Advances in Social Science, Education and Humanities Research, volume 528
Proceedings of the 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS 2020)

The Development of Diagnostic Test Instrument for Verbal Representation Ability in High School Physics Learning

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ABSTRACT
Verbal representation ability is an important part of learning physics at school and is also useful for adapting to the environment. The verbal representation ability is also a need for education in the 21st century, so having this ability can help students to understand the physics language, physics quantity, and physics concepts. This research purposes to determine the feasibility of developed test instruments in terms of validity and reliability. The test instrument developed as a diagnostic test instrument in the form of multiple-choice with a total of 27 questions. The content validity analysis of the test instruments was carried out using the Aiken's V Coefficient. The validity and reliability of empirical evidence from the test instruments were estimated using Item Response Theory (IRT). The results of this research indicate that the developed test instrument is feasible to be used as an instrument to diagnose the verbal representation ability with valid results according to the Aiken's V coefficient between 0.81 to 1.00 and can be relied on with a reliability value according to IRT of 0.96 whereas developed questions are declared reliable according to IRT if used by students with abilities ranging from -2.0 to 1.9 on a logit scale.

Keywords: *Development, Diagnostic Instruments, Verbal Representation, Word and Energy.*

1. INTRODUCTION

Education plays an important role in preparing generations to have the abilities needed in the industrial revolution era 4.0 [1], this set of abilities is called 21st-century skills. Problem-solving ability is one of the abilities required in the 21st century. Problem-solving is an important element in every discipline. Learning physics at the high school and higher education levels emphasize problem-solving. Students are required to be able to solve the problem being studied [2], [3]. Therefore, some research in the field of physics education is designed to improve problem-solving. problem-solving ability as one of the abilities that must be possessed by students has to do with the representation ability. The ability of representation is an expression, or idea that is realized in various ways or forms to solve a problem. Representations are grouped into visual representations (diagrams, pictures, graphs, tables), symbolic, mathematical and verbal [4], [5].

The use of representation is an effective way for students to understand physics problems so that it helps in solving problems [6], [7]. The verbal representation ability is an important ability which is one of the fundamental abilities of learning physics. Many physics concepts that need to be defined to facilitate students in solving problems. However, it is often found that students still have difficulty in understanding problems involving verbal representation so that errors occur when solving problems [8]–[10]. This can occur because of the habit of students studying physics which tends to memorize mathematical equations without applying their

physics concepts. Therefore, students must be able to understand problems or concepts of physics verbally.

The verbal representation ability is very important to be mastered by humans because it can provide meaningful information. The verbal representation process is used during the process of understanding the problem. Problems, ideas, and concepts can be expressed in the verbal form [11]. Verbal representation is a good way to express a definition, concept, oral, or written process [12], [13]. A physicist can use the concept of physics if he understands the physics language. The activity of the thinking process systematically and regularly can be done well if you master this ability.

The right strategy in achieving completeness of physics subject, namely by providing an assessment to diagnose students' verbal representation ability. The assessment has basic purposes, one of which is conformity with the learning purposes to be implemented. Assessment can measure learning success, can review the effectiveness of student success, and diagnose student errors. Assessment must be following the characteristics of a good test or assessment, namely (1) valid, (2) reliable, (3) objective, and (4) practical [14], [15]. Assessment is arranged following indicators that are useful for measuring one of the potential students such as the verbal representation ability in physics subject, so that it can be used well if it meets the criteria/ conditions of a good assessment. Table 1 shows the results of the synthesis of several articles related to verbal representation ability.

Table 1. Verbal Representation Ability Synthesis Results

Aspect	Sub-Aspect	Indicator
Describe	Describing the data	Students can describe the concept verbally from a physics problem when presenting data in mathematical form, pictures, or symbols.
	Explaining the concept	Students can explain a concept verbally about physics problems.
Interpret	Interpreting data	Students can interpret verbally the problems represented in the form of images, symbols, or mathematical concepts.

