Identification of students' misconception about light using a four-tier instrument

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Abstract. The research objective is to make a valid and reliable identification of junior high school students' misconceptions about light. The four-tier light instrument (FTLI) was administered to 456 students from two junior high schools in Jambi, Indonesia. Data were analyzed to obtain the percentage of students who have scientific concepts and misconceptions. The results indicated that only 7.7% understood the concept well, and 12.1% had misconceptions about light. The remaining students were categorized as experiencing false positives, false negatives, and lack of knowledge. There are 12 types of misconceptions about light that can be identified. Some of them are: (1) Light cannot reach faraway places, but distant observers can see the light source; (3) The distance traveled by the candles during the day is shorter than at night; and (3) The color vision of an object is not determined by the color of the light hitting the object.

1. Introduction

Studying science, especially physics, for some students is not easy [1], [2] even some students can experience misconceptions [3], [4]. The misconception is a deviation from the understanding of scientific conceptions or theories that scientists have and are used in many kinds of literature [5]. The Misconceptions usually arise because students make their conceptions based on their daily experiences that are not following the actual conceptions and as a result of the existence of wrong propositions on the relationship between concepts. Misconceptions occur in almost all concepts of physics, for example, in temperature and heat [3], work and energy [4], electric circuit [6], [7], waves [8], optics [9], [10], and color [11]. The presence of misconceptions in students can hinder the achievement of learning objectives because students who have already experienced misconceptions will still hold the conceptions that they think are correct; therefore, misconceptions need to be identified.

Light is a phenomenon that is close to students because it is often found in everyday life. Light material is also taught in primary and secondary schools in Indonesia. Even so, teachers rarely identify misconceptions of their students using the right methods and instruments. Identification of misconceptions about color and other physics topics is a crucial thing to do in the physics learning process. If the identification process is not carried out, the teacher will not know whether the students understand the material they teach and are free from
misconceptions. The effort to identify misconceptions must be made appropriately to avoid mistakes because misidentification will lead to errors in concluding and overcoming them.

One type of instrument developed and recognized to identify misconceptions well is a four-tier multiple-choice instrument type. This type of tool's strength is that it can distinguish students who understand scientific concepts well, have no knowledge, and experience false positive and false negative or misconceptions. How do junior high school students understand the concept of light? Do they experience misconceptions? How are the descriptions of the misconceptions they experience? The use of FTLI in this research activity provides meaningful information for teachers and science educators, especially physics. The purpose of this study is to identify junior high schools' students' misconception about light using a four-tier instrument.

2. Method
This type of research is a quantitative descriptive study with a research focus to determine junior high school students' misconceptions about light. The respondents were 456 grade 9 students from two schools in Jambi City who had studied light material. The instrument used to collect data was a Four Tier Light Instrument (FTLI), consisting of 10 items, and each item has four tiers. The first tier is multiple choice questions and answers. The second tier is the level of confidence in the answers. The third tier is the reason for the answers given, and the fourth tier is the confidence level of the reasons. Item 1 and 9 in Figure 1 are example items of the FTLI that has been used in this study.

| 1.1 | A car is pulling up on a flat straight road one night. The driver of the vehicle showed the headlights of the car. Straight ahead was a pedestrian at some distance that was out of sight of the driver. Can pedestrians see the headlights of the car? a. No, he cannot b. Yes, he can |
| --- | --- |
| 1.2 | The level of confidence in the answer: a. Sure b. Not Sure |
| 1.3 | Reason: a. The light will only travel a short distance in front of the car, which the driver can see. b. Pedestrians are not visible to the driver, so pedestrians cannot see the light from the car. c. Pedestrians can see car headlight because their eyes can still detect the light, and the light continues to move farther away. d. Pedestrians cannot see the light so the light can reach how far the pedestrian is. e. The light from the car could not reach far away. But pedestrians could see the distant light source. |
| 1.4 | The level of confidence in the reason: a. Sure b. Not Sure |

| 9.1 | When someone shines a red piece of glass with white light, that light looks red on the other side. |
| --- | --- |
| 9.2 | The level of confidence in the answer: a. Sure b. Not Sure |
| 9.3 | Reason: a. Glass adds red color to white light so that it looks red. b. Glass lets in all the light but only pass the red color with the light. c. White light is made up of many different lights. Red glass only lets red light through it; other colors are absorbed. d. The glass turns white light into red light by bending it. |
| 9.4 | The level of confidence in the reason: a. Sure b. Not Sure |

