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Development of Physics Test Instrument to Measure Verbal Representation of High School Student on Optical Instrument Topic

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Abstract: In the context of Physics learning, verbal representation is very important to foster problem solving skills. However, the role of these representations has not been thoroughly measured and supported by good measurement instruments. In addition, the topic of optical instruments has concepts that can be expressed with verbal representations and is one of the important topics in physics. Therefore, in this study, an instrument was developed to measure students' verbal representation ability on optical instrument topic. The objectives of this research are to (1) determine the instrument's construction and (2) find out the feasibility of the instrument. The instrument was developed following the modified Wilson, Oriondo, and Antonio procedure through three stages: design, testing, and test preparation. The test was piloted on 88 randomly selected students who had studied optical instrument topic. The analysis carried out in this development includes content validity, item-model fit, reliability, and item difficulty level analysis. The development was successful in providing feasible test instrument items for evaluating students' verbal representation of optical instrument topic. This instrument is expected to be used to capture information about students' verbal representation ability, which will then be analyzed to produce more appropriate physics learning instructions.

Keywords: Optical Instruments Topic; Test Instrument; Verbal Representation;

Introduction

The ability to represent a concept is an essential competency that must be fostered in 21st-century physics education. This ability must be fostered since it facilitates problem-solving, have correlation with critical thinking skill, and contributes to students' conceptual understanding (Bollen et al., 2017; De Cock, 2012; Wulandari & Nurhayati, 2018).

In learning, there are three types of representations, namely (1) verbal representations, which is related to verbal explanations, (2) visual representations, which is related to pictures, graphs, and diagrams, and (3) symbolic representations, which is related to symbols and mathematical operations (Castellanos et al., 2009; Khairunnisa et al., 2018). Among the three representations, verbal representation ability has a close relationship with symbolic representation. The relationship between verbal representation and symbolic representation can be proven by the relationship between verbal ability in counting and mathematical difficulties (Koponen et al., 2019) as well as the existence of cognitive processes that are used together in verbal and mathematical abilities (Bonifacci et al., 2016).

In addition, many studies have found an important role for verbal representation skills in the problem solving process. One of these studies was conducted by Anwar & Rahmawati (2017) who found that verbal representation skills appear and are used when students begin to understand the problem. This is reinforced by the finding of Harra Hau et al. (2020) which indicates the

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use of verbal representations in solving physics problems.

Understanding that verbal representation is essential in facilitating problem-solving ability has not made the teacher push further the role of this representation in physics learning. This is evidenced by the low ability of students to represent various physics learning topics (Furqon & Muslim, 2019; Kusumawati et al., 2019; Pebriana et al., 2022; Prahani et al., 2021), especially students' low verbal representation ability (Meltzer, 2002; Setyani et al., 2017). This poor verbal representation competence is due to a lack of diversified representations during the physics learning process. (Fatmaryanti & Sarwanto, 2015; Setyani et al., 2017).

Since students' verbal representation in physics learning is still weak, various studies have been conducted to improve this representation ability. Various innovations that have been successfully carried out and proven effective in improving verbal representation ability include learning with the help of augmented reality-assisted worksheets (Nuha et al., 2021), learning with the help of multimedia learning physics (Fithrathy & Ariswan, 2019), learning using guided inquiry model (Fatmaryanti & Sarwanto, 2015), and learning with tracker-assisted multimedia learning modules (Oktavia et al., 2019).

The implementation of learning innovations to improve verbal representation ability cannot be applied effectively without an assessment of verbal representation ability that is valid, reliable, and capable of being used for large-scale assessments. For this reason, developing a verbal representation ability assessment instrument is essential. There are currently a number of verbal representation test instruments in physics learning. Some examples of instruments that have been developed such as those created by (Adawiyah & Istiyono 2021; Tumanggor et al., 2021; Pradana et al., 2023; Pamungkas et al., 2019).

The verbal representation ability test instrument turned out to have several limitations. Several instruments are still being developed in the type of multiple-choice and two-tier multiple-choice (Adawiyah & Istiyono, 2021; Tumanggor et al., 2021). The instrument was designed to assess verbal representation associated with the concepts of kinematics, work and energi, momentum and impulse, and Newton's laws (Adawiyah & Istiyono, 2021; Mahardika et al., 2020; Pradana et al., 2023; Tumanggor et al., 2021). On the other hand, one of the instruments has been developed as an open-response question, but the instrument used to measure verbal representation and diagrammatic representation and the topic being tested is not mentioned (Pamungkas et al., 2019). Seeing the limitations, developing other instruments that can measure verbal representation ability on a specific topic is necessary. Furthermore, the topic of optical instrument is one of the essential topics in physics learning closely related to verbal representation ability. However, no verbal representation test instrument was developed for the topic of optical instrument.

