THE EFFECT OF STEAM-BASED LEARNING ON STUDENTS’ CONCEPT MASTERY AND CREATIVITY IN LEARNING LIGHT AND OPTICS

Gita Ayu Wandari1, Agus Fany Chandra Wijaya1, Rika Rafikah Agustin2\*

1Departement of Physics Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia

2International Program on Science Education, Faculty of Mathematics and Science Education, Universitas Pendidikan 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 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 *kurikulum 2013* in teaching learning process. The sampling techniques was convenience sampling. The number of participants in this research was 27 students. The quantitative data in this research was obtained through 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 Bessemer and O’Quinn. 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 is categorized into enough with 65.3 %. Overall, students’ concept mastery and creativity in 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 towards science and creative convergent thinking. Therefore, 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 and 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 and Yoon, 2016).

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 (Ibrahim, Rochintaniawati, & Sanjaya, 2017). Mastery concept is very important, Anderson and Krathwohl (2001) states that mastery concept can improve their intellectual skills and help them solve the problem they face and lead them to the meaningful learning.

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 (Mishra & Henriksen, 2013). 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 relay on daily life such as camera, microscope, telescope, etc. The concept of 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 the better product.

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 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. Creswell also stated that mixed method is combination of quantitative and qualitative methods provides a better understanding of 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 convergent parallel design. The rationale for this design is to complete the understanding of research problem result from collecting both quantitative and qualitative data in the same time (Creswell, 2012).

The quantitative data focuses on students’ concept mastery that is measured by objective test in form multiple choices test while the qualitative analysis focuses on students’ creativity that is measured by rubric of CPSS developed by Bessemer and O’Quin. 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.

The location of this research was in Private Junior High School in Bandung. The school was using *Kurikulum* 2013 in 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 (2012) stated that convenience technique is used because there is a group of individuals who (conveniently) are available for study (Fraenkel, 2013).

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**, 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. 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 are 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 judged by the expert the objective is only twenty questions as a representative for each learning indicators. Then, test was distributed to students in grade 8 as a test. The next step after conducting 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 O’Quin was adapted to analyze students’ creativity. This analysis was used to assess students’ product in the end of the class. Adapted rubric of CPSS constructed by the author has been judged by two experts.

# 3. Result and Discussion

The results shows 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 project in 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 have 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 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 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 (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 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 showed the improvement of concept mastery by processed the pre-test and post-test results the gain as much as 44.26. In order to categorized the students’ concept mastery improvement, the normalized gain is used. The result of the normalized gain is 0.78 which is categorized as high improvement. Therefore, the hypothesis is accepted that STEAM-Based Learning improves students’ concept mastery. This result is supported by previous findings by Kim 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 stimulate the students understanding related the activities in STEAM itself. Choi, Yang, and Hong (2016) also stated in their research that STEAM Education significantly influenced the improvement of academic achievement, basic scientific process skills and affective domain. This result also supported by Presley, Carrol, and Gobert (2016) that resulted 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 (2001). There are three cognitive level used in this research which are 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 judgement.

Light and optics is though in *kurikulum* 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 teacher to make the student understand about the topic is 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 about 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 situation; 2) creative design; 3) emotional experience. The first steps implemented in the beginning of meeting until all the concept has been delivered to make the student understand the relationship between the concept and real life (Baek et. al., 2016).

Compare to the other method, in Pratiwi (2018) stated that the improvement of students’ concept mastery after implemented the multiple intelligent-based learning resulted the medium improvement as much as 0.61. hence, every method will have the 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 O’Quin (1986). Besemer and O’Quin (1986) suggested that product creativity is grouped into three creative dimension 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.

The figure 2 present 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 are good. The students was more attractive and excited when they make the project. Every group has a good collaboration because every group consist of the students who has same chraracteristic, thus they were enjoy when make the project. The result of the creativity in each group is presented in figure 3 below.

Based on the figure 3, every dimension in each group has 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 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 consists of three aspects which are novelty, resolution, and elaboration and synthesis (Besemer et. al., 1998). 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 criteria of creativity are used to assess students’ creative product as the final result of STEAM-Based Learning implementation. Overall, the students’ creative product is categorized as good (Purwanto, 2008).

