Using Four-Tier Multiple Choice Diagnostic Test to Identify Misconception Profile of 12th Grade Students In Optical Instrument Concepts

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Abstract. During physics learning process, quite often students experience a misunderstanding between their initial knowledge on certain concept in physics and that was taught in class by teacher. For example, students’ initial knowledge on Optics was that a white object can emit light so that someone can see the object even though the object is in a dark room. Meanwhile, in Physics concept, an object can only be seen by eyes only when there is light that hits the surface of the object and the light is reflected back by the object in all directions, including reaching to the eyes. This misunderstanding quite often leads to misconceptions. Such misconceptions should be detected as early as possible so as not to disturb student's understanding on the other concepts. This present study aims to analyse the misconceptions profile of 12th grade students in Senior High School 1 Cerme Gresik East Java in "Optical Instruments" concepts using the developed four-tier multiple-choice diagnostic test. Identification on the causes of students' misconceptions, especially that arising from theirselves was also presented. The most frequent misconception found is on the sub concepts of: 1) "Eye and Camera" caused by student's wrong preconceptions, 2) "Lup" due to associative thinking and 3) "Microscope" due to intuitive thinking. Meanwhile, for the "Binocular" concept, almost all students have had scientific conception, meaning that they have understood the concept well.

1. Introduction
Learning Physics means that studying natural phenomena along with the concepts [1]. Teaching and learning activities are a process of interaction between teachers and students. Teachers play an important role in the process of teaching and learning activities, a good teacher should always create conducive and effective learning so that students can easily understand the concepts. In the teaching-learning process, quite often occurs a mismatch between the concepts that students had already understood (termed as preconceptions) and the concepts taught by the teacher in class. This mismatch may lead to misconceptions on the students. [2, 7]. Misconception in learning physics is one's initial understanding of a physics concept that is not in accordance with the agreement of the physicists.

Based on the initial survey on the misconception in learning physics held by the authors in Senior High School 1 Cerme Gresik East Java, it was found that many students in grade 12 in Science class experienced misconceptions in “Optical Instruments” concepts. For example, when students were asked about the concept of how the objects around them can be seen by the human eyes, they answered that every white colored object emits light so that it can be seen by our eyes, even though the white object is placed in a dark room. However, physics concept in [3, 8] says that an object can only be seen by someone eyes when there is light that hits the object which is then reflected back in all directions, including hits the eyes so that the object is visible to human eyes. Figure 1 shows an illustration of an
object (in this case an alarm clock) that is visible to the eyes due to the presence of light. This survey revealed that the students' initial understanding on the concept of “Eyes” taught in class is still wrong. Some of them have alternative conceptions or even misconception.

![Figure 1. Illustration showing the process of seeing an object (an alarm clock) by the human eye due to the presence of light [3]](image)

Initial knowledge possessed by students on phenomena found in daily life is usually termed as a preconception of students. Without guidance by a competence teacher, such preconceptions may lead to misconceptions [2]. Such misconceptions should be prevented and detected early so as not to affect subsequent concepts. A diagnostic test is commonly used as a tool to detect student’s misconceptions [4]. In terms of completeness of the answers given by tested students and also time efficiency, so far a four-tier misconception diagnostic test has become the favorite diagnostic test instrument [5]. The first tier of the intended diagnostic test comprises of multiple-choice questions. The second tier reveals the level of students’ confidence in answering the questions, i.e. “sure” or “not sure”. The third tier represents the reason on answering the questions, while the last tier is the level of students’ confidence on choosing the reason. This paper reports the work to identify misconception profile of the 12th grade students in Science class at Senior High School 1 Cerme Gresik East Java in “Optical Instruments” using the developed four-tier misconception diagnostic test.

2. Method
2.1 Sample
The students at grade 12 in Science class at Senior High School 1 Cerme Gresik East Java were being the target of this study since they have learnt Optical Instrument concepts in the previous semester. Thirty of them were selected randomly on the basis of gender (boys and girls) and were involved in this work as the participants of this study.

