treffinger (1981) was adapted to analyze students' creativity. This analysis was used to assess students' product at the end of the class. The

Table 1 The result of students' concept mastery

No	Component	Pre-test	Post-test	G	<g>	Cate-gory
1	Participant	27	27			
2	Average	43	87			
3	Lowest Score	15	70	44.26	0.78	High
4	Highest Score	70	100			

adapted rubric of CPSS constructed by the author has been judged by two experts.

3. RESULT AND DISCUSSION

The results show quantitative and qualitative data. The pre-test and the post-test are conducted to determine the students' concept mastery before and after treatments. Qualitative analysis will describe the students' product of the project at the end of the class.

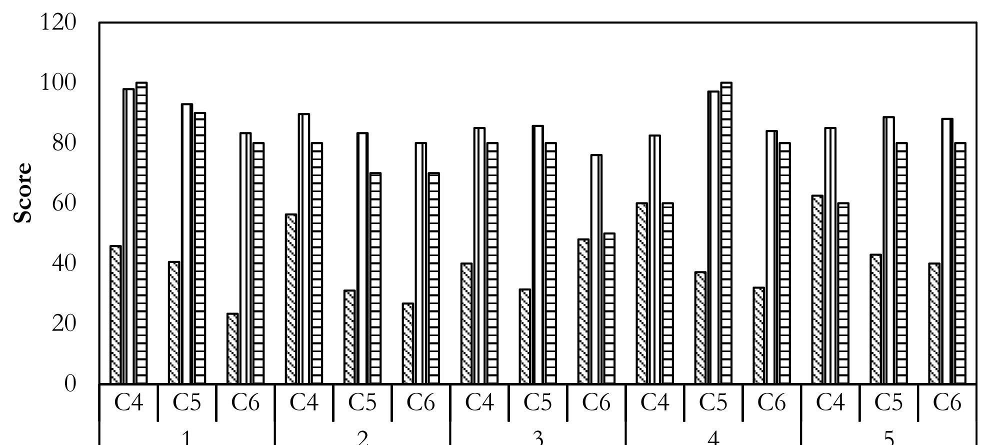
3.1 Students' Concept Mastery

The profile of students' concept mastery was obtained from objective test consisted of 20 multiple choice question that has been given as pre-test and post-test while implementing STEAM-Based Learning in chapter light and optics. The test item has been tested in term of validity, reliability, discriminating power, and difficulty level. Besides, it also has been judged by some experts and revised so it is appropriate to be used as a research instrument to obtain the data of students' concept mastery.

The improvement of students' concept mastery is determined by the calculation of the normalized gain <g>. Normalized gain is calculation processed through data of pre-test and a post-test score of students. The result is presented in Table 1. The average of the pre-test conducted before the implementation of STEAM-Based Learning is 43.14 and it is improving into 87.40 in the post-test. For the score of the students, the lower score of the student in pre-test is 15 and the highest is 70. Merely, the lower score of post-tests is 70 and the highest is 100. To get the improvement score, a normalized gain <g> was calculated. Based on the result, the students' concept mastery is improving with the normalized score 0.78 that assume as high improvement according to Hake (1998).

In order to analyze the profile of students' concept mastery, the improvement of each test item in every cognitive domain should be processed. The test item used in this research was developed based on the Bloom' Taxonomy Revision by Anderson and Krathwohl (2001). There are three levels considered to be used in this research based on the basic competence that is used. Those are analyzing (C4), evaluation (C5), and creating (C6). The result is presented in Table 2.

In order to analyze the improvement of concept mastery in each group, the test item was analyzed based on



	C4 (1)	C5 (1)	C6 (1)	C4 (2)	C5 (2)	C6 (2)	C4 (3)	C5 (3)	C6 (3)	C4 (4)	C5 (4)	C6 (4)	C4 (5)	C5 (5)	C6 (5)
Pre (%)	45.8	40.5	23.3	56.3	31	26.7	40	31.4	48	60	37.1	32	62.5	42.9	40
Post %	97.9	92.9	83.3	89.6	83.3	80	85	85.7	76	82.5	97.1	84	85	88.6	88
<g>	100	90	80	80	70	70	80	80	50	60	100	80	60	80	80

Cognitive Level of Group

Figure 1 Concept mastery's improvement of each group

Table 2 The summary of students' concept mastery based on Bloom' Taxonomy Revised Edition

Cognitive Domain	Amount of Question	Number of Students	Average Score		G	<g>	Category
			Pre-test	Post-test			
C4	8	27	52.8	88.4	35.6	0.75	High
C5	7	27	36.5	89.4	52.9	0.83	High
C6	5	27	33.3	82.2	48.9	0.73	High

the students' group. The result of each cognitive domain in each group is presented in Figure 1.

