Development of computer simulations to overcome students' misconceptions on light and optical instruments

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Abstract. This study aims to develop computer simulations on light and optical instruments topic for junior high school students. The simulations are developed according to the students’ misconception having assessed with two-tier multiple choice test of light and optical instruments concept. The simulations are reviewed by six science teachers to gain comments and suggestion for further development using a set of questionnaires which consists of 10 items with 5-point Likert scale. The items of the instrument are created to assess simulations from aspects of content explanation and its deepness, display, language use, content, curriculum, and students’ misconception. The results of the study show that: (1) The computer simulations program is suited with the contents in the science curriculum, (2) The quality of computer simulations based on science teacher responses is in very good criteria. In conclusion, computer simulations are feasible for junior high school students to overcome misconceptions on light and optical instruments concept.

1. Introduction
Learning process begins informally when a student starts to construct knowledge about the phenomenon while experiencing that particular phenomenon in real life [1]. Students come to the class with existing knowledge that they construct with their experiences and developing various ideas about scientific concepts [2,3]. The structure of knowledge based on students’ experiences tends not to be in parallel with the scientifically accepted understanding. These kinds of knowledge that contradict the scientific concepts described as misconceptions. Misconceptions are stable cognitive structures to change, affect students’ conceptual understanding, and must be overcome so that students learn scientific concepts effectively [4,5]. The previous researchers show that students’ misconceptions are a barrier for their further learning and may still exist even after instruction [6,7]. These misconceptions should be overcome and replace with correct concepts to provide meaningful learning.

Overcoming students’ misconceptions in science have been explored by previous researchers in the science education field. One strategy to overcome misconceptions is using the teaching method. Research related to misconceptions had shown that traditional teaching methods are not effective for overcoming students’ misconceptions [8]. Overcoming misconceptions require teaching methods which provide chances for students to reveal their pre-concepts and dissatisfaction with their concepts. According to [1] suggested that effective teaching methods must be used to minimize or eliminate the misconceptions that students have. From the previous research, there are several ways methods for
overcoming students’ misconceptions in science learning, such as graphical or visual tools such as conceptual maps, using an interactive whiteboard, using drawing analysis, using inquiry activities, and using computer simulations. From these teaching methods, one of the effective methods for overcoming misconceptions is using computer simulation in the classroom [9,10].

A review from previous research on the effectiveness of computer simulations for supporting science teaching and learning during the past four decades by [11] stated that simulations could help students to eliminate their misconceptions. According to [12], simulations provide interactive, authentic, and meaningful learning opportunities for students because simulations facilitate the learning of abstract concepts, such as light and optical instrument. This concept is one of the concepts in science learning that difficult for students. According to [13], light and optical instruments is a complex concept that lends itself to misconceptions among teachers and students. A review of the literature on this concept have shown various difficulties in dealing with abstract concepts in the learning process. Because of these difficulties, students tend to develop misconceptions about light and optical instruments. Computer simulations provide a bridge between students’ prior knowledge and the learning process of new concepts, also helping students develop scientific understanding through an active reformulation of their misconceptions. Therefore, very important to develop computer simulations to overcome students’ misconceptions. Thus, the purpose of this study is to develop computer simulations to overcome students’ misconceptions about light and optical instruments concepts.

2. Method

2.1. Research Design

This study is a research and development research (R&D). This study aims to develop computer simulations on light and optical instruments concept for 8th grade junior high school students in Indonesia. The development of computer simulations using four D models namely define, design, development and disseminate shown in Figure 1.

![Figure 1. Research and development procedure](image)

Step 1 was the define phase, the data of students’ misconceptions in light and optical instruments concept were assessed using a two-tier multiple choice test. The result from this test is several misconceptions have found in light and optical instruments concept. Step 2 was the design phase. In this phase, the computer simulations of “light and optical instruments” were developed using software Adobe Flash Professional CS6. This software is a program that has been widely used by animators to produce professional animations and simulations. Step 3 was the developing phase. The simulations program were reviewed by six science teachers to gain comments and suggestion for further improvement using a set of questionnaire which consists of 10 item questions with a 5-point Likert scale. The items of the instrument are created to assess simulations from aspects of content explanation and its deepness, display, language use, content, curriculum, and students’ misconception. Step 4 was the disseminating phase. In this phase, computer simulations were disseminating to the three schools in Semarang city, Indonesia.

