Improving students’ conceptual knowledge on optical device materials with computer simulations

S Rahmadani*, A Samsudin, A Danawan, I Kaniawati and E Suhendi
Departemen Pendidikan Fisika, Universitas Pendidikan Indonesia, Bandung, Indonesia

*Corresponding author’s email : srirahmadani@student.upi.edu

Abstract. One of the factors causing the low level of student’s conceptual knowledge on optical device materials is the difficulty of students to observe the shadow formation process so that one can see an object. Students difficult to understanding the function and way of working the parts of the eye. Therefore, it is necessary to develop computer-based instructional learning media on optical device materials. The development of learning media using development method with the sample of research as many as 23 high school students. The instruments utilized to determine the increase of students’ conceptual knowledge were pre-test and post-test in the form of FTOPT (Four-Tier Optic and Photonics Test). After using Optics Simulation (OpSi) in physics learning, student’s conceptual knowledge of optical device material has increased as indicated by the normalized gain $g = 50.93\%$ with the medium category.

1. Introduction

Physics is learning about of natural laws and their submission in life. Phenomena in physics are not always observable, there are some concepts that are abstract and require considerable effort to explain them. Finally, the students concluded that physics is difficult and boring, except if the concepts connected with daily life, students will be interested to learning physics [1].

Currently, science and technology growing rapidly. Technology make the learning process more effective, helping the instructors and students in teaching-learning practices [1-3]. On the whole, teachers in school using a computer, limited to displaying subject matter on Microsoft PowerPoint. The content displayed is the definition, formulas, images, and sometimes video related concepts being studied. Consequently, the skills gained by the students are direction knowledge. It is in order with Prince [4] and Bobadilla [5] which states that at this time, knowledge is gained through books and information submitted by teachers, not through student learning experiences.

Teacher-cantered teaching which has been exposed, to be very ineffective. Traditional, teacher-cantered learning has been shown to short-range upright learning solitary in a lesser part of students. Physics lecturers have consequently to treaty by students that are not particularly interested for the matter, whose predetermined impression is that physics is actual difficult, uninteresting and useless [6].

The light is included in the wave type electromagnetic (EM), which is a wave propagate without the need for medium intermediation [7]. Light has properties reflected, refracted, and spreads in all directions.
Figure 1. The lights spread in all direction (divergent) when out from lamp, then through the cylinders lens and the light converging in a focal point (convergent).

Light shows an important role in the looking process. All optical devices such as eyes, loops, cameras, microscopes, and telescopes will work when there is the light. Many are found at the secondary school level that students should be able to describe the way light rays use singular rays (Figure 2), but most students have difficulty understanding the shadow formation process using lenses. Each optical tool has a different shading process and the position of the object also affects the resulting image.

Figure 2. There is a converging lens, an object in the shape of an arrow is positioned a distance larger than the focal length to the left of the lens, as shown in the diagram on the right.

Students asked for drawing several rays from the head of the arrow and several rays from the foot of the arrow to show how the image of the arrow is formed by the lens. Is this a real or a virtual image? Almost all student in preface at the senior high school in Bandung couldn’t finished the question. The students not understand how to drawing several rays from the object, so that forming the image. If the students can’t to solving the problems, so students certainly do not know the shadow properties generated by converging lenses.

The student’s conceptual knowledge about optics is low category, preface identification if the student can’t to calculated the distance of object and image to lens using cameras. The following is the equation for determining the distance of the object to the lens by the camera.

\[
\frac{1}{s} = \frac{1}{f} - \frac{1}{s'} \tag{1}
\]

\(s\) showed distance of object to lens, \(s'\) is distance of image to lens, and \(f\) is focal point of the lens by camera. Magnification on the lens can be calculated using the focal point of the lens, according to the second Equation 2.

\[M = \frac{1}{f} \tag{2}\]

Based the second equation, so the relation of a magnification and focal point is exponential. The following picture showed the graphic exponential \(M\) to \(f\).
Figure 3. Magnification and focal point of the lens is having exponential graphics.

This study was designed to test the suitability physics learning computer simulation-assisted to improving students’ knowledge and mastery concept about optic and photonics in high school at Bandung. In this study considers the following research questions:

1. Is the OpSi-based ALOP effective for improving conceptual knowledge of light and optics?
2. How is the benefit of students using OpSi computer simulation learning media?