The result of STEAM-Based Learning implementation shows the average of pre-test is 43.35, meanwhile the average of post-test is 87.42. it is showing the improvement of concept mastery by processed the pre-test and post-test results the gain as much as 44.26. In order to categorize the students' concept mastery improvement, the normalized gain is used. The result of the normalized gain is 0.78 which is categorized as a high improvement. Therefore, the hypothesis is accepted that STEAM-Based Learning improves students' concept mastery. This result is supported by previous findings by Kim, Ko, Han, and Hong (2014) that is STEAM education influenced the improvement of academic achievement, creative problem-solving abilities, and scientific attitude. The research compared the control and experimental group in post-test and analyze it quantitatively and found out there is differences in the results.

Another research by Kim and Park (2012) resulted that the STEAM Teaching Model is stimulated the students understanding related the activities in STEAM itself. Henriksen (2014) also stated in their research that STEAM Education significantly influenced the improvement of academic achievement, basic scientific process skills, and affective domain. This result showed the improvement of students' assessment in content knowledge from 30% to 40%.

The instrument was arrange based on Bloom's Taxonomy revised edition by Anderson and Krathwohl (2001). There is three cognitive levels used in this research which is analyzing (C4), evaluating (C5), and creating (C6). The result shows that n-gain for C4 level is 0.78 which categorized as high, C5 level is 0.83 which categorized as high, and C6 level is 0.73 which categorized as high. The higher value of n-gain is evaluating (C5). The result shows the students are easier to checking, critiquing, testing something, or making a judgment.

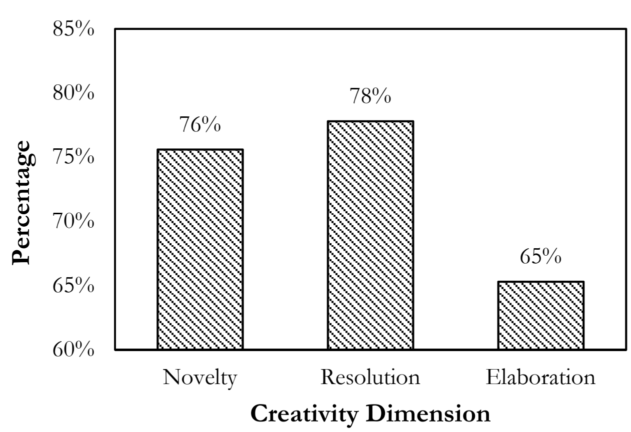


Figure 2 Result of creativity dimension

Light and optics are though in Indonesian Curriculum 2013 and it delivered when implementation of STEAM-Based Learning. In the process of the implementation, the students find a problem in learning light and optics. They said the topic is too abstract and many concepts deliver in this chapter. The strategy of the teacher to make the student understand the topic is to divide the class into groups and give them a problem related to the concept. The students are pro-active. They always ask the question outside the class if they do not understand the concept. The students have high curiosity makes the students give more attention while the implementation.

There are steps of STEAM-Based Learning implemented in this research. There are 3 steps, those are 1) presentation of the situation; 2) creative design; 3) emotional experience. The first steps implemented at the beginning of the meeting until all the concept has been delivered to make the student understand the relationship between the concept and real life (Baek & Yoon, 2016).

Compare to the other method, in Pratiwi, Rochintaniawati, & Agustin (2018) stated that the improvement of students' concept mastery after implemented the multiple intelligent-based learning resulted in medium improvement as much as 0.61. hence, every method will have a different result.