In learning practices, many types of assessments are often used, such as written and oral assessments. The written assessment is a test with questions and answers presented in writing. One form of written assessment is a multiple-choice test. Multiple-choice tests are tests that require students 'choices to measure or obtain information about students' abilities or knowledge about factual information [15], [16]. Based on the explanation above, various types of written judgments, multiple choices are good and practical alternatives to measure the verbal representation ability. This requires the development of physics multiple choice tests to measure the verbal representation ability in high school. Therefore, the purposes of this study are: (1) developing physics multiple choice tests to diagnose the verbal representation ability, and (2) to obtain the characteristics of physics multiple choice tests.

2. RESEARCH METHODS

This research is a research development. The development stages follow the Oriondo & Dallo-Antonio development model which includes: 1) Planning the Test, 2) Trying out, 3) Establishing Test Validity, 4) Establishing Test Reliability, and 5) Interpreting the Test Score [17], [18]. The development procedure of the test instrument is shown in Figure 1.

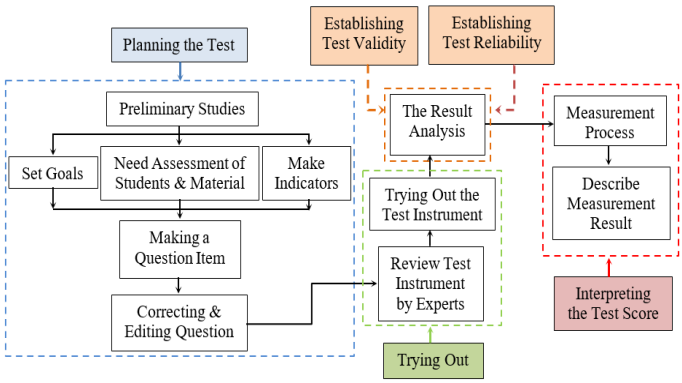


Figure 1. Test Instrument Development Procedure

The main product of this research is an instrument that can be used to diagnose the verbal representation ability in high school physics subjects, especially Work and Energy. Data analysis techniques using qualitative and quantitative descriptive analysis. Qualitative analysis purpose to review instrument construction through expert judgment. Quantitative analysis is used to determine instrument validity and reliability. The draft instrument was created and developed into questions, and the test instrument was given to experts for content validity. The test instrument consisted of 27 multiple choice questions with a cognitive level between C_2 to C_4. Then, 27 questions divided into two question packages A and B, where each packet prepared by considering the representation of each indicator measured by the verbal representation ability. Each package consists of 15 multiple choice questions, including three questions as *anchor items*.

2.1 Population

The test instrument was entered into a trying out in March 2020 involving 284 students in three high schools

located in the Special Region of Yogyakarta, especially Bantul Regency. The three schools are SMA Negeri 1 Banguntapan, SMA Negeri 1 Sewon, and SMA Negeri 3 Bantul.

2.2 Data Collection

The data obtained in this study are the results of content validation through expert judgment, empirical evidence through the trying out stage, and the item reliability results. The content validity of the test instrument is obtained by providing the test instrument developed to the experts for review. The assessment was conducted by seven raters namely: the assessment expert, physics learning expert, physicist, two practitioners of physics education evaluation, and two peer reviewers. The instrument readability test also carried out on ten students. Readability test results are used to improve the instrument.

2.3 Data Analysis

The content validity assessment of the test instruments was analyzed using the Aiken's V formula. The content validity coefficient based on expert judgment as much as *n* raters can represent the measured item construct. Aiken's V index value is formulated in equation 1.

$$V = \frac{\sum s}{[n(c-1)]} = \frac{\sum[r-lo]}{[n(c-1)]} \qquad (1)$$

Description, n is the number of raters, c is the highest validity rating, lo is the lowest validity rating, r is the number given by the rater [19].