2.2 Instrument
The four-tier diagnostic test instrument was prepared step-by-step before being used. First, potential misconceptions on the “Optical Instruments” were explored both from literatures and interview to the students. The results were discussed and consulted to a physics educator and two physics teachers. Second, an opened test instrument were written based on the consultation results above. The instrument was tested to a number of the first-year students in Physics Department, Universitas Negeri Surabaya. The aim was to collect students’ responses on the conceptual questiones. The responses were analysed. The meaningful responses and that appear frequently were chosen to produce alternative options of a multiple choice misconception diagnostic questions that were being prepared. At last, the 18-numbers of four-tier misconception diagnostic questions were finally produced. The intended test instrument, the
content validity and reliability of the questions was available in Rohmanasari 2019 [4, 6]. The first tier, as mentioned before, is the conventional multiple choice answers. The second tier is the confidence level of the answer on the first tier. The third tier is the possible reasons of given answers on the first tier. The reason options were designed in such a way that each given option represents the possible causes of misconception, namely preconception (PRE), associative thinking (AST), humanistic thinking (HUT), incomplete or wrong reasoning (WOR) and wrong intuition (WOI) and one correct reason. By this way, possible causes of students’ misconceptions should be easily detected. The last tier is the confidence level of the reasons on the third tier. Table 1 shows one of the developed four-tier question.

Table 1. One of the developed four-tier misconception diagnostic test in Optical Instruments

| Tier     | A sample of question |
|----------|----------------------|
| First-tier |                      |
|          | Figure 2. Three objects with the same height but at different viewing angles [8] |
|          | In Fig.2, OA, OB, dan OC are objects with the same height but viewed at different angles. OA is the farthest object and has the smallest angle compared to OB and OC. Determine the magnitude of shadow on retina starting from the biggest to the smallest based on its angle! |
|          | a. $\alpha_3 > \alpha_2 > \alpha_1$ |
|          | b. $\alpha_3 < \alpha_2 < \alpha_1$ |
|          | c. $\alpha_3 = \alpha_2 = \alpha_1$ |
|          | d. $\alpha_3 \geq \alpha_2 \geq \alpha_1$ |
|          | e. $\alpha_3 \leq \alpha_2 \leq \alpha_1$ |
| Second-tier | Are you sure about your answer? |
|          | a. I’m sure |
|          | b. I’m not sure |
| Third-tier | Which one of the following is the reason for your answer? |
|          | a. With the same height, the shadow of the retina is the same |
|          | b. The location of objects is getting farther away (the smaller the angle), the bigger the shadow on the retina |
|          | c. The location of the object is getting closer to the eye (the bigger the angle), the bigger the shadow on the retina |
|          | d. The size of the angle does not affect the shadow of the retina, which affects the height of the object |
|          | e. The size of the shadow on the retina is influenced by the size of the shadow formed by the eye |
| Four-tier | Are you sure about the reason for your answer? |
|          | a. I’m sure |
|          | b. I’m not sure |

2.3 Data Analysis
The students’ answers were classified into five types, i.e. 1) misconception (MC) that is when the answer and reasons are wrong, but the students are sure of the answer and reasons, 2) understood the concept (UC) when the answer and reasons are correct and they are sure of the answer and reasons, 3) did not
understand the concept (NUC) when the answer and the reasons were wrong and they are not sure of the answer and reasons, 4) understood partially (UP) when the answer and reasons were correct but they are not sure of the answer and the reasons, and 5) cannot be coded (CND) when the students either did not answer the question or did not give the reason or did not choose the level of confidence. Equation (1) was occupied to analyse the students answer [9],

\[ PJ = \frac{n_x}{n_s} \times 100\% \]  

(1)

where \( PJ \) is the answers % on each concept; \( n_x \) is the number of students grouped as MC, UC, NUC, UP, and CND, while \( n_s \) is the total number of student participants (30).

The causes of misconceptions, i.e. preconception (PRE), associative thinking (AST), humanistic thinking (HUT), wrong intuition (WOI), and wrong reasons (WOR) were analysed using the Equation (2) [9],

\[ PPM = \frac{n_x}{n_M} \times 100\% \]  

(2)

where \( PPM \) is the causes % of misconceptions; \( n_x \) is the total number of students due to the PRE, AST, HUT, WOI, and WOR reasons while \( n_M \) is the total number of participants (30).

3. Results and Discussion

Figure 3 shows the distribution of conceptions of 30 numbers of student participants under the “Optical Instruments” that comprises of the sub concepts of “Eye”, “Lup”, “Camera”, “Microscope” and “Binoculars”.

![Figure 3](image)

Figure 3. The distribution of students’ conception (%) in various sub concept in “Optical Instruments”. UC = understand the concept, UP = understanding partially, MC = misconceptions, NUC = not understand the concept, and CND = cannot be coded.