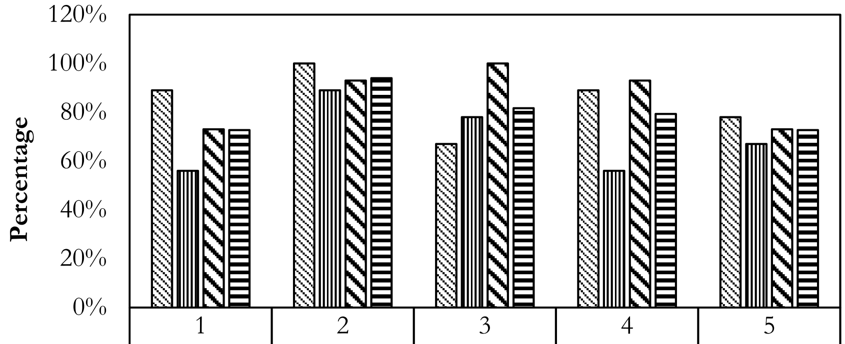
3.2 Students' Creativity

In this research, students' creativity is measured by telescope they made as a final project. Students' creativity is assessed by using CPSS rubric adapted from Besemer and Treffinger (1981). Besemer and Treffinger (1981) suggested that product creativity is grouped into three creative dimensions which are novelty, resolution, and elaboration and synthesis. Each aspect has several criteria and also sub-criteria to make easier to assess the product of creativity.

The criteria of novelty used are original, germinal, and surprising; for the resolution are valuable, logic, and useful; and the last, resolution and synthesis are organic, well-crafted, elegant, understandable, and complex. The result of creativity is stated in Figure 2.

Figure 2 presents the result of every creativity dimension. For novelty dimension is 75.6%, resolution dimension is 77.8 %, and elaboration is 65.3 %. In order to see the whole profile of creativity in each group, the creativity in each group is necessary to be processed. The category of all dimensions is good. The students were more attractive and excited when they make the project. Every group has a good collaboration because every group consists of the students who have the same characteristic, thus they enjoyed when making the project. The result of the creativity in each group is presented in Figure 3.

Based on Figure 3, every dimension in each group has a different result. Group 1 got 89% for novelty, 56% for resolution, and 73% for elaboration in average 73%. Group 2 got 100% for novelty, 89% for resolution, and 93% for



	1	2	3	4	5
Novelty	89%	100%	67%	89%	78%
Resolution	56%	89%	78%	56%	67%
Elaboration	73%	93%	100%	93%	73%
Average	73%	94%	82%	79%	73%

Dimension in Each Group

Figure 3 Result of creativity in each group

elaboration in average 94%. Group 3 got 67% for novelty, 78% for resolution, and 100% for elaboration in average 82%. Group 4 got 89% for novelty, 56% for resolution, and 93% for elaboration in average 79%. The last, group 5 got 78% for novelty, 67% for resolution, and 73% for elaboration in average 73%.

Creativity dimensions of a product consist of three aspects which are novelty, resolution, and elaboration and synthesis (Besemer, 2000). Each aspect has some criteria. The criteria of novelty are original, surprising, and germinal; for resolution are valuable, logic, and useful; for elaboration and synthesis are elegant, well-crafted, organic, complex, and understandable. Each criterion of creativity is used to assess students' creative product as the final result of STEAM-Based Learning implementation. Overall, the students' creative product is categorized as good (Henriksen, 2014).

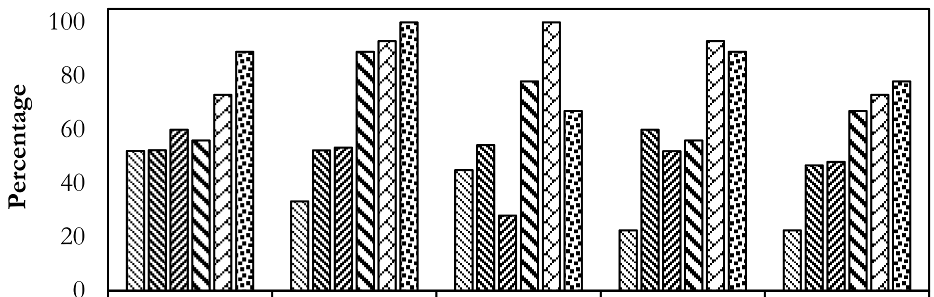
This result is supported by research conducted by Kim, Ko, Han, and Hong (2014) that significant improvement was found in students' creativity by using STEAM-Based Learning compared to the control group. It happens because in STEAM-Based learning consist of the creative process in every step of the implementation. In line with the research of Kim, Chung, Woo, & Lee (2012) that STEAM leads to processes that result in creativity, innovation, and continued growth and exploration of the world. Another research supported this result conducted by Kim, Ko, Han, and Hong (2014) that there is significant improvement found in the creativity and scientific interest in elementary students.