Evidence of content validity was empirically obtained through the items' response analysis of the test results in the form of dichotomous data. Dichotomous data were analyzed using Item Response Theory (IRT) according to the Partial Credit Model (PCM). Analysis using the *Quest* and *Parscale* program. The *Quest* program is used to determine the goodness of fit, reliability, and item difficulty index. The *Parscale* program is used to determine information functions and Standard Error of Measurement (SEM) [14], [20], [21].

3. RESULT AND DISCUSSION

The content validity of the developed test instruments was reviewed by 7 raters with 4 rating scales. Based on the standard set by Aiken, the minimum standard of Aiken's V coefficient for this research is 0.76 with a probability of 0.045. The results of the content validity analysis are shown in Figure 2.

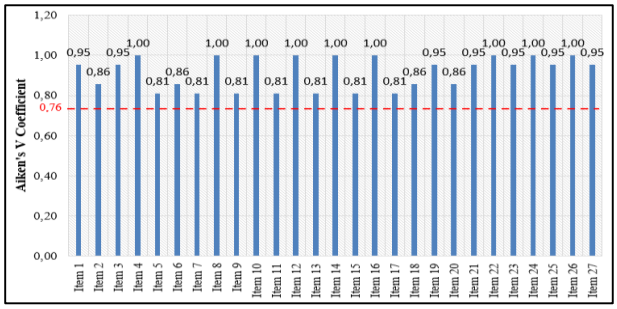


Figure 2. Experts Validation Result

Figure 2 shows all items exceeding the minimum of Aiken's V coefficient. All instrument items can be declared valid based on content validation analysis using the Aiken's V coefficient.

Evidence of content validity was empirically obtained from the try out results is in the form of dichotomous data analyzed according to the *Rasch model*. The results of the *goodness of fit* analysis can be seen from the INFIT parameters for *Mean Square* (MNSQ) and *INFIT t*, which shows that the verbal representation ability test instrument meets the statistical fit criteria according to the *Rasch model* which is fully presented in Table 2.

Table 2. Fit statistics Test Parameter at 0.5 Probability Level

Test Parameter	Items Estimation	Cases Estimation
Mean & Standard Deviation	0,00 ± 1,02	-1,78 ± 0,56
Adjusted Standard Deviation	1,00	0,12
Mean & Standard Deviation of INFIT MNSQ	1,00 ± 0,08	1,00 ± 0,15
Mean & Standard Deviation of OUTFIT MNSQ	0,98 ± 0,16	0,98 ± 0,56
Mean & Standard Deviation of INFIT t	0,36 ± 1,82	0,13 ± 0,55
Mean & Standard Deviation of OUTFIT t	-0,04 ± 1,14	0,08 ± 0,71
Reliability of Estimate	0.96	
Mean Difficulty	0,00 ± 1,02	

The analysis shows the reliability of the item estimate is 0.96, which means the test sample suitable with the item being tested, or the sample provides consistent results and information as expected. The suitability map of 27 items with the *Rasch model* is shown in Figure 3.

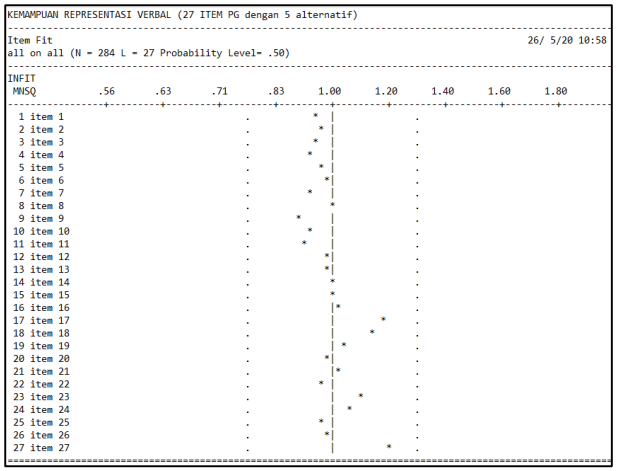


Figure 3. INFIT MNSQ Distribution Value for each item in the FIT Model

The items tested are fit with the *Rasch model* if the *MNSQ INFIT* value is between 0.77 to 1.30 [22]. Based on Figure 3, 27 items suitable the *Rasch model*, with the *MNSQ INFIT* value of items between 0.80-1.20.

