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Dissemination of Online Diagnostic Test Instrument to Diagnose High School Students' Mathematical Representation Ability: The Case of Work and Energy

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ABSTRACT
Diagnostic test instruments used to detect students' mathematical representation abilities and adjusted to the main principles of mathematical representation abilities, is students can determine the right equation according to the problem and operationalize mathematical equations to solve problems. This research aims to disseminate valid, reliable, and effective diagnostic test instruments for use in physics learning, especially to diagnose mathematical representation abilities. The assessment is based on the results of developing an online web-assisted student's mathematical representation ability instrument. This research uses the Research and Development (R&D) method which is carried out by taking samples from several high schools in the Bantul Regency. The product was applied to 63 students from two schools in Bantul Regency, Special Region of Yogyakarta with the *Cluster Random Sampling* (*Area Sampling*) technique. The development model in this research is the 4D model. The 4D model combined with Oriondo & Dallo-Antonio is implemented through the Define, Design, Develop and Disseminate stages. The research results are (1) the dissemination results of valid diagnostic test instruments to diagnose the mathematical representation ability with V-Aiken coefficient of 0.86 to 1, and reliability can be categorized as "Excellent", (2) The results of the dissemination to determine the profile of students' abilities can be categorized "Medium" in terms of the student ability distributions, and (3) the practicality level of the *PhysDTRA* product assessment was categorized as "Very Good" according to the assessment by the teacher and student responses.

Keywords: *Dissemination, Diagnostic instrument, Mathematical representation, Online, Work and energy*

1. INTRODUCTION

One of the important abilities in the 21st century needs that must be prepared to become a competitive human being is the problem-solving skill. Physics learning that has been received should provide experience for students so that they have the ability to build, understand, and establish the physics concepts that have been learned to solve problems [1], [2]. problem-solving is always related to learning physics because every discussion of physics requires solving problems that are synergistic in it [3], [4].

Docktor & Mestre [5] define representation as a solution to solving physics problems. The representation in question can be presented in image, analogy, mathematical, diagrammatic, vector and verbal formats related to the concept of physics [6]. One representation that can solve physics problems is a mathematical representation [7]. The same thing was also presented by Kohl & Finkelstein [8] that to solve physics problems it is necessary to use verbal problems in the form of pictures, and ends with the use of mathematical formulas in solving problems. Mathematical abilities are needed to explain how equations are used differently in the context of

physics, but the performance for solving calculation problems is worse than other formats [5]. Mathematical representation in physics is the description of variable values which includes equations and functions to explain the physical state of an event. Treagust, Duit & Fischer [9] explain that mathematical learning uses a lot of symbolic quantities and thematic proofs, whereas physics is a subject that involves many abstract formulas. Work and energy are physics materials that can identify students' mathematical representation abilities. Neumann [10] argues that students still have difficulty in pouring ideas and concepts of work and energy into mathematical equations.

The results of the 2018 PISA (Programme for International Student Assessment) study explained that the performance of students' abilities in Indonesia has decreased from the three aspects measured when compared to 2015. One of the three aspects measured is a mathematical ability which is closely related to mathematical representation [11]. The decline in student ability is an evaluation for teachers and education practitioners in planning appropriate learning to improve student abilities and competencies. One of the concerns for increasing competence is improving the assessment system. Appropriate assessments need to be designed and focused on detecting student weaknesses and difficulties. The results of the assessment will also be reported in a form that is useful for improving classroom teaching practices and the formulation of education policies. The teacher's effort in detecting students' difficulties and weaknesses is a challenge in learning [12]. One form of assessment to detect student weaknesses is to do a diagnostic assessment [13].