2. Methods

Methods in this research is the scientific way to get data with a specific purpose and usefulness. The body of research literature that directly pertains to instructional development is known as developmental research: "the systematic study of designing, developing and evaluating instructional programs, processes and products that must meet the criteria of internal consistency and effectiveness [8].

2.1. Participant and Instrument

A group comparison experiment of two high school classes, with pre and post implementation testing, was implemented using two 11th grade classes of senior high school at Bandung, West Java. Both classes have the same number of students to be a sample of the experiment (N=23).

The Implementation using Four-Tier Optics and Photonics Test (FTOPT) for identification students’ knowledge in pre and post implementation. FTOPT consist 18 item questions and include five sub-concepts of optics and photonics (Eye, camera, lop, microscope, and telescope). Students worksheets about optics and photonics gives for guide learning implementation, there is two kind of worksheet for EXP group (Base on real experiment and virtual experiment), to CTRL group worksheets base on real experiment only.

2.2. Designing development research

The style of this research is development. Produces advanced in this education a computer simulation (Analogy-Based Simulation) to the concept of Optical Devices, here in after referred to Optics Simulation (OpSi). Improvement model used in researchers is the adaptation procedures offered development studies by Borg and Gall [9] and Thiagarajan [10]. The subsequent design scheme described in Figure 4.
OpSi improvement steps contain the investigation step (determine), Planning (design), Production (develop), and Evaluation (dissemination).

1. Literature review journal and computer simulation explosion and connecting analogy
2. Analysis of computer simulation toward changing student’s conception
3. Determining the type of computer simulation toward changing student’s conception on Optic Devices.

**Figure 4.** The design of research.

Learning approach both classes is similar. An eight-step procedure is used to instruction demonstration [11]. Real physics demonstration are shown to students, then make predictions about demonstration on prediction sheet, collaborate with fellow students by discussing their predictions in small group. The teacher then asks the volunteers to explain their prediction was discussed. Therefore, the students observe the results of demonstration to verified their prediction. On this step of OpSi presentations that have been developed (quantitative stage) practiced a Quasi Experiment by research design using Pretest-Posttest Control Group Design, the design is shown in Figure 5.

| Experiment | O₁ | O₂ | X |
|------------|----|----|---|
| Control    | X  | O₂ | X |

**Figure 5.** Control group design.

Note:
X : Pre-test=Post-test
O₁ : Physics learning use OpSi software in experimental group
O₂ : Physics learning use Microsoft power point without computer simulation in control group

Detail of the design both the class experiment and control class, contains learning methods, medias, and syntax, show at Figure 6.
2.3. ALOP with OpSi-assited

The instructional approach for the experiment class (EXP) and control class (CTRL) is the ALOP approach, but EXP class with OpSi-assisted and CTRL class using the MS. PowerPoint. Steps of ALOP approach have activity POD (Predict, Observe, and Discuss). The ALOP approach consists six modules for training manual (basic topics of Geometrical Optics, Lenses and Optics of the Eye, Interference and Diffraction, Atmospheric Optics and Optics in Communication), but the module that using in this experiment is Geometrical Optics [12-14].

Generally, justification done by the subject experts and media experts the result is a high average with some improvements to be done to perfect the OpSi program. Developments completed include dipping the amount of text, addition animations to stimulate students more. The simulation shown on Figure 7.

![Figure 6](image)

**Figure 6.** Characteristics experiment and control class.

![Figure 7](image)

**Figure 7.** Simulation of analogy human vision.

2.4. Data analysis

Treating and analysis of quantitative data by statistical test with the following steps (1). The development before and after learning was calculated by dividing normalized gain equation \( <g> \). Test the variance made by using t-test of two tail. The determination of hypothesis testing is to catch a significant change between the increases in N-gain in the control group with the experimental group. Normalized gain criteria which proposed by Hake [15] can be referred in Table 1.
### Table 1. Normalized gain criteria.

| <g>         | Criteria   |
|-------------|------------|
| (<g>) ≥ 0.7 | High       |
| 0.3 ≤ (<g>) | Moderate   |
| (<g>) < 0.3 | Low        |

### 3. Results and Discussion

Base results implemented in EXP class and CTRL class, showed that student enjoying the learning with ALOP. Figure 8 showed students activity when implemented the ALOP approach.