The difficulty level of each item can be viewed from the results of the *Quest* program output shown in Figure 4.

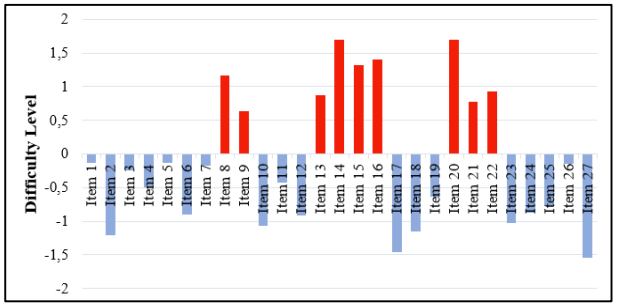


Figure 4. Difficulty Item Level

Figure 4 shows the results graph of the student answers distribution with difficulty ranging from easy to difficult questions. Hambleton and Swaminathan [23] said that the item difficulty level (*b*) is good if it has an item difficulty index between -2.00 to 2.00. The item with a difficulty level of -2.00 indicates that the item is very easy, while the difficulty level of 2.00 indicates that the item is very difficult.

Test instrument reliability can be determined based on IRT using the total information function (TIF) curve and SEM. *Parscale* program is used to obtain the TIF and SEM curves. Instrument reliability for measuring students' verbal representation ability is shown in Figure 5.

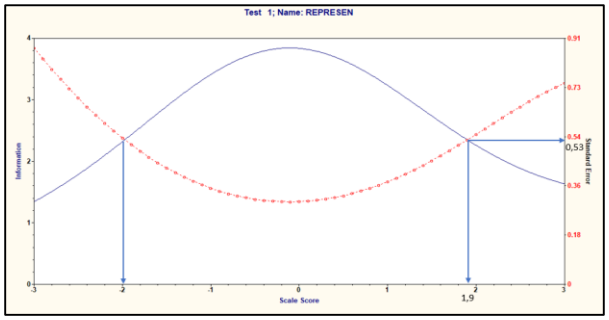


Figure 5. Total Information Function (TIF) and Standard Error of Measurement (SEM)

Figure 5 explains that the verbal representation ability test instrument is suitable for students who have the ability (θ) between -2.0 to 1.9 ($-2.0 < \theta < 1.9$). This test instrument has a Total Information Function (TIF) of 2.4 and a Standard Error of Measurement (SEM) of 0.53.

Students' abilities can be determined from the *PH3* and *SCO* format files in the *Parscale* program output. Students' verbal representation abilities are presented in the ability column on the logit scale. The results of the measurement of verbal representation ability of 284 students showed a distribution of grades between -3 to 3 on a logit scale between -4 to +4 is shown in Figure 6.

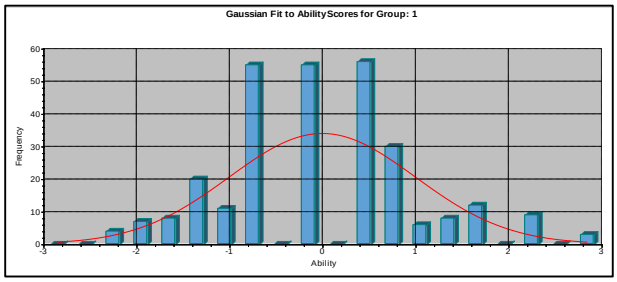


Figure 6. Histogram of Estimated Ability

One of the 27 items of test instruments developed to diagnose student's verbal representation ability in the Work and Energy subject is shown in Figure 7. This item instrument follows the cognitive level C2 (Understanding) from A revision of Bloom's Taxonomy.