The challenge in implementing diagnostic assessments is that teachers must adapt learning to the needs and character of students. The diagnostic assessment focuses on analyzing students' incorrect answers on the items being measured. The analysis that is carried out must measure the ability of students at the individual level [14], [15]. Time and implementation limitations for a large number of students in learning are one of the reasons for the difficulty of conducting diagnostic assessments. Therefore, we need a media that helps teachers and education practitioners in carrying out diagnostic assessments. One of them is by using a website-based online assessment. The use of online assessment media can help teachers analyze student answers and provide suggestions so that assessment activities are more effective and efficient [16]–[18]. The advantage of using this online assessment media is that it can be accessed easily at certain times and places [19], [20]. In addition, the 4.0 industrial revolution encourages automation systems in all activity processes. This change has an impact on the world of education, especially in the assessment system.

Therefore, it is necessary to assess the dissemination of the development results of an online diagnostic test instrument which has a characteristic form of suggestions contained in each answer choice so that it can diagnose the mathematical representation ability of high school students on the Work and Energy.

2. RESEARCH METHODS

This research is a research development. The development stages follow 4D model (Define, Design, Develop, Disseminate) [21] with 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 [22].

The dissemination stage of this research is the field trying out stage to ensure product development in the form of a diagnostic test instrument combined with web-based online media to be effective when viewed from the results of the study of product practicality by teachers and student responses to product use. After that, the product can be implemented to determine the ability profile of students. The development procedure of the test instrument and product is shown in Figure 1.

2.1. Population

The dissemination stage was implemented online in September 2020, involving 63 students in two high schools located in Bantul Regency, Yogyakarta Special Region with the Cluster Random Sampling (Area Sampling) technique. The two schools are SMA Negeri 1 Sewon and SMA Negeri 3 Bantul.

2.2. Data Collection

Product implementation is carried out using a valid and reliable diagnostic test instrument of 21 questions of mathematical representation, after which it is combined in an online assessment media in the form of a web called PhysDTRA (Physics Diagnostic Test for Mathematical Representation Ability). PhysDTRA instruments were distributed to obtain profiles of students' mathematical representation abilities. Practicality review sheets for PhysDTRA products

will be distributed to determine the responses of teachers and students after using these products.

2.3. Data Analysis

The assessment of the student response questionnaire and the teacher's response results to the practicality of working with web-assisted instruments is said to be feasible if the instrument is in a good category. The assessment step carried out changes the scale of the statement to a value scale. The explanation is as follows: No = 0 and Yes = 1. Data tabulation will be carried out from all data obtained from the assessment instrument component. Descriptive analysis was carried out using the following equation [23]:

$$\overline{X} = \frac{\sum X}{n} \quad (1)$$

Description; n is the number of raters, $\sum X$ is the number, and $\overline{X}$ is the mean score. The next step is to interpret the mean score into a value with the category for changing the score as shown in Table 1 [24].

Table 1. Categorization of assessment score

No	Test Parameter	Category
1	$X > \overline{X}_i + 1.8\ Sb_i$	Very Good
2	$\overline{X}_i + 0.6\ Sbi < X \leq \overline{X}_i + 1.8\ Sbi$	Good
3	$\overline{X}_i - 0.6\ Sbi < X \leq \overline{X}_i + 0.6\ Sbi$	Good Enough
4	$\overline{X}_i - 1.8\ Sbi < X \leq \overline{X}_i - 0.6\ Sbi$	Less
5	$X \leq \overline{X}_i - 1.8\ Sbi$	Very Less

Description; X is actual score, $\overline{X}_i$ is ideal mean = ½ (ideal maximum score + ideal minimum score). Sb_i is ideal standard deviation = 1/6 (ideal maximum score - ideal minimum score).

Categorization table of assessment score also applies to determine the assessment category of students' abilities by changing the description of the categories to Very Low, Low, Medium, High and Very High.