This result is supported by research conducted by Kim et. al. (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 creative process in every steps of the implementation. In line with the research of Zhao (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 et. al. (2014) that there is significant improvement found in the creativity and scientific interest on 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 cognitive used was analyzing, evaluating, and creating. Dimension of creativity used here was novelty, resolution, and elaboration and synthesis. Anderson (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. Dimension of creativity used here novelty, resolution, and elaboration and synthesis. Besemer (1981) stated that novelty is the newness of product, new techniques, new process, and other 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 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 describe it. Creating is closest to novelty which is constructing or making something new.

Based on the explanation, the students’ concept mastery and creativity relate each other. It is proven with the pattern of the relation between students’ concept mastery and creativity result. The data of the students’ concept mastery and creativity shown in figures 4.1 From the data, it is clear that every cognitive level paired with 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 (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 is higher than other cognitive level and dimension of creativity. Different with 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:

1. 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.
2. 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 are novelty, resolution, and elaboration and synthesis. Students’ creativity on novelty gain 76%, on resolution is 78%, while on the elaboration and synthesis is 69%. All creativity is categorized as good.

# Acknowledgment

The authors acknowledge Mrs. Rika Rafikah for stimulating discussion about educational assessment.

# References

Ahn, H., & Choi, Y. (2015). Analysis on the Effects of the Augmented Reality-Based STEAM Program on Education, *92*(Education), 125–130.

Amabile, T. M. (2012). Componential Theory of Creativity. *Harvard School Business*.

Anderson, L. W., & Krathwohl, D. R. (2001). *A Taxonomy for Learning, Teaching and Assessing (A Revision of Bloom’s Taxonomy of Educational Objectives)*. United States: Addison Wesley Longan, Inc.

Baek, J.-E., & Yoon, M.-B. (2016). Development and Application of STEAM Education Program Based on Robots: Through a Theme-Based Robot Soccer. *International Journal of Computer Science and Information Technology for Education*, *1*(1), 27–34. https://doi.org/10.21742/ijcsite.2016.1.05

Besemer, S. P. (2000). Creative Product Analysis to Foster Innovation, *11*(4).

Besemer, S. P., & Treffinger, D. J. (1981). Analysis of Creative Products : Review and Synthesis, *15*(3).

Bloom, B. S. (1984). The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring. *Educational Researcher*, *13*(6), 4–16. https://doi.org/10.3102/0013189X013006004

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. *Educational Research* (Vol. 4). United States: Pearson. https://doi.org/10.1017/CBO9781107415324.004

Crocker, L., Alglna, J., Staudt, M., Mercurio, S., Hintz, K., & Walker, R. A. (2008). *Introduction to Classical and Modern Test Theory*. United States: Cengage Learning.

Cronbach, L. J. (1951). Coefficient Alpha and The Internal Structure of Tests, *16*(3), 297–334. https://doi.org/10.1007/BF02310555

Cutnell, J. D., & Johnson, K. W. (2012). *Physics*. (S. Johnson, Ed.). United States: John Willey and Sons, Inc.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2013). *How to Design and Evaluate Research in Education*. *Climate Change 2013 - The Physical Science Basis* (Vol. 53). New York: McGraw-Hill, Inc. https://doi.org/10.1017/CBO9781107415324.004

Giancoli, D. C. (2005). *Physic Principle with Application 6th Edition*. United States: Pearson, Inc.

Glynn, S. M., & Koballa, T. R. (2006). Handbook of College Science Teaching. *Motivation to Learn College Science*.

Gurteen, D. (1998). Knowledge , Creativity and Innovation.

Halliday, D., Walker, J., & Resnick, R. (2011). *Fundamental of Physics* (9th ed.). United States: John Wiley & Sons, Inc.

Hsu, T. (2007). *Foundation of Physical Science with Earth and Space Science*. *Waste Management* (Vol. 1).