Based on Figure 3 above, it can be seen that around 16-51 % of the students experienced misconceptions on the concepts of “Eyes”, “Cameras” and “Microscopes”. There are 13-27 % of students understood the concepts well, less than 23 % of them only have partial understanding the concept, less than 21 % didn’t understand the concept at all and less than 11 % cannot be encoded. Those 11 % of the students were therefore skipped. On the “Binoculars”, about 30 % of the participant have good understanding on the concept. Another 10 % of them cannot be coded, 60 % of students were
identified suffered from misconceptions, understood the concept partially, and didn’t understand the concept, each was 20%.

As reported in Rohmanasari [6], the most common problem faced by secondary high school students in Senior High School 1 Cerme Gersik is misconception. When the students were given a conceptual question, they experienced a difficulty in working on it. They prefer to solve question-related to formulas since the only requirement to answer such question well is memorising the related mathematical formula. However, the “Optical Instruments” mostly required good understanding on the related concepts. Below is one of the conceptual questions in the “Eye” written in the instrument (Question No. 1): “Given two different books, one is white and the other is black. Those books were placed in a dark room. According to you, can the two books be visible by your eyes?” Similarly, in Question No. 2, “Given an object in the form of a white flower vase was filled with water and colorful flowers. When the object is placed in a room where there is no light source, according to you, can it be seen by the eye?” The students assumed that the white book and white vase can be seen by the eyes, because white objects can emit light. However, based on the Physics concept [3, 8] an object can be seen by the eyes when there is a light source that bounces about the object and is reflected back to the eyes. Therefore when there is no light bouncing from the surface of the object to the eyes, the intended object was unseen.

In Figure 3, the distribution of students who understood the “Camera” concept are almost equal with that who understood the concept partially, who suffered from misconception and who did not understand the concept at all, i.e. 14 – 18%. Question No. 13: “Given three different size of images of the same object, i.e. small, medium and large size. Those images were taken from the same type of camera but the lens diameter of each camera (d) was different, i.e. \( d_1 \) = the lens diameter of camera 1, \( d_2 = 2d_1 \) and \( d_3 = 3d_1 \). Sort the three cameras based on the size of the images, starting from the smallest image to the largest”. Students assumed that the larger the lens diameter of a camera, the greater the image of the object produced because a camera with a larger lens diameter is able to capture more light. However, Physics concept in [8] says that when someone observes an object through the camera lens with the focus rotated from the smallest to the largest one, the object looks bigger (fills the frame). When the focus is small, the viewing angle is large so that the area that enters the frame is wide and causes object to look small. If the area that goes into the frame is getting narrower, the object looks bigger and bigger. Therefore, the focal length of the camera affects the size of the resulting image. The longer the focus, the narrower the angle of view of the image so that the resulting image size becomes large, and vice versa. The difference between students’ assumptions and the physics concept has the potential to cause misconceptions on students.

![Figure 4](image-url)  
**Figure 4.** Distribution of students’ misconceptions in various sub concepts in “Optical Instruments” based on different causes: PRE = preconceptions, HUT = humanistic thinking, WOR = wrong reason, WOI = wrong intuition, and AST = associative thinking.
Figure 4 above shows the distribution of the causes of misconceptions of the students in various sub concepts in the “Optical Instruments” due to preconception (PRE), associative thinking (AST), humanistic thinking (HUT), wrong intuition (WOI), and wrong reasons (WOR). In each sub concept found misconceptions originating from various causes. Overall more than 18% of the misconceptions on the Eyes, Camera, and Binoculars concepts are dominated by PRE. Another 17-18% was due to WOR on the Eyes and Cameras, the rest was caused by WOI and AST. On the Lup concept, misconception is dominated by AST, while on the Microscope concept, the WOI cause dominated. Misconceptions caused by PRE are likely to be difficult to overcome because the students’ initial knowledge has embedded in student’s minds. An alternative, a teacher should provide students with new experiences and hands-on activities on learning physics concepts on a regular basis. Such regular activities are believed to be able to eliminate the students’ misconceptions and accept the correct concepts. A similar approach can also be introduced to eliminate the other causes of misconceptions.

4. Conclusion
This study confirmed that misconception on the Optical Instruments concepts identified on the 12th grade students in Science class in Senior High School 1 Cerme Gresik East Java. The dominant causes was preconceptions. Having these results, it is recommended for Physics teacher in Secondary High School to take a concrete action by involving the students to empirical learning processes.

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