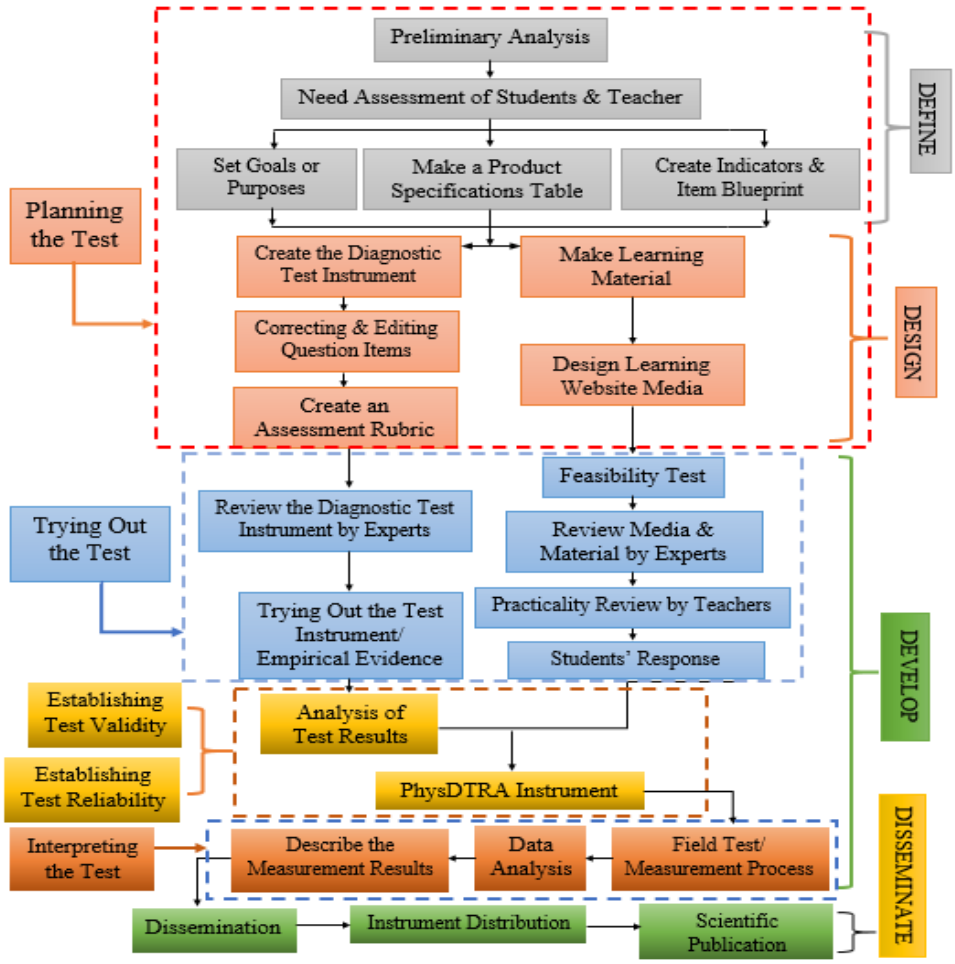


Figure 1. Research and development procedure

3. RESULT AND DISCUSSION

Students at the high school level /equivalent should be able to select, use and translate mathematical representations to solve problems because students who have mathematical representation ability will be more critical in evaluating their understanding [4], [25]. Mathematical representation is defined as a format used to describe problems into a mathematical model and its relationship between variables [26]. Based on the opinion of some researchers, the synthesis of mathematical representation indicators can be shown as in Table 2 [27]. One of the 21 items of test instruments developed to diagnose student's mathematical representation ability in the Work and Energy subject is shown in Table 3. This item instrument follows the cognitive level C4 (Analyzing) from A revision of Bloom's Taxonomy.

Diagnostic test instruments to detect students' mathematical representation abilities have gone through the content validity stage and empirical tests to determine the validity and reliability of the test instruments. The content validation coefficient was assessed by expert judgment and declared valid based on the V-Aiken equation [28] with a minimum value of 0.86. Furthermore, based on empirical tests, the diagnostic test instrument has been reliable with the item reliability results of 0.95. This shows that the diagnostic test instrument is ready to be implemented in learning.

The product made is an online web-based which is used as a forum for conducting diagnostic assessments with questions that have a diagnosis and suggestions for each answer choice. There are 21 items of valid and reliable diagnostic test instruments to be combined in an online web-based and named the product PhysDTRA (Physics Diagnostic Test for Mathematical Representation Ability). 21 items are divided based on 4 indicators of mathematical representation ability and divided into 3 meetings based on sub-material of the Work and Energy. PhysDTRA products can be accessed using a PC (Personal Computer) or a Smartphone. PhysDTRA product display can be seen in Figure 2.

