The development physics essay test to measure vector and mathematics representation ability in senior high school

A C Pratama*, Supahar, Warsono, and Jumadi
Department of Physics Education, Yogyakarta State University, Indonesia
*corresponding author email: tamaalfan@yahoo.co.id

Abstract. Problem solving is one of the focuses in physics education research. To solve the problem in physics, students often apply the vector representation to facilitate in understanding problems before they use mathematics representation. To measure both representations well requires a good assessment, so in this research we aims to: 1) develop an instrument test to measure the vector and mathematics representation ability of high school students, 2) determine the characteristics of the instrument test items. The research method used was the combination of 4D and ADDIE model. The test instrument developed was an essay test consisting of 15 items. These items had been validated by instrument experts, practitioners and peers. The sample is determined by purposive sampling which consisting 285 high school students in Samarinda. The polytomous data were analyzed according to the partial credit model (PCM). Research results show that 13 items of the test fit to PCM with the test reliability 0.83 and the items’ difficulty indexes ranged from -1.11 to 1.58. Based on the information function and SEM, this test is suitable for students that whose ability -1.40 to over 3.00. Therefore, the test instrument is valid and reliable to measure the vector and mathematics representation ability.

1. Introduction
Prepare the human resource become the educational priority to facing the competition in era of globalization. A good education would prepare the human resource to facing the career in the future [1]. Physicist are human resource which is needed in the future [2]. Physicist are needed because career in the future demands the human resource who could solve the problems with various ways to fit the needs of society [3].

Ability to solve the problems with various ways in physics learning has a high value. This ability is usually called "representational ability". The representational ability is the ability to interpret problems, choose and organize the various of ways/shapes to understand the concept or solve the problem [4,5]. There are many different forms that usually used in physics learning, such as picture, graph, diagram, vector, verbal, mathematical, etc [4,5,6]. In this case, only vector and mathematics representation will be discussed.

Vectors represent most of the concepts in physics learning [7]. Although students are accustomed to involving vectors in most concepts, some students still have difficulties [8]. The difficulties that experienced by students involving several topics such as: magnitude and direction of a vector, addition and subtraction vector, vector component, unit-vector notation, etc [8,9,10]. Therefore, involve the vectors requires the complete and basic understanding.
Physics and mathematics have a close relationship. Mathematics is considered as the language that represents concepts in physics [11]. However, difficulties in understanding physics considered originated from mathematics itself, because many symbols and combinations are unfamiliar by the students [12]. Therefore, to improving students abilities need to combine mathematical representation and physical knowledge as a whole [13].

To obtain information of student characteristics related to the process, progress and learning outcomes of students can use assessment. Assessment is the process of collecting information about student learning outcomes that used to make decisions [14]. In the practice of learning there are many types of assessment that are often to used, such as written and oral assessment [15]. Written assessment is a test with questions and answers presented in writing. One form of written assessment is essay test. Essay tests are tests that demand responses from students to measure or obtain information about the ability or student's knowledge of factual information [16].

Based on the explanation above, various type of written assessment, essay test is a good alternative to measure vector and mathematics representation ability. So, it is needed development of physics essay test to measure vector and mathematics representation ability in senior high school. Therefore, the aims of this research is : (1) to develop physics essay test to measure vector and mathematics representation ability, and (2) to obtain the characteristic of physics essay test.

2. Method

2.1. Research Method
This research is the development research. The research method used was the combination of ADDIE and 4D model. ADDIE model consists of analyze, design, development, implementation and evaluation. 4-D model consists of define, design, develop, and disseminate. The combination of these two models resulted in a development stage consists of analyze, design, develop, implementation, evaluation and disseminate [17]. The diagram combination of both models and procedures for each stage can be seen in Figure 1 and 2.

![Diagram of combination between ADDIE and 4-D](image-url)
2.2. **Data Analysis**

The polytomous data with four categories was analyzed using IRT according to Partial Credit Model (PCM) using Quest and Parscale program. The Quest program is used to determine goodness of fit, reliability and item’s difficulty index, and Parscale program is used to determine information function and standard error of measurement (SEM).

2.3. **Research Subject**

The subject that used in this research is 11th and 12th grade of science students of senior high school in Samarinda. The sample is determined by purposive sampling which consists 285 students of: SMAN 1 Samarinda, SMAN 3 Samarinda and SMAN 8 Samarinda, the sample distribution are shown in table 1. Purposive sampling was used to obtain samples consisting of high, medium and low school groups in order to obtain logistical curve. The selection of schools as research subjects is determined by National Examination rank in 2015/2016.