Seeing the importance of verbal representation ability, the importance of assessment instruments in learning, the vital position of the topic of optical isntruments in physics learning, and the limitations in the development of previous assessment instruments indicate the need to develop a test instrument to measure verbal representations ability on optical instruments topic. For this reason, in this article we present about the development of a verbal representation test instrument on optical instrument topic. This study’s objectives are to (i) find out the construction of the physics test instrument for measuring the high school students' verbal representation on the topic of optical instruments and (ii) find out the feasibility of the physics test instrument for measuring the high school students' verbal representation on the topic of optical instruments. With the development of this instrument, it is expected that a verbal representation test instrument will be created that is both valid and reliable, which can measure the verbal representation of students on the topic of optical instruments in more detail.

Method

This research is a type of R&D (Research & Development) research focusing on developing educational assessment instruments. The development design followed Wilson, Oriondo, and Antonio's framework, which was adopted based on research by Istiyono et al. (2014). The procedure for developing test items includes the (1) design of test items, (2) test trials, and (3) test preparation. Respondents involved in the test trial were high school students who had studied optical instruments topic, as many as 88 randomly selected students from SMA Negeri 4 Yogyakarta.

The test trials were conducted to collect data on student responses to the test. The data received through this test is quantitative data, which will be further analyzed using item analysis. Other data collected through this research is content validity data. To verify the instrument's content validity, six raters were asked to evaluate the content validity of the developed items. Aiken's V Index was analyzed to evaluate the item's content validity. According to the table of V index by Lewis. R. Aiken (1985), with six rater and four rating categories, the item should have a minimum Aiken's V Index value of 0.78.

This research's item analysis includes item-model fit, reliability, and item difficulty level analysis. Classical test theory is used as a model in item analysis. Item-model fit analysis can provide information on the validity of items empirically. If the infit MNSQ value is between 0.77 and 1.30, an item is considered valid or fits with the assessment model (Bond et al., 2021). The reliability analysis was considered from the reliability of the item estimations section of the Quest program's output. The Quest analysis results are then matched with Guilford's interpretation table of reliability scores (Putri et al., 2019), which is provided in Table 1. Using Nitko & Brookhart (2011) method, it is possible to calculate the difficulty level index for polytomous item. The difficulty index (p*) is obtained by dividing the difference between the item's mean score and minimum score by the difference between the item's maximum score and minimum score. After getting the item difficulty index value, this value is interpreted using the interpretation by Magno & Ouano (2010), which is provided in Table 2.

Table 1. Reliability index interpretation

Reliability index	Interpretation
0 – 0.20	Very low reliability
0.21 – 0.40	Low reliability
0.41 – 0.60	Intermediate reliability
0.61 – 0.80	High reliability
0.81 – 1.00	Very high reliability

(Reference: Putri et al., 2019)

Table 2. Interpretation of item difficulty index

Item difficulty index (p*)	Interpretation
0.75 < p*	Difficult item
0.25 < p* < 0.75	Medium item
P * < 0.25	Easy item

(Reference: Magno & Ouano, 2010)

Result and Discussion

In this study, we developed a verbal representation test instrument on optical instrument topic by following a procedure consisting of three steps. In the first step, namely the design of the test, six items of verbal representation test instruments were arranged in the form of essay questions. The instrument's items were developed based on three points of indicators of verbal representation ability that is presented in Table 3. All the items are written in Indonesian language because the test targets Indonesian high school students who are studying physics.

Table 3. Verbal representation indicator for each item number

Item Number	Verbal Representation Ability Indicator
1.2	Solve physics problems that are presented in various verbal representations
3.4	Finding concepts verbally from data, phenomena, or information
5.6	Interpret a concept that is presented in various verbal representations

We also do content validity analysis in the first stage. Of the six items, the results of content validity analysis for six raters with four rating categories showed that The V index for Aiken varied from 0.83 to 0.94 for all six items. This value indicates that all items are valid because they have a V Aiken index of more than or equal to 0.78 (Lewis. R. Aiken, 1985).

In the second stage, namely test trials, the test which consists of six items is administered to 88 students who have studied optical instruments to obtain student responses. The student's response was then analyzed to obtain information on item reliability, characteristics, and item-model fit. From the item analysis, the Infit MNSQ for items numbered 1 to 5 ranges from 0.77 to 1.13, whereas item number 6 has an Infit MNSQ of 1.47. Figure 1 illustrates the distribution of Infit MNSQ values.