After the PhysDTRA product has been designed, the product will then be reviewed in the form of media validation by a media expert. The media expert consisted of 7 experts consisting of assessment experts, physics learning experts, physicists, 2 physics education evaluation practitioners, and 2 peer reviewers. The results of the analysis of the media validation analysis or *PhysDTRA* products obtained the "Very Good" category results. And several product reviews have been revised for product improvement.

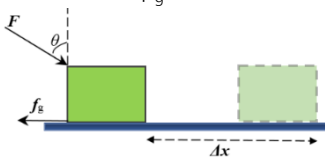
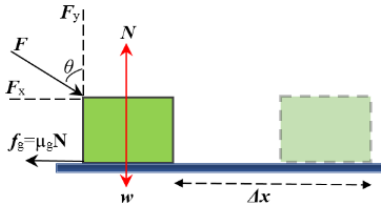
In the next step, to ensure the practical assessment aspects of using *PhysDTRA* products, the results of the study in the form of assessments and input to *PhysDTRA* products were given by 12 physics teachers throughout Yogyakarta in the UNY 2020 Postgraduate Community Service (PPM) activities. The results of the assessment stated that *PhysDTRA* products were practical. can be used well. However, there is a suggestion from the reviewer that the time efficiency on each item must be clear, which is 2 minutes and when the time runs out it will automatically proceed to the next question. Improvements have been made to *PhysDTRA* products from the teachers' reviews. Data on the results of *PhysDTRA* product assessments by education practitioners (teachers) can be seen in Table 4.

Table 2. Mathematical representation ability synthesis results

Aspect	Sub-Aspect	Indicator	Sub-Material		
			Work	Kinetic & Potential Energy	Conservation of Mechanical Energy
Mathematical Representation Ability			Meeting 1	Meeting 2	Meeting 3
Interpret Data	Interpreting Variable	Students are able to interpret variables according to concepts in the form of pictures, tables, diagrams, and graphs to solve problems.	1, 2	8, 9	15, 16
	Associating Variables	Students are able to connect the variables contained in a problem in the form of images, tables, diagrams, and graphs to solve problems.	3, 4	10, 11	17

Aspect	Sub-Aspect	Indicator	Sub-Material		
			Work	Kinetic & Potential Energy	Conservation of Mechanical Energy
Operate Equation	Operate Data	Students are able to operate equations appropriately in the form of numbers, symbols, or pictures in solving problems.	5, 6	12	18, 19
	Formulate Results	Students are able to conclude conditions with mathematical equation operations to get results.	7	13, 14	20, 21

Table 3. Item Test Instrument to Diagnose Mathematical Representation Ability

Item Indicator	Question Number 6	Solution
Presented an illustrative image of an object on a flat plane, students can operate the Work equation on the system appropriately.	An object is placed on a horizontal plane, then pushed with a force F so that it experiences a displacement $\Delta\mathbf{x}$ with the friction coefficient μ_g as shown below.  The work W equation in the system is... a. $W=\left(\mathbf{F}\cos\theta-\mu_g\mathbf{N}\right)\Delta\mathbf{x}$ b. $W=\left(\mathbf{F}\sin\theta-\mu_g\mathbf{N}\right)\Delta\mathbf{x}$ c. $W=\left(\mathbf{F}\cos\theta-\mu_g\mathbf{N}\right)\mathbf{s}$ d. $W=\left(\mathbf{F}\sin\theta-\mu_g\mathbf{N}\right)\mathbf{s}$ e. $W=\left(\mu_g\mathbf{N}-\mathbf{F}\sin\theta\right)\Delta\mathbf{x}$	Answer: B *Answer:* • An angle θ is formed from F about the y-axis. Projection of F about the x-axis:  $\mathbf{F}y=\mathbf{F}\cos\theta$ $\mathbf{F}x=\mathbf{F}\sin\theta$ • The work W equation: $W=\sum\mathbf{F}\ \mathbf{s}$ $W=\left(\mathbf{F}_x-\mathbf{f}_\mathbf{g}\right)\Delta\mathbf{x}$ After all variables have been substituted, it is obtained: $W=\left(\mathbf{F}\sin\theta-\mu_g\mathbf{N}\right)\Delta\mathbf{x}$

