Diagnosis of Students' Conception on Light and Optic Topics with Four-Tier Test

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Abstract. Students' conception is defined as the way students make sense of a range of natural phenomena. Identifying students' conception is essential because it leads to more focused teaching and enables teachers to prevent and eliminate misconceptions. The four-tier test is chosen because it is a stronger and more sensitive diagnostic test. Light and optic topics are chosen because it is an essential topic at school and there are repetitive misconceptions in these topics. Therefore, students' conception on light and optic topics is diagnosed with the four-tier test in this research. The instruments were constructed from a list of indicators. The questions were administered online to 817 8th-grade students. Students' conception is categorized into five which are scientific knowledge, false positive, false negative, misconception, and lack of knowledge. Frequencies and percentage are calculated with excel program and the data is further analyzed with Mann-Whitney U test to see if there is any significant difference between students who have learnt the topics and who have not. The result shows that in general, students have more misconceptions than scientific knowledge, students did best in the formation of images on mirrors, students did worst in the optical instruments, and there is no significant difference between students who have learnt the topics and those who have not. The causes are unconfronted misconceptions, online learning, and unfamiliarity. This indicates that teachers need to address common misconceptions in class, facilitate conceptual change through hands-on activities, and relate the concept with students' daily life.

Keywords: Diagnostic Tes, Dour-Tier Test, Light and Optic Topics, Students Conception

Introduction

Students come to the class with preconceptions they get from their intuition and experiences [1], [2], [3], [4]The preconceptions might be in line with scientific concept [5]. However, when it is not in line with scientific concept then it is identified as misconception [6]. Misconception can be caused by various reason such as the book that students read, daily experiences, intuition, or family guidance [7], [8]. Diagnosing

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students conceptions has been one of the trends in science education research [6]. It is one of pedagogical competence for teachers so they can plan the best learning experiences that accomodate students' need [9], [10], [11], [12]. More importantly, it prevent the misconceptions to stay or get worse [13][14], [15]. The essential of diagnosing students conception is also strengthen by the facts that misconceptions have a lot of bad impacts. It lowers stundets persistence and performance [16], [17]. It inhibits science learning and causing resistance to the proposed development [18], [19].

Along with the popularity of students' conception as a research topic, the instruments to diagnose students' conception are also developed by researchers. There are various types of diagnostic instruments such as interviews, open-ended tests, simple multiple-choice, two-tier multiple-choice, three-tier multiple-choice, and four-tier multiple-choice [20]. Each one was developed to overcome drawbacks from the previous types of instrument [21]. The four-tier test instrument is more sensitive and powerful [22]. Since each question consists of four tiers, this type of instrument enables researchers to have a better view of students' understanding. The confidence level is rated by two options which are sure and not sure [23], [24]. Diagnosing students' conception had been done in Biology, Chemistry, and Physics alike. However, in this study, Light and Optic Topics are chosen considering that it is one of the essential topics at school based on the 2013 National Curriculum. It is also closely related to students' daily life as light is very vital in the process of seeing. The topic is also chosen because there are findings that point to the identification of the same misconception over time such as we see things without the light being reflected, light travels differently at night and day, and we can adjust to see in total darkness had been found since 1984 [25], [26].

Students' conceptions are often being compared in various ways. For instance, it is compared between control groups and experimental groups to see if a certain intervention is effective to reduce misconception [27]. In another study, students' conceptions are being compared between aboriginal and urban junior high schools [28]. The conceptions of students have been also compared with pre-service science teachers [3], [29]. The comparison had also been done related to light and optic topics. Research in 2013 was done to analyze students' conception on light propagation and visibility of objects. This research also investigated whether or not grades, student achievements, teaching approach, and education system were predictive variables. The result shows that there is no significant difference among grades [30]. However, there has been no research that compares students' conception between those who have and have not learned the light and optic topics. Moreover, previous research also found that courses conducted online resulted in a higher misconception percentage than courses that are conducted offline [31]. It is relevant to the learning method used in Indonesia during the pandemic era. So in this research students' conception on Light and Optic Topics identified with the four-tier test will be analyzed. This research will also talk about the misconception identified. Lastly, the comparison of both groups of students will also be discussed.