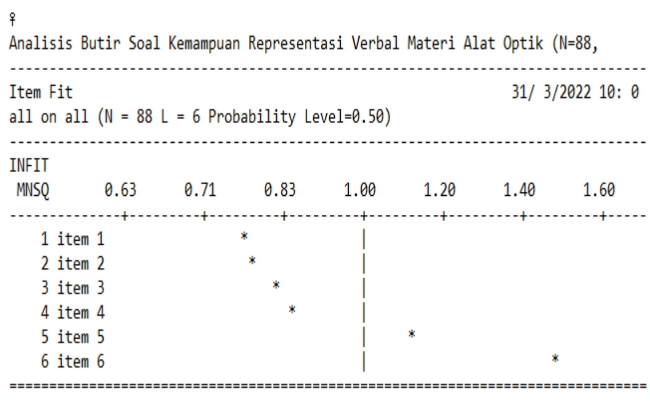


Figure 1. Item distribution map for infit MNSQ values

From the infit MNSQ values and Figure 1, it can be interpreted that there are five items from six developed items that fit with the assessment model. Items that fit the model are items number 1 to 5, and item that does not fit the model are item number 6. The item that does not fit with the model can arise possibly due to several factors such as a question that is too difficult or there are some terms in the questions that are difficult for students to understand. The instrument's reliability based on the Quest output in the reliability of item estimate section shows a value of 0.54. This value can provide information that the instrument has reliability in the intermediate reliability category based on Guilford criteria (Putri et al., 2019). The item difficulty level was analyzed based on classical test theory and then interpreted according to Magno & Ouano (2010). The results of the analysis of the item difficulty index and its interpretation are presented in Table 4.

Table 4. Table of instrument item difficulty levels at the test trial stage

Item No.	Difficulty Index	Interpretation
1	0.69	Medium
2	0.70	Medium
3	0.52	Medium
4	0.23	Easy
5	0.08	Easy
6	0.30	Medium

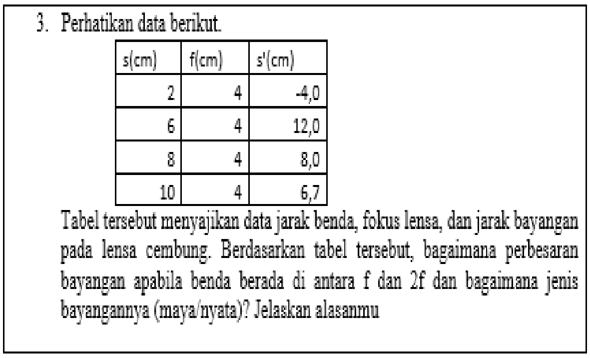
From Table 4, it can be deduced that all items developed have difficulty levels ranging from easy to medium. The difficulty level range shows that the instrument has not accommodated the existence of questions with a high level of difficulty.

After doing the item analysis, it can be continued in the third stage, namely the test preparation. At this stage, the test instruments are arranged based on the criteria of validity, reliability, and item difficulty index so that a proper test instrument is arranged. Based on item analysis, almost all of the items fulfilling the criteria of a good instrument based on content validity analysis, reliability analysis, and item difficulty analysis. However, on the item-model fit analysis, there is one item that does not fit with the model.

Table 5. Item characteristics for final instrument

Item Number	Reliability Index	Infit MNSQ	Difficulty Index
1	0.54	0.77	0.69
2	0.54	0.78	0.70
3	0.54	0.82	0.52
4	0.54	0.85	0.23
5	0.54	1.13	0.08

According to these arguments, the instrument is feasible because they meet the criteria of validity and reliability except for item number 6, which does not meet the criteria of item-model fit and requires further evaluation. Therefore, the final instrument is composed of 5 items that are items number 1, 2, 3, 4, and 5. The characteristics of the final test instrument are presented in Table 5. An example of a final question item is provided in Figure 2.


3. Perhatikan data berikut.

s(cm)	f(cm)	s'(cm)
2	4	-4,0
6	4	12,0
8	4	8,0
10	4	6,7

Tabel tersebut menyajikan data jarak benda, fokus lensa, dan jarak bayangan pada lensa cembung. Berdasarkan tabel tersebut, bagaimana perbesaran bayangan apabila benda berada di antara f dan 2f dan bagaimana jenis bayangannya (maya/nyata)? Jelaskan alasanmu

Figure 2. An example of a final item question that is written in Indonesian language

In the development of this instrument, we are still experiencing various limitations in the study. One of the limitations of this development is the use of classical test theory in item analysis. The use of classical test theory has drawbacks, one of which is that this analysis cannot describe the performance of individuals with certain trait abilities on items (Crocker & Algina, 2006). This analysis was chosen because researchers were only able to use a limited number of respondents due to limited funds and time in the study. For this reason, it is necessary to conduct further research using modern analysis with a larger number of respondents. Analysis using modern test theory is able to provide test opportunities to be used in large-scale measurements.

Conclusion

Relying on the study's findings, it can be said that the instrument used to measure high school students' verbal representation ability on optical instruments topic consists of five essay questions. The items measure the three indicators of verbal representation ability that have been shown previously. The five items are feasible to use because they are valid according to the content validity and item-model fit analysis, are quite reliable, and have difficulty in the medium-easy range. For further research, it is necessary to develop verbal representation ability instruments with different question forms and on different materials. In addition, the participation of more respondents and the application of item response theory in the analysis can be utilized in future studies.

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Conflicts of Interest
The authors declare that there is no conflict of interest.

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