3.3 The Relation between Student's Concept Mastery and Creativity

In order to compare and relate the result of students' concept mastery and creativity, the charts of the comparison between student's concept mastery and creativity is made. The chart is shown in Figure 4.

The relation between students' concept mastery and creativity could be seen through the cognitive level of concept mastery and dimension of creativity. Here, the level of cognitive used was analyzing, evaluating, and creating. The dimension of creativity used here was novelty, resolution, and elaboration and synthesis. Anderson and Krathwohl (2001) stated that analyzing is finding, integrating, something, and organizing something or breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose. Evaluating is checking, critiquing, of testing something or making judgments based on criteria and standards. Creating is designing, constructing, planning, or making something or putting elements together to form a novel, coherent whole or make an original product. The dimension of creativity used here novelty, resolution, and elaboration and synthesis. Besemer and Treffinger (1981) stated that novelty is the newness of the product, new techniques, new process, and another element of newness. Resolution is how well the product does what it is supposed to do. Elaboration and synthesis consider product's presentation style.

There is a similarity between the cognitive level and the dimension of creativity. If we relate the level of cognitive and the dimensions of creativity, we can see that analyzing is closest to resolution. Both analyzing and resolution are to make something in order, relate to one another, and how something does what it is supposed to do. Evaluating is closest to elaboration and synthesis which is testing or judging something or product and how to describe it. Creating is closest to novelty which is constructing or making something new.



	1	2	3	4	5
C4	52.1	33.3	45	22.5	22.5
C5	52.4	52.3	54.3	60	46.7
C6	60	53.3	28	52	48
Resolution	56	89	78	56	67
Elaboration	73	93	100	93	73
Novelty	89	100	67	89	78

Group

Figure 4 Comparison between students' concept mastery and creativity

Based on the explanation, the students' concept mastery and creativity relate each other. It is proven with the pattern of the relationship between students' concept mastery and creativity result. The data of the students' concept mastery and creativity is shown in Figures 4. From the data, it is clear that every cognitive level paired with a dimension of creativity will be the same. The higher the value of C4, the novelty value will be high. as well as elaboration and C5 also resolution and C4. It also can be related also with the implementation of STEAM-Based Learning where the students more excited to prove something whether it is right or wrong and in the presentation session, they were so excited to explain the product. It is proven by Kim and Park (2012) stated that the STEAM improves the student understanding and interest. This condition is proven with the value both of evaluating and elaboration and synthesis are higher than other cognitive level and dimension of creativity. Different from the result of analyzing and novelty which gains the lowest value. The students are hard to analyze something and making the product different with the example given.

4. CONCLUSION

Based on the result of STEAM-Based Learning implementation that has been conducted, STEAM-Based Learning effect significantly to Students' Concept Mastery and Creativity in Learning Light and Optics. There are some other conclusions gained:

Implementation of STEAM-Based Learning on light and optics concept improves students' concept mastery. It can be noticed by the gain of pre-test and post-test score that is 0.78 which included as high improvement category.

Implementation of STEAM-Based Learning can be used to profile students' creativity through the project. Students' creativity is assessed based on CPSS rubric focuses on tree dimension which is novelty, resolution, and elaboration and synthesis. Students' creativity on novelty gain 76%, on the resolution is 78%, while on the elaboration and synthesis is 69%. All creativity is categorized as good.

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Room S-201 FPMIPA A Building
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Jl. Dr. Setiabudi 229 Bandung 40154
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