Diagnostics	Advice
If you choose A: *Your Answer is Wrong* Students have not been able to describe variables and develop equations appropriately, a mistake occurs in the process of projecting the Force to the direction of displacement. If you choose C: *Your Answer is Wrong* Students have not been able to describe variables and develop equations appropriately, a mistake occurs in the process of projecting the Force to the direction of displacement and the use of variables that are still wrong. If you choose D: *Your Answer is Wrong*	If you choose A: You should learn how to project the direction of the force against the direction an object is moving to be able to develop the equation precisely. If you choose C: You should learn how to project the direction of the force against the direction an object is moving and use the correct variables to be able to develop the equation correctly. If you choose D:

Students have been able to describe variables and develop equations appropriately, but there is an error with the displacement variable which should be expressed as *Δx*. If you choose E: *Your Answer is Wrong* Students have not mastered the Work concept which is influenced by force and displacement, so they have not been able to describe variables and develop equations correctly.	You should be more careful in reviewing the examples or alternations of variables that affect the development of the equation. If you choose E: You should review the concept of work caused by the force-producing displacement, to be able to develop the equation correctly.

Table 4. Analysis Results of Product Practicality by The Teachers

Aspect	Sub-Aspect	Average	Criteria
Product Display	Instructions for use of *PhysDTRA* product	0.89	Very Good
Software Engineering	Ease of Access	0.89	Very Good
	Creativity and Innovation	0.92	Very Good
Learning	Suitability of indicator with KI, KD and curriculum	1	Very Good
	Suitability of learning objectives with indicators	1	Very Good
Material	Explanation of the material concept	1	Very Good
	Accuracy of using the language	1	Very Good
	Suitability of writing question formulations	1	Very Good
	Suitability of the answer key to the question	1	Very Good
	Suitability of the diagnosis with the questions	1	Very Good
	Suitability of advice with diagnosis	1	Very Good
TOTAL		0,97	Very Good

Table 5. Students' Response Results

Aspect	Sub Aspect	Average	Criteria
Product Display	A Positive Impression on Display Quality	0.87	Very Good
	A Positive Impression on The Illustration Quality	0.83	Very Good
The Functionality of Use	Ease of Program Operation	0.90	Very Good
	Ease of Use Navigation	0.86	Very Good
	Update and Interest in The Software	0.84	Very Good
Test Construction	Questions Presented Follow the Material	0.83	Very Good
Language	Ease of Language Use	0.95	Very Good
TOTAL		0,86	Very Good
Aspect	Sub Aspect	Average	Criteria
Product Display	A Positive Impression on Display Quality	0.87	Very Good
	A Positive Impression on The Illustration Quality	0.83	Very Good
The Functionality of Use	Ease of Program Operation	0.90	Very Good
	Ease of Use Navigation	0.86	Very Good
	Update and Interest in The Software	0.84	Very Good
Test Construction	Questions Presented Follow the Material	0.83	Very Good
Language	Ease of Language Use	0.95	Very Good
TOTAL		0,86	Very Good