2.2. Techniques and data collection instruments

The data were collected using questionnaires to assess the feasibility of the computer simulations. The questionnaires used by science teachers consist of 10 items with 5-point Likert scale. Analysis of the
result questionnaires using descriptive percentage. Then, make the criteria for the average based on the interval of percentage obtained. Criteria for teacher validation can be seen in Table 1.

| Range of percentage | Criteria    |
|---------------------|-------------|
| 86-100              | Very good   |
| 71-85               | Good        |
| 56-70               | Acceptable  |
| 41-55               | Poor        |
| 25-40               | Very poor   |

### 3. Results and Discussion

The computer simulations on light and optical instruments concept contains several parts, such as opening page, competency, material, and evaluation. The opening page shows to users that the computer simulations were developed to overcome students’ misconceptions in light and optical instruments concept. The competency part shows the core competency, basic competency, and indicator of competency achievement. The material part is the main parts of the computer simulations. In this part, the concept of light and optical instruments divided into five topic materials, namely (1) light, (2) mirror, (3) lens, (4) optical instruments, and (5) Eye.

![Figure 2](image_url)

**Figure 2.** Parts of computer simulations content on light and optical instruments concept

The material part contains summaries and additional materials that students can use to complete the science learning about light and optical instruments. Furthermore, the material also equipped with the simulations that can facilitate students to overcome students’ misconceptions and understand the concept of light and optical instruments. For instance, simulation on concave mirror, simulation on a convex mirror, simulation on a concave lens, simulation on a convex lens, and simulation on the human eye. The material in the simulation also adjusted with the content of the science curriculum in Indonesia. Finally, the last part is the evaluation part. The students can use the evaluation part to check their understanding of the concept of light and optical instruments that consist of 20 items multiple choice test questions. The screenshot from computer simulation parts on light and optical instruments concept can be seen in Figure 2.
The development process of computer simulations also considering the content of light and optical instruments concept by adjusting the content of the computer simulations and the structure of Indonesia curriculum. Based on Indonesian national curriculum, the structure of curriculum consist of organizing of core competency and basic competencies. The core competency for light and instruments concept is understanding (factual, conceptual and procedural) based on curiosity about science, technology, art, culture-related phenomena and events that can be seen with our eyes [14]. Light and optical instruments concept consist of five topic material, namely, the properties of light, the formation of images in mirrors, the formation of images in lenses, optical instruments, and the human eye. Details of information about the topic material of light and optical instruments concept can be seen in Table 2.

Table 2. The content of simulations in light and optical instruments concept

| Concept               | Topic material                        | Content of simulations                  |
|-----------------------|---------------------------------------|-----------------------------------------|
| Light and Optical     | 1. The properties of light             | a. Light travel in a straight line      |
| Instruments           |                                        | b. Light reflection                     |
|                       |                                        | c. Light refraction                    |
|                       |                                        | d. Light is an electromagnetic wave    |
|                       |                                        | e. Light dispersion                    |
|                       | 2. The formation of images in mirrors  | a. Images formation in a plane mirror   |
|                       |                                        | b. Images formation in a concave mirror|
|                       |                                        | c. Images formation in a convex mirror |
|                       | 3. The formation of images in lenses   | a. Images formation in a concave lens   |
|                       |                                        | b. Images formation in a convex lens   |
|                       | 4. Optical instruments                 | a. Magnifying glass                    |
|                       |                                        | b. Camera                               |
|                       |                                        | c. Microscope                           |
|                       |                                        | d. Telescopes                           |
|                       | 5. Eye                                 | a. Human eye anatomy                    |
|                       |                                        | b. The process of seeing in the human eye|
|                       |                                        | c. Accommodation of human eye          |
|                       |                                        | d. Myopia, hypermetropia, presbyopia    |

In Indonesia, light and optical instruments concept are taught at 8th grade in junior high school according to the national curriculum. This concept is expanded and taught in the upper grade in senior high school. If the students’ misconceptions about light and optical instruments concept are not corrected, students will carry these misconceptions to the upper grades. Because of this reason, one of the alternatives ways for removing misconceptions is using computer simulations. The computer simulations in this research were developed based on the students’ misconceptions that have found in the pilot study using two-tier multiple choice test. Twenty-two misconceptions were identified and grouped under the headings of ‘the properties of light’, ‘the formation of the image in mirrors and lenses’, ‘optical instruments’, ‘human eye’, and ‘eye disorders’. The example of several computer simulations program to overcome students’ misconceptions were provided in Table 3.

Table 3. Several simulations to overcome misconception in light and optical instruments concept

| No | Misconceptions                                | Simulations to overcome misconceptions | Correct concept                                      |
|----|-----------------------------------------------|----------------------------------------|-----------------------------------------------------|
| 1. | Light is an electromagnetic wave and has an infinite speed | ![Image](image.png) | Light is an electromagnetic wave and has a finite speed |
2. The magnification of the image is the result of comparison of the height of the object with the height of the image.