**Figure 1.** Item example of FTLI

Data analysis is done by calculating the percentage of correct scores for each tier, false positive, false negative, and lack of knowledge and determining the misconception score. The percentage of the correct score for each item used the equation:
The X value shows the percentage of each item's correct score, and CS is the item's Correct Score according to the tier. For example, for the first tier, if the answer is correct, CS = 1, and if it is wrong, it is given a score of 0. Whereas for the first and third tier, if the answer is correct and the reason is correct CS = 1, otherwise it will be given a score of 0. Furthermore, after the correct score data is analyzed, the researcher continues to analyze data about misconceptions, classify students’ misconceptions according to the percentage, and identify which sub-concepts the students experience misconceptions. Several categories of misconceptions based on the percentage can be seen in Table 1.

Table 1. The percentage category of misconceptions

| Percentage       | Category |
|------------------|----------|
| 0%-30%           | Low      |
| >30%-60%         | Medium   |
| >60%-100%        | High     |

3. Result and Discussion

3.1. Survey results of junior high school students' correct answers to FTLI

The results of the research on the correct answers given by students for each item are shown in Figure 2. The percentages of correct answers are categorized by scoring only the first tier, first and third tiers, and all four-tiers.

Figure 2 shows that the correct answers at the first tier are the highest among all categories. The first tier score is only determined by the correct answers given by students without taking into account the reasons and the level of student confidence in both the answers and/or the reasons given. If FTLI is considered a conventional multiple-choice instrument based only on the answer given (the first tier), then 34.6% of students have given the correct answer and have understood the concept of light. This
percentage drops to 10.4% when the reason is also taken into account in the scoring. This fact shows that 24.2% of students do not have the right reasons, even though the answer choices are correct. The percentage dropped to 7.7% when students' confidence in the answers and the reasons accounted for the scoring. Based on measurements using FLTI, it can be said that students who have scientific knowledge about light are only 7.7%. The other proportions are categorized as false positive (correct answers but wrong reasons), false negative (wrong answers but right reasons), lack of knowledge (not sure about their answers and or explanations), and have misconceptions in Table 2.

### Table 2. Percentage of a false positive, false negative, and lack of knowledge

|   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | Mean |
|---|----|----|----|----|----|----|----|----|----|----|------|
| FP| 54 | 0.9| 44 | 9.3| 10 | 17 | 4.9| 9  | 16 | 13.3| 17.8 |
| FN| 2.2| 1.5| 0.6| 13 | 3.4| 6.8| 15 | 2.2| 7.1| 6.5 | 5.8  |
| LK| 15 | 19 | 30 | 30 | 31 | 22 | 34 | 26 | 27 | 35.2| 26.9 |

FP= False Positive  
FN= False Negative  
LK= Lack of Knowledge

3.2. Survey results of junior high school students’ misconception about light

In contrast to determining each item's correct score, the misconception score is determined based on different criteria that describe the misconception (M1, M2, and so on). One item can measure more than one kind of misconception, and conversely, several items can simultaneously measure a misconception. For example, the first misconception (M1) that light cannot reach distant places, but distant observers can see the light source is measured by item 1 and item 3. The number of misconceptions that can be identified using the ten items FLTI instrument is as many as 12 kinds of misconceptions. Figure 3 shows the percentage of misconceptions categorized by scoring only the first tier, first and third tiers, and all four-tiers.

![Figure 3. Percentages of misconception](image-url)

Figure 3 shows that the order of the percentage of students who experienced misconceptions from the highest to the lowest was: misconceptions only for the first tier, then the first and third tiers, and...
misconceptions for all tiers. The average percentage of misconception scores for the first tier is 37.2%. The percentage of students who have misconceptions according to the first tier is the highest because the scoring is only seen from the students' answers, regardless of the reasons and the level of confidence in choosing answers; so that if the student's answer is the same as the answer key for the misconception or in other words the student's answer is not in accordance with the scientific conception, the score is 1.