2 Method

This research is survey design research with cross sectional methods [32]. The researcher administered an instrument to collect data from the sample at a particular point of time [33]. There are 817 participants in this research taken by convenience sample or those who are easy to reach [34]. They are 7,8, and 9 graders from schools that use 2013 National Curriculum located in the West Java Province, Indonesia. The participants are divided into two groups. 372 students who have learned light and optic topics and 445 students who have not. In this research, a four-tier diagnostic test on Light and optic topics is used to diagnose students' conception on the topics. The instrument is based on a list of indicators from the previous research [35]. There are 19 sets of questions with four sub-topics which are the properties of light, the formation of images on mirrors, human eyes, and optical instruments. The distribution and the indicators can be seen in Table 1.

Table 1 Distribution of Questions

Sub-topic	Indicator of Question	Item
The properties of light	Light as magnetic wave	Q1
	The relationship between light and vision	Q2
	Monochromatic and polychromatic light	Q3
	Light refraction	Q4
	Light pass through materials	Q5
	Light travel in a straight line	Q6
	The moon reflects light	Q13
The formation of image on mirrors	Distance of image in plane mirrors	Q7
	Left-right reverse in plane mirror image	Q8
	The angle between mirror, object, and image in plane mirrors	Q9
	Formation of Image between two plane mirrors	Q10
	Convex mirror image characteristics	Q11
	Concave mirror image characteristics	Q12
Human eye	Myopia	Q14
	Hypermetropia	Q15
	Concave lens correcting myopia	Q16
	Convex lens correcting hypermetropia	Q17
Optical Instrument	What can be seen with microscopes	Q18
	Type of mirror in microscopes	Q19

Each set of questions consists of four tiers. Questions in tier one are made in the form of multiple choices with four options. The second tier is about the confidence level of the answer on the first tier. There will be 2 options which are sure and not sure. The third tier will be about the scientific reason for the answer on the first tier. There will be 4 options in the third tier. The fourth tier is about the confidence level of the answer on the third tier. The sample question is shown in Table 2.

Table 2 Sample Question

Tier	No	Question
1	2. a	A plumber is told to repair a leaking pipe in the basement. He goes down the stairs and gets in the room. He finds the switch and turns on the lamp. With the lamp on he studies the leaking pipe. However, just before he finishes his work, the electricity is off and the lamp is off too. What do you think the plumber is seeing now? a. He still can see all the stuff in the room b. He can see only the silhouette of all the stuff in the room c. He can see some stuff near him d. He see nothing
2	b	Are you sure about your answer? A.Sure B. Not sure
3	c	Reason: a. Eyes can see even without light because of it's special structure b. Eyes can produce light, so the eyes can see objects c. Eyes need light source that coming right into it d. Eyes need light source to hit the object an so the light is reflected to the eyes
4	d	Are you sure about your answer? A.Sure B. Not sure

The Instruments were then administered online for about a month with Google Form and students filled it in without the author's presence. Once the data collected, students' answer combinations were coded into scientific knowledge (SK), false positive (FP), false negative (FN), misconception (M), and Lack of Knowledge based on decision in Table 3. Those are done with the "IF" and "AND" function in the excel program. Frequencies and percentages were calculated in the data analysis. In the first stage, the percentages of scientific knowledge, false positive, false negative, and misconception were analyzed. The value of students' conception was tested with the Mann-Whitney U test. This is a test to see if there is any significant difference between the two independent groups [36]. On the second stage, the questions with more than 50% misconception were also analyzed. The option combination of students' answer on those questions were analyzed deeper. Frequencies and percentages were also calculated.

Table 3 Combination Answer and Decision on Four-tier Test

Tier 1	Tier 2	Tier 3	Tier 4	Decision
True	Sure	True	Sure	SK
True	Sure	False	Sure	FP
False	Sure	True	Sure	FN
False	Sure	False	Sure	M
True	Sure	True	Not Sure	LK
True	Not Sure	True	Sure	LK
True	Not Sure	True	Not Sure	LK
True	Sure	False	Not Sure	LK
True	Not Sure	False	Sure	LK
True	Not Sure	False	Not Sure	LK
False	Sure	True	Not Sure	LK

Tier 1	Tier 2	Tier 3	Tier 4	Decision
False	Not Sure	True	Sure	LK
False	Not Sure	True	Not Sure	LK
False	Sure	False	Not Sure	LK
False	Not Sure	False	Sure	LK
False	Not Sure	False	Not Sure	LK

3 Results and Discussions

The research findings are discussed below. The data was taken and underwent statistical analysis procedures. The results that are elaborated below are about conception of students who have learned Light and Optic Topics compared to students who have not. Misconceptions that has more than 50% are also discussed.