**Table 1.** Sample distribution

| School   | 11th Grade | 12th Grade |
|----------|------------|------------|
| SMAN 3   | 60         | 55         |
| Samarinda|            |            |
| SMAN 1   | 46         | 40         |
| Samarinda|            |            |
| SMAN 8   | 31         | 53         |
| Samarinda|            |            |
3. Result and Discussion

3.1. Physics Essay Test Development
The physics essay test consists 15 items including 9 items test of vector representation ability and 6 items test of mathematics representation ability. The sub-indicator of vector representation ability include a magnitude and direction of a vector, drawing a vector, and vector operation. The sub-indicator of mathematics representation ability include an equation and mathematical operation. The development of this test is aimed at the physics matter of impulse momentum. The indicator description of item test are shown in Table2.

| Topic | Sub-indicator | Competency Standard |
|-------|---------------|---------------------|
|       |               | Applying the concept of momentum, impulse, and the momentum conservation law in daily life | Presents the results of testing the assembling of momentum conservation laws, such as free falling ball to the floor and simple rocket |
|       |               |                     |                     |
| Drawing a vector | Magnitude and direction of a vector | Students drawing a vector of velocity and momentum of an object moving in a certain angle. Students drawing a vector of velocity and impulses of an object that hit the target. Students analyze the momentum component vector of the object moving in a certain angle. Students analyze the direction and magnitude of the impulse of an object that hit a target. Students analyze the direction and magnitude of the impulse force of an object that hit a target. Students analyze the concept of momentum conservation law in daily life. Students analyze the concept of momentum conservation law in daily life based on test result data. |
| Vector Representation | Vector operation | Students analyze the magnitude of momentum changes in daily life. Students analyze the magnitude of impulses in daily life. Students analyze the test result of momentum changes in daily life. Students analyze the comparison of impulse force of the object based on test result data. |

The items distribution is presented on Table 3. The items that have been made are validated by instrument experts, practitioners and peers amount 8 rater.
Table 3. Item Distribution

| Topic                 | Sub-indicator                              | Number of item |
|-----------------------|--------------------------------------------|----------------|
| Vector representation | Drawing a vector                           | 1, 2, 7        |
|                       | Magnitude and direction of a vector         | 3, 8, 12       |
|                       | Vector operation                            | 4, 9, 13       |
| Mathematics           | Equation                                    | 5, 10, 14      |
| representation        | Mathematical operation                      | 6, 11, 15      |

3.2. Content Validity
Items with 3 rating categories and 8 raters are declared valid if the Aiken’s validity coefficient is \( V \geq 0.88 \) [18]. The result of all vector and mathematics representation ability items is valid with Aiken’s \( V \) index between 0.88 to 1. Based on rater suggestion, the items were revised in terms of stem (sentence and clarifying the direction of motion of objects for vector representation items) and assessment rubrics to be adjusted to items difficulty index. The next steps, these items were tested to 285 high school students in Samarinda to see the characteristics of items about goodness of fit, reliability, difficulty index, information function and standard error of measurement (SEM).

3.3. Goodness of Fit
Item or testee is fit to the model if INFIT MNSQ value is between 0.77 to 1.30 [19]. Based on Figure 3, 13 items are fit to the model, with INFIT MNSQ values of items between 0.80 to 1.18. The other two items are not fit to the model. These item are item 1 and item 8 which has INFIT MNSQ values of 1.34 and 0.76. These values are out of range of items fit to the model.

3.4. Reliability
Reliability of item estimates indicates the reliability of items or samples. The analysis result show the reliability of item estimate of 0.78, it means the test sample fit by item tested, or the sample provides information as expected. Another results shows the reliability of case estimates of 0.83. It means that measurements provide the consistent results.

3.5. The Difficulty Index
The item is good if it has the item’s difficulty index between -2.00 to 2.00. Based on Figure 4, the overall items is good because it has an item’s difficulty index range of -1.15 to 1.58. Item 12 whose difficulty index of -1.15 indicates that this item is very easy. And, item 5 whose difficulty index of 1.58 indicates that this item is very difficult.
3.6. Information function and SEM

Based on the result of analysis using the PARSCALE program, it was obtained information function and standard error of measurement (SEM). Figure 5 shows that the test is suitable for the students who have the ability (g) between -1.40 to more than 3.00.