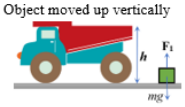
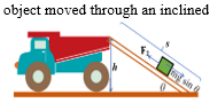
Item Number 4 Package B	Solution & Diagnostics
An object on the ground will be moved to the top of the truck at height h. An object is moved in two ways, namely: the object is lifted vertically upward with the work W_1 done by the force $\mathbf{F_1}$, while the other way is that an object is moved through the inclined plane with the work W_2 done by the force $\mathbf{F_2}$. The correct statement below is … a. The force $\mathbf{F_1}$ is greater than $\mathbf{F_2}$ and the work W_1 is the same as the work W_2 b. The force $\mathbf{F_1}$ is smaller than $\mathbf{F_2}$ and the work W_1 is smaller than the work W_2 c. The force $\mathbf{F_1}$ is greater than $\mathbf{F_2}$ and the work W_1 is greater than the work W_2 d. The force $\mathbf{F_1}$ is greater than $\mathbf{F_2}$ and the work W_1 is smaller as the work W_2 e. The force $\mathbf{F_1}$ is the same as $\mathbf{F_2}$ and the work W_1 is greater than the work W_2	**Answer Key: A** • An Object moved up vertically  $\mathbf{F_1}=m\,g$ $W_1=\mathbf{F_1}\,h$ $W_1=m\,g\,h$ • An object moved through an inclined plane  $\mathbf{F_2}=m\,g\,\sin$ $W_2=\mathbf{F_2}\,s$ $W_2=(m\,g\,\sin$ $W_2=m\,g\left(\frac{h}{s}\right)s$ $W_2=m\,g\,h$ so, the force $\mathbf{F_1}$ is greater than $\mathbf{F_2}$ and the work W_1 is the the work W_2. The work W_1 is as big as the work W_1 beca work does not depend on the shape of the track but dep the position of the object.
If you choose B: ***Your Answer is Wrong*** The student has not been able to associate variables in the content of the problem. The student descri the smaller the force exerted, the work produced is also small. **If you choose C:** ***Your Answer is Wrong*** The student has been able to determine the right force quantity in different treatments but can not con force concept with the work concept on objects moved in the same position. **If you choose D:** ***Your Answer is Wrong*** The student has been able to determine the right force quantity in different treatments but can not con force concept with the work concept on objects moved in the same position. **If you choose E:** ***Your Answer is Wrong*** The student has not been able to connect the variables correctly, this causes an error/ is confused with work concept with the force concept.	

Table 3. Item Test Instrument to Diagnose Verbal Representation Ability

4. CONCLUSION

Physics multiple-choice test successfully developed to diagnose the verbal representation ability of high school students. Physics multiple-choice test consists of 27 items. 27 items of physics multiple choice test suitable with the *Partial Credit Model* (PCM) based on dichotomous data. The physics multiple-choice test is qualified based on the Aiken's V coefficient and the reliability of the item estimate is declared valid and reliable. Based on the information functions and SEM that the teacher can use this physics multiple-choice test to measure the student's verbal representation ability who have low until high ability on a logit scale.

AUTHORS' CONTRIBUTIONS

A. M. R. Tumanggor analyzed the preliminary studies, developed diagnostic instrument, participated in the research design, and performed the statistical analyses. Supahar guided the whole research and coordinated the development of test instruments. M. F. T. Nirmala participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

ACKNOWLEDGMENTS

The author would like to thank for funding support from the Directorate of Research and Community Service (DRPM), Deputy for Strengthening Research and Development of the Ministry of Research, Technology, and Higher Education/ National Research and Innovation Agency through Masters Thesis Research, No. T/9.65/UN34.21/PT.01.03/2020.

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