3.1 Student's Conception on Light and Optic Topics

Students' conception is categorized into five. The categories are scientific conception, false positive, false negative, misconception, and lack of knowledge. The conceptions of students who have been taught light and optic topics and who have not can be seen in Fig. 1. Both groups of students have low scientific knowledge, high level of misconception, and they have more misconception than scientific knowledge. The research findings are in line with previous research. Students are identified to have misconceptions about acts of vision, properties of light, shadow formation, light reflection, and image formation [37] light and its properties [38], optical instrument [39], and light and optic topics [40].

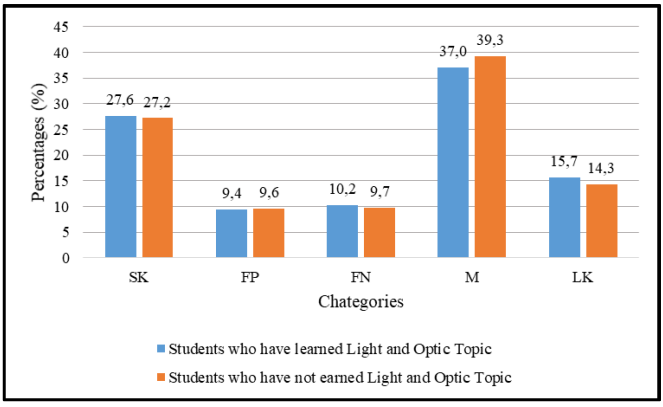

Fig. 1 Students' Conception on Light and Optic Topics

The low level of scientific understanding and the high level of misconception can be caused by everyday experience, language, teachers, and textbooks [40], poor language proficiency [41], [42], and books [7], [26]. This can be remediated by textbooks,

classroom teaching, and practical work. The data collected from two groups of students. The data is considered good. This is because based on research by Kiray and Simsek, Hestenes and Halloun recommend less than 10% false positive and false negative [43]. To see if the difference between groups is significant, the data underwent normality and significance tests. The result shows that in all categories there is no significant difference between students who have learnt the topics and who have not. The result is inline with previous research. It shows that lessons in class do not help students to build their conceptual knowledge and eliminate misconceptions in Light and Optic Topics [11]. This is caused by wrong intuition and needs to be remediated by hands-on activities.

Another research about Light also shows that there is no significant difference in students' misconceptions among grades 7, 8, and 9 [30]. The article also elaborates the causes and those are language difficulty, lack of contextual learning, and no demonstration kit for students. Teachers didn't provide students with knowledge about how the fundamental concepts related to students' daily life in different situations. It is proposed that teachers should give contextual learning to connect the concepts to real-life phenomena and provide students with demonstration kits. It can also be caused by online learning [31], unconfronted misconceptions [13], and unfamiliarity [44].

Students' Conception on The Properties of Light.

In the properties of light subtopics, it is found that there is no significant difference between students who have learnt the topics and those who have not in all five categories. It is also found that students have misconceptions about light sources, ray diagrams, and how light propagates to human eyes [45]. The first reason to it is that teachers focus more on basic concepts rather than guiding students to understand daily life phenomena from the properties of light point of view. Teachers don't take the learning difficulties and the common misconception into account. This is bad because students' unconfronted misconceptions might stay or even get worse [13]. Students also have misconceptions about the properties of light because teachers don't emphasize common misconceptions and do not giving hands-on activity in class [46]. In line with a study done in 2010. It shows that even after instruction, students still have a high level of misconception and a low level of scientific knowledge [47]. The reasons for because students' misconceptions are not taken into consideration during the lesson. Moreover, the lesson might not use student-centered approaches. Conceptual change curriculum might be used to overcome the problems [48].

Students' Conception on The Formation of Image on Mirrors

In the conception of the formation of Image on mirrors there is no significant difference between both groups in the four chategories in all five categories but misconception. Differ with the other four categories, Misconception category has 0.007 as the significance value. This shows that there is a significant difference between both groups in this particular category. Students who have learnt the Light and Optic Topics significantly have less misconception on the image formation on mirrors subtopic than students who have not. The result found in this research is in line with previous research. Beforehand, students' conceptual understanding of geometric optics were

compared. The result shows that students from grades 8-12 have rising scientific knowledge levels [49]. Students' low scientific knowledge and high level of misconception on Image formation on mirrors subtopic can be caused by several reasons. The first is students' interpretation of everyday experience [50]. Students also have misconceptions on image formation on mirrors subtopic because of the lesson at school only focus on how to use the equation related to mirrors [51]. Interacting with mirrors or having experiments can overcome the low level of scientific knowledge and misconceptions [52]. Students can also practice drawing ray diagrams to confront and elicit their misconceptions [53]. Related to the significant difference between students who have learnt the Light and Optic Topics in the misconception category,