4. Conclusion

The physics essay test was successfully developed to measure the vector and mathematics representation ability of high school students. The physics essay test consist of 15 item. 9 items including sub-indicators of vector representation: drawing a vector, magnitude and direction of a vector, and vector operation. 6 items including sub-indicators of mathematics representation: equation and mathematical operation. 13 items of physics essay test is fit with Partial Credit Model (PCM) based on polytomous data four categories. The physics essay test is qualified based on reliability of item estimates of 0.78 and reliability of case estimates of 0.83. Based on information function and SEM, teachers can use this physics essay test to measure the ability of vector and mathematics representation in students who have low ability to high ability of -1.40 to more than 3.00.
References

[1] Alismail H A and Mcguire P 2015 21st Century Standards and Curriculum: Current Research and Practice (J. Educ. Pract, vol.6) pp 150–155

[2] Baran M 2016 An Analysis on High School Students’ Perceptions of Physics Courses in Terms of Gender: A Sample from Turkey (J. Educ. Train. Stud, vol. 4) pp 150–160

[3] Aithal P S and Aithal P S 2015 An Innovative Education Model to realize Ideal Education System (Int. J. Sci. Res. Manag., vol 3) pp 2464–2469

[4] De Cock M 2012 Representation use and strategy choice in physics problem solving (Phys. Rev. Spec. Top. - Phys. Educ. Res., vol.8) pp 1–15

[5] Kohl P B and Finkelstein N D 2006 Effects of representation on students solving physics problems: A fine-grained characterization (Phys. Rev. Spec. Top. - Phys. Educ. Res., vol.2) pp 1–12

[6] Kohl P B and Finkelstein N D 2008 Patterns of multiple representation use by experts and novices during physics problem solving (Phys. Rev. Spec. Top. - Phys. Educ. Res., vol.4) pp 1–13

[7] Shubha S and Meera B N 2015 Students’ Perception of Vector Representation in the Context of Electric Force and the Role of Simulation in Developing an Understanding (Int. J. Soc. Behav. Econ. Business Ind. Eng., vol.9) pp 408–416

[8] Barniol P and Zavala G 2014 Test of understanding of vectors: A reliable multiple-choice vector concept test (Phys. Rev. Spec. Top. - Phys. Educ. Res., vol. 10, no. 1)

[9] Barniol P and Zavala G 2014 Students’ difficulties in problems that involve unit-vector notation (Lat. Am. J. Phys. Educ. vol. 8) pp 4043-4053

[10] Van Deventer J and Wittmann M C 2007 Comparing student use of mathematical and physical vector representations (AIP Conf. Proc. vol. 951) pp 208–211.

[11] Guttersrud O and Angell C 2008 Mathematics in physics: Upper secondary physics students’ competency to describe phenomena applying mathematical and graphical representations (Oystein Guttersrud) pp 1–7

[12] Dewi I N, Poedjijastoeti S and Prahani B K 2017 Elsii learning model based local wisdom to improve students’ problem solving skills and scientific communication (Int. J. Educ. Res. vol. 5) pp 107–118

[13] Bing T J and Redish E F 2007 The cognitive blending of mathematics and physics knowledge (AIP Conference Proceedings vol.883) pp 26–29

[14] Nitko A J and Brookhart SM 2011 Educational assessment of students 6th ed (Pearson Education, Inc, Boston)

[15] Wragg E C 2001 Assessment and Learning in the Secondary School (Taylor and Francis Group, New York)

[16] Miller M D, Linn R L and Gronlund N E 2009 Measurement and assessment in teaching. (Pearson Education Ltd, Boston)

[17] M. Yadiannur and Supahar 2017 Mobile Learning based Worked Example in Electric Circuit (WEIEC ) Application to Improve the High School Students’ Electric Circuits Interpretation Ability (Int. J. Environmental Sci. Educ. vol.12 ) pp 539–558

[18] Aiken L R 1985 Three Coefficients for Analyzing the Reliability, and Validity of Ratings (Educ. Psychol. Meas., vol. 45) pp 131–142

[19] Hambleton and Swaminathan 1991 Fundamentals of Item Response Theory (SAGE Publications, Inc., Los Angeles)