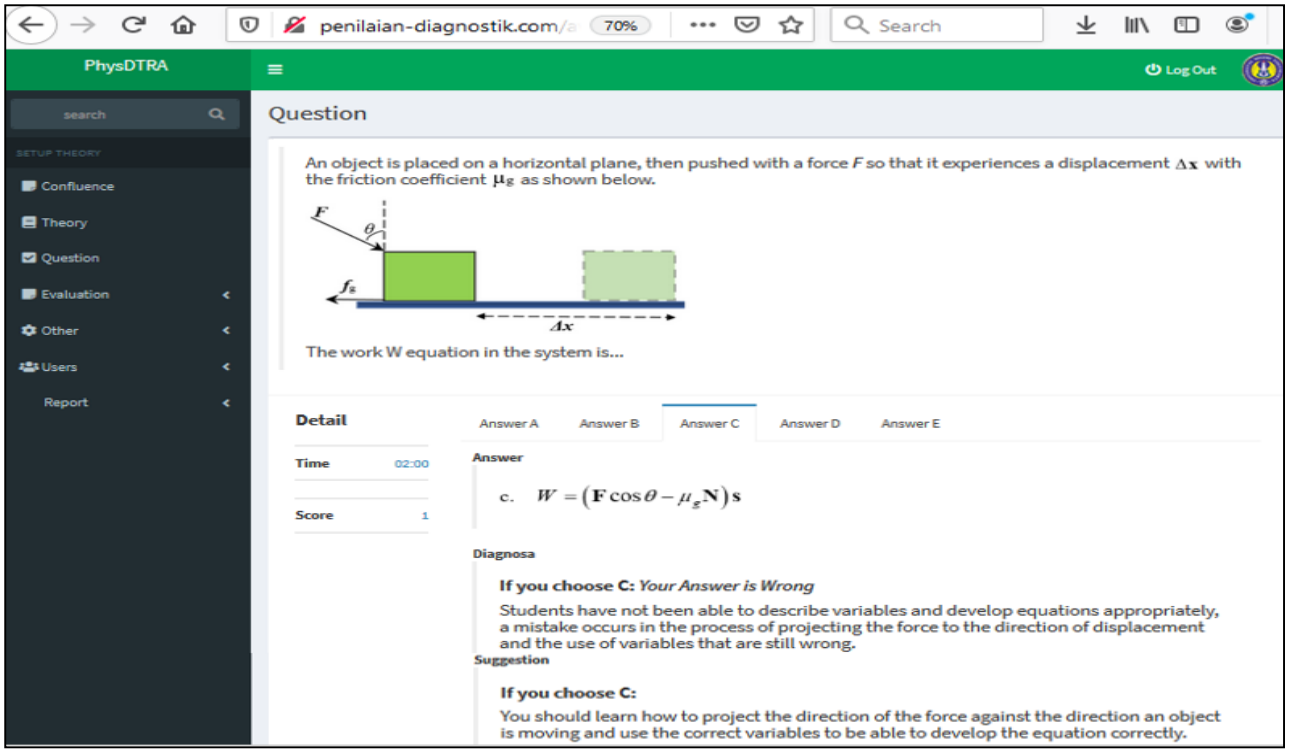


Figure 2. Product Display of *PhysDTRA*

The results of the calculation through the assessment category (Table 1) related to the practicality of *PhysDTRA* products obtained an average assessment of all aspects of 0.97 which is in the "Very Good" category. This shows that the practicality of *PhysDTRA* products can be used in research. The data for calculating student responses using *PhysDTRA* products provide in Table 5. The study result data in the form of assessments and responses from the media aspect were provided by 46 students. The results of the calculation through the assessment categories (Table 1) related to student responses to *PhysDTRA* products obtained an average assessment of all aspects of 0.86 which is included in the "Very Good" category. This shows that *PhysDTRA* products can be used in research.

The dissemination stage was carried out on 63 high school students who had studied the Work and Energy material. Students take a diagnostic test for 3 meetings with different sub-material for each meeting. Descriptive explanations are shown in Table 6 and Table 7 to analyze the representation ability profile of high school students on the work and energy material.

Table 6. Ability Measurement Results based on Aspects

Aspect	Sub Aspect	Average	Criteria
Interpret Data	Interpreting Variable	1.78	Less
	Associating Variables	1.93	Less
Operate Equation	Operate Data	2.07	Less
	Formulate Results	1.95	Less
TOTAL		1.93	Less

Table 7. Ability Measurement Results based on Meetings.