![Figure 8. ALOP approach both of the class (CTRL & EXP).](image)

To evaluate the efficiency of active learning of optics and photonics OpSi-assisted, the Four-Tier Optics and Photonics Test (FTOPT) was given in both groups, just before (Pre) and after (Post) instruction. The collected data allowed for calculation of the absolute Gain \( G = \langle \text{Post} \rangle - \langle \text{Pre} \rangle \), then compare with different initial knowledge (100\% - \langle \text{Pre} \rangle), and get the normalized-Gain <g>.

Item average to included high category is 11\%, then item included to high category is item number 4 and 4. Moderate category is 44\%, number of items included to this category is thirteen (1,3,5,6-13,15, and 18). Therefore, items of FTOPT to included low category is item number 14, 16, and 17, with items average 11\%.

Figure 8 showed normalized gain for each item FTOPT in CTRL group. Item average to included high category is 44\%, then item included to high category is item number 1-6, 8, and 11. Moderate category is 44\%, number of items included to this category is 7, 9, 10, 13, and 15-18. Therefore, items of FTOPT to included low category is item number 12 and 14, with items average 11\%.

Knowledge for optic devices concept by OpSi software was implemented in five sub-concepts that classified to Optics and Photonics concept. Otherwise photonics concept has demonstration that show image forming by lens, so students will analysis the characteristics of photonics. The results of the normalized gain analysis of each sub-concept for control group and experiment group are exited in Table 2.

### Table 2. Normalized gain review in each sub-concept for control and experiment group.

| Sub-concept | Test item | CTRL | EXP | <g>ctrl | <g>exp |
|-------------|-----------|------|-----|---------|--------|
| I- Eye      | 1-2-3-4-5-6 | 18.48 | 67.75 | 28.99 | 88.77 | 0.56 | 0.84 |
| II- Lup     | 7-8-9     | 14.49 | 57.69 | 18.84 | 60.14 | 0.51 | 0.51 |
| III- Camera | 10-11     | 16.30 | 45.65 | 14.13 | 64.13 | 0.35 | 0.58 |
| IV-Microscope | 12-13-14-15 | 15.76 | 43.48 | 22.28 | 48.37 | 0.33 | 0.34 |
| V- Telescope| 16-17-18  | 18.12 | 37.68 | 18.12 | 44.48 | 0.23 | 0.31 |
| Mean        |           | 16.63 | 50.51 | 20.47 | 60.98 | 40.64 | 50.93 |
Overall group performance showed, mean before (Pre) implementation performance of EXP and CTRL classes are low. Based on the pre-test value it can be seen that the two classes have limited knowledge related to the concept of light and optics. Figure 5 and 6 on pre-implementation is known the item number six is most students answer wrong. As a matter of number six is a sub eye concept and photonic, almost all students both of the classes do not know how the function of the photonics to vision process. Therefore, post-test both classes show the knowledge is increasing, the EXP class have average value (71.74%) higher than CTRL class (63.04%). Overall the first sub concept (Eyes) for EXP class include high category (normalized gain 0.84) and CTRL class for firs sub concept included to moderate category. The second sub concept is Lup have normalized gain 0.51 for both of the class. Third sub-concept Camera for EXP class higher (0.58) than CTRL class, but the both of the class is moderate category. Sub-concept Microscope for CTRL and EXP class have almost same normalized gain (0.33 for CTRL and 0.34 for EXP). The last sub-concept is Telescope, normalized gain CTRL and EXP class is 0.23(low) and 0.31(moderate).