Students' Conception on Human Eye

In this subtopic there is no significant difference between both groups in the four categories. Differ to the other four categories, the Misconception chategory has 0.040 as the significant value. This shows that there is a significant difference between both groups in this particular category. The result however is in line with the previous research. Students' conception about human eyes and the lenses used to remediate myopia and hyperopia had been done in previous research. Around 20% of secondary school students have misconceptions about what lens to help with myopia and hyperopia [49] and there are only 3% of students who have a sound understanding.

Another research has also found that students have misconceptions about lenses [51] This result might be caused by the unfamiliarity of students with lenses. This is because if we compare to mirrors, students are likely to have less experience with lenses [54]. Unfamiliarity is proved to be the cause of students' misconceptions [44]. It could also be caused by personal experience, textbooks, language, or the teachers. Students' intuitive thinking might lead them to an incorrect conclusion. Students also can get misconceptions from the book they read. Teachers who don't inform students or who don't confront students' misconceptions can also cause misconceptions because unconfronted misconceptions might stay or even cause more misconceptions [13].

Students' Conception on Optical Instrument

When the conceptions of students who have learnt the topic and who have not been compared, we can see that this subtopic is quite different from the previous three. The first is that the misconception percentage for both groups is more than 50%. This percentage is the highest among other subtopics. This is added by the fact that students who have learnt the topics have a higher percentage of misconceptions than students who have not learnt the topics. The second is that the Scientific Knowledge percentages are less than 10% for both groups. This percentage is the lowest among other subtopics. Moreover, the Scientific Knowledge percentage for students who have not learnt the topics is higher. It might be caused by the unfamiliarity of students with the instruments. However, the results found in this research are much higher than the previous research where only 35% of students have misconceptions about microscopes [55]. The reason for the very high level of misconceptions is because of students' intuitive thinking. When students are given new knowledge, they will try to fit that knowledge into what they've already had. This can be done by their intuition. But, their intuition can be

wrong. This is getting worse because that intuitive thinking might not be confronted or considered during class even though it is true that expressing their ideas is good for students [45]. The unconfronted misconception will stay or even students can develop a new one [13].

The next possible reason is that students are unfamiliar with microscopes since unfamiliarity causes misconception [44], [56]. Compared to mirrors and lenses, students are less familiar with microscopes. Very few students have had experience with microscopes in their daily life. Students' understanding of microscopes is also affected by students' understanding of the properties of light, mirrors, and lenses, since microscopes work with those concepts. However, as can be seen in this research, students' conception of those three is still low. Students are identified to have misconceptions on the properties of light, mirrors, and lenses [54]. When students have misconceptions in those things, students will find it hard to have a good conception about microscopes [18].

With the COVID situation, teachers have no choice to deliver the topics through online learning or to assign students to read books. However, online learning is proven to cause more misconceptions [31]. Besides, online learning also inhibits teachers' immediate feedback for students. Books can also cause misconceptions. Some books contain misconceptions [7], [8]. Even there are books which cause misconception because it doesn't talk about any misconceptions to confront them [26]. Students also lose their chance to interact with microscopes to understand it better. The reasons show that even though students have learnt the light and optic topics, they didn't get the experience as they should. They don't get to experiment, observe, and relate how the concept works in daily life. This condition is causing them to have no better experience and conception than the students who have not learnt the topics. That is how their conceptions are not significantly different.

3.2 Students' Misconception on Light and Optic Topics

Both groups of students who have learnt light and optic topics and who have not, surprisingly have more than 50% misconceptions on the same questions. Those are questions 10, 13, 18, and 19 as can be seen in Fig. 2 below. Misconceptions for each question will be elaborated. Question 13 represents the properties of light subtopics. It identifies students' conceptions on why we can see the moon at night. Students are expected to have a sound understanding that the light from the sun is reflected by the moon so that we can see it at night. The students believe that they can see the Moon at night because humans' eyes emit special light that enables them to see. This is in line with previous research [25], [37]. Some also believe that they can see the moon at night because it produces its own light. This happens because the teachers are more focused on the concept of light propagation and shadow formation rather than light source [45].