3. Myopia can help using positive eyeglasses.

The simulations were assessed by science teachers. The purposes of this assessment are: (1) to determine whether the simulations are suited with the content in science textbooks or not; (2) to determine the quality of the simulations. To achieve these purposes, the data was collected using a questionnaire. The questionnaires used by science teachers consist of 10 aspects with 5-point Likert scale. The items of the questionnaire are created to assess simulations from aspects of content explanation and its deepness, display, language use, content, curriculum, and students’ misconception. The result of validation by science teachers was provided in Table 4.

Table 4. Assessment of simulations by science teachers

| Aspects                                                   | Average percentage | Criteria   |
|-----------------------------------------------------------|--------------------|------------|
| Readability of text and writing clearly                   | 90                 | Very good  |
| The use of simulations can clarify the material           | 96                 | Very good  |
| Simulations facilitate conceptual understanding           | 96                 | Very good  |
| The display colour of simulations is interesting          | 86                 | Very good  |
| The language in simulations is easy to understand         | 96                 | Very good  |
| The simulations are easy to operate                       | 96                 | Very good  |
| The depth of concept in simulations is enough             | 96                 | Very good  |
| The content of simulations suitable with curriculum       | 90                 | Very good  |
| Simulations in accordance with learning objectives        | 90                 | Very good  |
| Simulations can overcome students' misconception          | 86                 | Very good  |
| **Average overall simulations assessment**                | **92**             | **Very good** |

Table 4 shows that the results of the average percentage of the overall simulations assessment. The aspects to assess the computer simulations are the content explanation and its deepness, display, language use, content, curriculum, and students’ misconception. The results of validation by science teachers showed an average overall 92% which indicate that the computer simulations on light and optical instruments concept in very good criteria and can be used in the learning process. The suggestion from the science teachers about the improvement of the computer simulations on light and optical instruments concept can be seen in Table 5.

Table 5. Improvement of computer simulations based on suggestions from science teachers

| No | Suggestions                                                                 | Improvement of computer simulations                                                                 |
|----|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| 1. | the simulation in the mirror and lens only provides the simulation of image  | Revising the simulation by adding the object in the room 1, 2, 3, focus point and the center of the mirror. |
|    | formation in object room 1, 2 and 3. Add the object to the focus point and   |                                                                                                       |
|    | the center of the mirror.                                                   |                                                                                                       |
2. In the human eye anatomy, add information about the pupil. Because it is not a clear picture.

Revising the simulation by adding the information in the pupil.

With the rapid development of information and communication technology (ICT), the use of computer technology in science education has become commonplace [15]. The using of a computer technology in education highly recommended by the Indonesian government, as indicated in the National Education System Law number 20 the year 2003. Furthermore, education policy in the Indonesian curriculum mentioned that a computer has the potential to support learning, and it should be used in each subject especially in the science subject.

The use of technology especially computers also contribute to better teaching and learning [16]. Previous research indicates that digital technology including simulations and animations as effective pedagogical tools that can enhance students’ understanding of science concepts, enabling them to integrate modes in visualizing the science concepts [16]. Computer simulations are considered as an effective tool to enhance and improve students conceptual understanding [17,18]. According to [12], computer simulations are computer-generated dynamic models that present theoretical or simplified models of real-world components, phenomena, or processes. Furthermore, computer simulations are used to model that which is not easily observed in real life [19]. By combining animations and visualizing science concepts, the computer simulations can support the development of insight into complex phenomena [20].

The previous research has been conducted in the science classroom and several advantages of computer simulations are quite compelling. Firstly, simulations can make abstract science phenomena more accessible and visible to students [21,22,23]. Secondly, simulations can animate dynamic changes in scientific processes that are difficult to infer from static illustrations found in the textbooks [23,24]. Thirdly, simulations help students visualize the phenomenon that might otherwise be difficult to depict [25]. Fourthly, simulation allows users to experience and interact with an environment like the real world [26]. Simulations allow students to play a more active role, thus allowing students to construct their own knowledge [27].

The computer simulations on light and optical instruments concept have advantages compared to the others simulations, such as the use of the simulation program is very easy; can be used repeatedly without using the internet; the display of simulation is simple and interesting; the simulation can be operated anywhere and anytime according to the need of students; the simulation can overcome students misconceptions and can improve students’ conceptual understanding in light and optical instrument concept.

4. Conclusion

Based on the analysis, the computer simulations were developed using 4D models (define, design, development and disseminate). The reason to develop computer simulations is to overcome students’ misconceptions on light and optical instruments concept. The results of the assessment by science
teachers showed an average overall 92% which indicate that the computer simulations on light and optical instruments concept in very good criteria and can be used in the learning process.

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