Students who answered according to the misconception answer key for the first tier were not fully said to have experienced misconceptions because there were two possible answers. First, students gave the wrong answer because they had misconceptions; second, students answered wrong because they only guessed. In order to determine whether students have misconceptions or not, all tiers must be considered, namely looking at answers, confidence in answers, reasons, and confidence in reasons. If the answers and reasons are correct, students are also sure of the answers and reasons were given, they will receive a score of 1. If among the four tiers, there is something wrong or not sure the score is 0. Therefore, the misconception that refers to all four tiers has the lowest percentage; in the data above, students who experience misconceptions are only 12.1%. Based on the categories in Table 1, the misconceptions experienced by junior high school students in Jambi City about light are classified as low because the percentage is still below 30%. However, misconceptions should not be allowed; it must be remediated because it will become an obstacle in the student learning process [3], [4], [12]. Another interesting finding is that it turns out that the percentage of students who experience a lack of knowledge is 26.9%. This figure is greater than the percentage of students who have scientific knowledge or who have misconceptions. It proves that there are still many students who are not sure about the knowledge they already have. Therefore, this study's information will be of great use and advantages to science teachers in junior high schools.

In more detail, all misconceptions about the light that have been identified using FTLI and associated items on the instrument are described in Table 3. The percentage of students who experience misconceptions for each description can be seen again at the bottom line (all four tiers) in Figure 3.

| M#  | Misconceptions                                                                 | Item                                                                 |
|-----|-------------------------------------------------------------------------------|----------------------------------------------------------------------|
| M1  | Light cannot reach distant places, but observers in that distant place can see the source of the light. | 1.1b 1.2a 1.3a 1.4a 3.1d 3.2a 3.3e 3.4a                               |
| M2  | Light only travels as far as the observer's position.                          | 1.1b 1.2a 1.3d 1.4a 3.1a 3.2a 3.3e 3.4a                              |
| M3  | If light can not illuminate a place, it does not reach that place.            | 1.1a 1.2a 1.3b 1.4a                                                |
| M4  | Dim light can only be seen when there is brighter light on it.               | 2.1a 2.2a 2.3a 2.4a                                                |
| M5  | The light intensity of a candle or lamp is smaller during the day than at night. | 2.1b 2.2a 2.3b 2.4a 10.1a 10.2a 10.3a 10.4a                       |
| M6  | The distance traveled by candles during the day is shorter than at night.    | 2.1c 2.2a 2.3b 2.4a                                                |
| M7  | Candlelight cannot reach great distances.                                    | 3.1a 3.2a 3.3b 3.4a                                                |
| M8  | When looking at objects, there is no reflection of light from the object to the eye. | 3.1c 3.2a 3.3b 3.4a 4.1c 4.2a 4.3e 4.4a 4.1a 4.2a 4.3b 4.4a 5.1d 5.2a 5.3a 5.4a |
| M9  | Objects can be seen because there is a signal emitted by the eye to the object. | 5.1a 5.2a 5.3d 5.4a                                                |
| M10 | White objects absorb light and do not reflect this light.                    | 5.1c 5.2a 5.3b 5.4a                                                |
| M#  | Misconceptions                                                                 | Item       |
|-----|-------------------------------------------------------------------------------|------------|
| M11 | The color of an object is not determined by the color of the light hitting the object. | 6.1c 6.2a 6.3d 6.4a |
| M12 | If polychromatic light passes through a colored object, the color of the object will affect the color of the light. | 7.1a 7.2a 7.3c 7.4a |

Based on the identification of misconceptions on light, there are still many students who have conceptions: (1) The light intensity of candles is lower during the day than at night, and the distance traveled by candles during the day is shorter than at night; (2) Light cannot reach distant places, but observers in that remote place can see the source of the light; (3) The color of an object is not determined by the color of the light hitting the object; (4) If sunlight or polychromatic light passes through a colored object, the color of the object will affect the color of the light. These findings are in line with other researchers' research, which finds that light stays around an object and does not travel at all during the day [13]; color is a property of things [11].

4. Conclusion
In this study, the four-tier light instrument (FTLI) can identify junior high school students' misconceptions more accurately than other forms (conventional multiple-choice test, two or three-tier test). Based on the results and discussion, it can also be concluded that students still have misconceptions about light even though they have learned the concepts of light before.

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