![Figure 9. Comparison of mean percentage of pre-test, postest, and N-Gain for control and experiment class.](image)

Implementation in EXP and CTRL class was used ALOP approach and FTOPT instrument showed the results of mastery of optic devices concept are existed in Figure 9. Overall EXP class % normalized gain (50.93%) higher than CTRL class % normalized gain (40.64). Therefore, understanding forming the image for normal eyes, miophy, hypermetrophy, and presbiophy. Then, decided what kind that use for helped the myopia and hypermetropia. The T test is one of the statistical tests used to test the truth or falsity of the null hypothesis which states that between two randomly sampled mean samples from the same population there is no significant difference [16]. To know is there any difference in the results of normalized gain of EXP and CTRL class performed the t-test, therefore the t-test technique used is the two-tail. Based on the paired two sample for means, calculation of $t_c = 2.75$ and $t_e = 2.07$, conclude $t_c$ and $t_e$ is different, $t_c > t_e$. This result showed Zero Hypothesis ($H_0$) is rejected and there is the difference of ALOP approach with OpSi-assisted on optic devices concepts and reduce of misconceptions is more effective than ALOP without OpSi-assisted. The same research Ugur [17] showed that when analogical analysis can change misconception and more enhanced than traditional learning. Fratiwi’s [18] study results concluded CS-PDEODE*E provided a large effect on enhancing students’ conception, the PDEODE*E worksheet and computer simulations remained to have insufficiencies essential to be overcome.

4. Conclusion
This research was designed to test the effectiveness of OpSi to improve student’s knowledge. Pre and Post-testing and based on data analysis clearly showed that the EXP class (using OpSi media’s learning) generate large benefits in the conceptual knowledge in these senior high school students, clearly higher than that CTRL class (without OpSi). The EXP class, average value performance each student of 62.32 % and the CTRL class have means value performance for each student is 54.35%. The results showed
that ALOP approach increasing student’s mastery concept both classes, but the using OpSi will be higher mastery concept.

The result of t-test showed implementation of ALOP approach OpSi-assisted is effective to increasing student’s knowledge on Optics and Photonics concept. Teaching with analogy-based simulations made abstract concept to be real and easily to understanding for students. Fact is important to be held for improving students’ motivation to learning physics. Developing of OpSi should be recommended to realize learning ends.

5. References

[1] Faizin M Noor and Samsudin A 2018 Journal of Physics: Conference Series 1013 1 012048
[2] Samsudin A, Suhandi A, Rusdiana D, Kaniawati I and Coştu B 2016 Asia-Pacific Forum on Science Learning and Teaching 17 1 1-41
[3] Samsudin A, Suhandi A, Rusdiana D and Kaniawati I 2016 Journal of Physics: Conference Series 739 1 012006
[4] Kaniawati I, Samsudin A, Hasopa Y, Sutrisno A D and Suhendi E 2016 Journal of Physics: Conference Series 739 1 012060
[5] Prince M 2004 Journal of engineering education 93 3 223-31
[6] Bobadilla C, Marina, Lorza L, Rubén, González V, Eliseo P, Gómez S and Fátima 2016 International Journal on Advances in Education Research 3 2 38
[7] Saleh B E and Teich M C 1991 Fundamental of Photonics (Toronto: John Wiley & Sons,Inc.)
[8] Richey R C and Klein J D 2005 Journal of Computing in Higher Education 16 2 2338
[9] Borg W R and Gall M D 1983 Educational Research: An Introduction (London: Longman,Inc.)
[10] Thagiagarajan S 1974 Instructional development for training teachers of exceptional children (A sourcebook)
[11] Sokoloff D R Physics teachers’ inventions fair 17
[12] Alborch A, Pandiella S and Benegas J 2017 Physics Education 52 1-9
[13] Sokoloff D R 2016 Phys. Teach. 54 18
[14] Sokoloff D R, Thornton R K and Laws P W 2012 (New York: Wiley)
[15] Hake R R 1998 American Journal of Physics 66 64-74
[16] Tae K K 2015 Korean Journal of Anesthesiology 68 6 540
[17] Ugur G, Dilber R, Senpolat Y and Duzugan B 2012 European Journal of Educational Research 1 3 211-23
[18] Fratiwi N J, Samsudin A and Coştu B 2018 Jurnal Pendidikan IPA Indonesia 7 2 214-223

Acknowledgments
The author thanks to members of Reducing Misconception with Active Learning Based on Computer Simulations group research Wulan Dwi Aryani, Widyatami Maulidina, and Grace Triyani. Thanks to research lecturer team to gives generous support, motivation and much ideas for this research. Development this media learning of optics and photonics (OpSi) wouldn’t be held without support from them.