Ibrahim, A. S., Rochintaniawati, D., & Sanjaya, Y. (2017). The Use of Self Construction Animation LearningSoftware to Improve the Students ` Concept Mastery on Structure and Functions of Plants, *6*(3), 1–10. https://doi.org/10.25037/pancaran.v6i3.31

Jackson, T. (2015). Reframing STEAM PD, *2*(1). https://doi.org/10.5642/steam.20150201.14

Kaplan, R. M. (2014). *Psychological Testing*. *Igarss 2014*. https://doi.org/10.1007/s13398-014-0173-7.2

Kim, D., Ko, D. G., Han, M., & Hong, S. (2014). STEAM 프로그램을 적용한 과학수업이 초등학생의 창의성과 과학교과 흥미도에 미치는 영향, *34*(1), 43–54.

Kim, H., & Chae, D. H. (2016). The development and application of a STEAM programbased on traditional Korean culture. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(7), 1925–1936. https://doi.org/10.12973/eurasia.2016.1539a

King, B. M., Rosopa, P. J., & Minium, E. W. (2011). *Statistical Reasoning in the Behavioral Sciences*. *Wiley*. United States: John Wiley & Sons, Inc.

Kolodner, J. L., Camp, P. J., Crismond, D., Fasse, B., Gray, J., Holbrook, J., … Ryan, M. (2003). Problem-Based Learning Meets Case-Based Reasoning in the Middle School Science Classroom: Putting Learning by Design Into Practice. *Journal of the Learning Sciences*, *12*(4), 495–547. https://doi.org/10.1207/S15327809JLS1204

Kong, Y. T., & Huo, S. (2014). An Effect of STEAM Activity Programs on Science Learning Interest. *Advanced Science and Technology Letters*, *59*(Education), 41–45. https://doi.org/http://dx.doi.org/10.14257/astl.2014.59.09

Lindeman, K. W., Jabot, M., Berkley, M. T., Lindeman, K. W., Jabot, M., & Berkley, M. T. (2016). The Role of STEM (or STEAM) in The Early Childhood Setting. *Advance in Early Education and Day Care*.

Mader, S. S., & Lyle-Ippolito, K. (2010). *Human Biology Eleventh Edition* (11th ed.). New York: The McGraw-Hill Companies, Inc.

Mishra, B. P., & Henriksen, D. (2013). Rethinking Technology & Creativity in the 21st Century, *57*(5).

Pratiwi, Wida Nur W., Rochintaniawati, D., & Agustin, Rika R. (2018). The Effect of Multiple Intelligence-Based Learning Towards Students’ Concept Mastery and Interest in Matter. *Journal of Science Learning.* Indonesia.

Quin, K. O., & Besemer, S. P. (2006). Using the Creative Product Semantic Scale as a Metric for Results-Oriented Business, *15*(1), 34–44. https://doi.org/10.1111/j.1467-8691.2006.00367.x

Reece, J. B., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2011). *Campbell Biology* (8th ed.). United States: Pearson, Inc.

Rickard, G., Clarke, W., & Whalley, K. (2010). *Science Focus 3*.

Skinner, B. F. (1984). The Evolution of Behavior. *Scientific American*, *239*(3), 176–192. <https://doi.org/10.1038/scientificamerican0978-176>

Song, M., & Kim, H. (2016). The Effect of S-STEAM Program on Creativity and Multiple Intelligences of Young Children. *Journal of Korea Academia-Industrial Cooperative Society*, *17*(4), 361–372.

Tipler, P. A., & Mosca, G. (2008). *Physics for Scienctist and Engineering.* New York: W. H. Freeman and Company.

# Table Lists

**Table 1** The result of students’ concept mastery

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **No** | **Component** | **Pre-test** | **Post-test** | **G** | **<g>** | **Category** |
| 1 | Participant | 27 | 27 | 44.26 | 0.78 | High |
| 2 | Average | 43.14 | 87.40 |
| 3 | Lowest Score | 15 | 70 |
| 4 | Highest Score | 70 | 100 |

**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 |

# Figure Lists

**Figure 1** Concept mastery’s improvement of each group

Figure 2 Result of Creativity Dimension

**Figure 3** Result of creativity in each group



**Figure 4** Comparison between students’ concept mastery and creativity

# Highlights

* STEAM-Based Learning improve the students’ concept mastery
* STEAM-Based Learning enhance the creativity of the student