Sub Material	Meeting	Average	Criteria
Work	1	2.49	Less
Potential & Kinetic Energy	2	2.33	Less
Conservation of Mechanical Energy	3	2.92	Good Enough
TOTAL		2.58	Less

The results of the measurement of students' abilities are in the "Less" criteria based on the aspect of mathematical representation abilities and the number of meetings of the Work and Energy sub-material. Even though the students have taken physics lessons on Work and Energy, in reality, the condition of the students after being measured using a diagnostic test instrument is proven to be still in "Less" criteria. This proves that the diagnostic test instrument is able to diagnose student weaknesses in depth. Remediation is needed to overcome student weaknesses after attending lessons. Diagnostic test instruments really help teachers or education practitioners to diagnose student weaknesses, so that remediation by teachers is more targeted to solve student difficulties.

Students' mathematical representation abilities are interpreted in five scales based on Table 1, namely very low, low, medium, high, and very high. The students' mathematical representation ability is theta (θ) and is shown in Figure 3.

Students' abilities can be determined from the *PH3* and *SCO* format files in the *Parscale* program output. Students' mathematical representation abilities are presented in the ability column on the logit scale. The results of the measurement of mathematical representation ability of 63 students showed that the students' abilities were at "Medium" abilities, so that the teacher/ educator was expected to be able to properly remediate the diagnosis of student weaknesses according to the students' abilities.

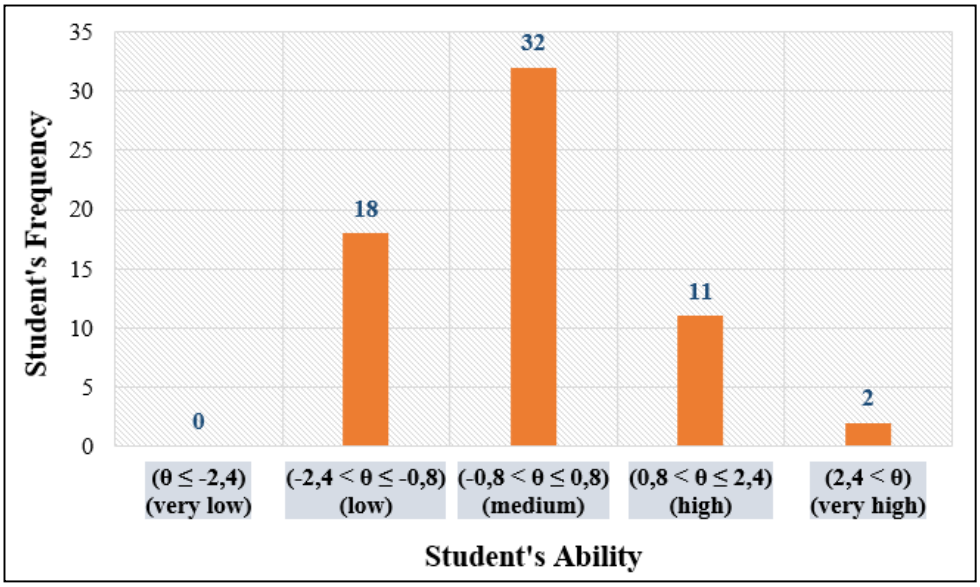


Figure 3. Histogram of estimated ability

4. CONCLUSION

Based on the research results and development of diagnostic test instruments, it stated that they are valid according to the judgment of experts who are analyzed using the Aiken's V equation. *PhysDTRA* instruments and products are also reliable based on the reliability of item and category estimations very well, so they can be used to diagnose students' mathematical representation abilities. *PhysDTRA* products have also met the "Very Good" category based on reviews of product practicality by teachers and student responses. Thus, the *PhysDTRA* instrument product developed has met the characteristics of a test that is feasible in terms of content, empirical evidence, validity, and reliability.

The results of the dissemination show that the distribution of students' mathematical representation abilities is classified into five scales according to Widoyoko, namely very low, low, medium, high, and very high (Figure 4). The frequency of students at 0% has very low representation abilities, and 17% with low ability categories. The frequency of students at a moderate level of mathematical representation ability is 56%. Then 29% of students have a high level of mathematical representation ability, and 3% are in the very high category.

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. All authors read and approved the final manuscript.

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