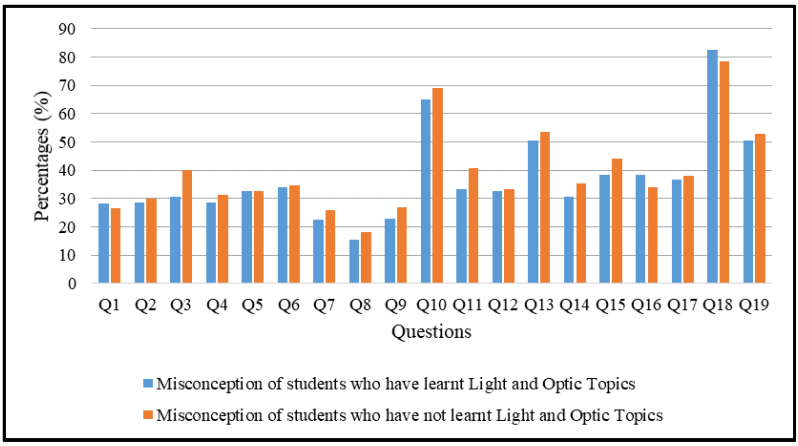

Fig. 2. Students' Misconceptions on Light and Optic Topics

Question 10 represents the formation of images on mirrors subtopic. This question tried to identify students' conception on how many images will they see if they put an object in front of two mirrors that form a right angle. Some students believe that they will see two images formed on the mirrors because there are two mirrors. This means that students associate the number of images formed to the number of mirrors and believe that the angle between the two mirrors has no effect at all on image formation. Others believe that there will be 4 images formed because both images will be reflected again. So even though students take the angle between the mirrors into account, they still got a wrong conception. Misconceptions about hinge mirror can be caused by only focusing on the equation [54]. Students also have less experience with it. This can be reduced by doing experiments that facilitate conceptual change so that students might get a better conception on mirrors [52]. It can also be reduced by taking advantage of Geogebra 3D Calculator that enables students to insert real pictures and draw virtual ray diagrams to help them understand the concept of image formation on mirrors [57].

Question 18 represents the optical instrument subtopic. In this question, students were asked about what they think they'll see if they try to see a virus under a light microscope. It is expected that students will answer that they will see nothing because the virus is too small for the light microscope to see. However around 80% of students from both groups are identified to have misconceptions. Students believe that when a scientist tries to observe a virus under the light microscope, the scientist will see a very clear image of the enlarged virus because a light microscope helps to see a very small object. Students also believe that there will be a very clear but small image of the virus when the scientist tries to observe it under a light microscope. In previous research it is caused by students' intuitive thinking and the unconfronted misconception [13], [55]. Most likely, teachers and books don't talk much about what cannot be seen through the light microscope.

Question 19 represents the optical instrument subtopic. In this question, students were asked about what types of mirrors need to be used in light microscopes so that the mirror helps to focus the light. students believe convex mirrors are used in light

microscopes to help to focus the light on observed objects. This is also a misconception because convex mirrors have diverging effects. It reflects light outward and is the opposite of focusing light. Students' answer indicates two things. The first is that students don't understand that only a concave mirror has converging effects. They don't understand that a plane mirror reflects light without any effect and convex mirrors have the opposite effect which is reflecting the light outward. To enhance students' scientific conception of light reflecting on concave mirrors, practicing ray diagrams can be done. This can elicit and confront students' misconceptions on geometrical optics and also facilitate conceptual change [53]. The second thing is that students are not familiar enough with light microscopes so that they don't understand which mirror is used to focus the light in it. It is very essential then, to introduce students to light microscopes. Students need to be given the chance to interact with the optical instruments so that they can understand them better. However, with online learning not all students have access to light microscopes even though the schools have them in their laboratory.

4 Conclusion

Two conclusions are drawn from the research. The first point is that in general, there is no significant difference between students who have learnt the light and optic topics and those who have not. Both groups of students have more misconceptions than scientific knowledge. Among the four subtopics, both groups of students did best in the formation of images on mirrors subtopic and did worst in the optical instrument's subtopic. The second point that can be concluded from this research is that students have more than 50% misconception on questions about the moon as a secondary source of light, the number of images in hinged mirrors, and microscope. There are various reasons for it such as unconfronted misconception, online learning, and unfamiliarity.

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