Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika

http://jurnal.untirta.ac.id/index.php/Gravity

ISSN: 244-515x; e-ISSN: 2528-1976

Vol. 6, No. 2, August 2020, Page 117-124

Item analysis: basic concepts of physics students in geometric optics

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(Received: 06 July 2020; Revised: 06 September 2020; Accepted: 11 September 2020)

ABSTRACT

The purpose of this study was to analyze students' items and abilities—the analysis for mapping test instruments and students' basic concepts regarding optics subjects before lectures are held. The test participants were 35 physics students. The analysis model of item response theory is a one-parameter logistic model or Rasch Model with the scope of analysis of the level of item difficulty, student ability, and statements that fit the item response model. Analysis of item responses and student responses carried out using Winstep version 3.73 software. The results of the qualitative analysis of the test items consisted of memory (C1) analysis (C4). The quantitative analysis using the Rasch model showed that 35% of the total items were difficult category items. For the suitability of test items in the instrument by 85% of items fit or generally function in measurement, more than 57% of students have the geometric optical ability in logit values of 0 to 1. The results of item analysis and student ability become information for teachers to design courses such as method selection, project implementation strategies, and assessments are undertaken.

Keywords: Basic concepts, geometry optics, item response theory

DOI: 10.30870/gravity.v6i2.8506

INTRODUCTION

Before teaching a specific topic, the teacher needs to know the basic conceptual abilities of their students. The basic knowledge of specific sciences serves as an essential signal with a broad coverage pattern. (Williams & Lombrozo, 2013). The basic concept of students is essential to know (Taub et al., 2014). It can be seen whether students already have the knowledge, which is a prerequisite for participating in learning, and the extent to which students already know the material to be presented (Lestari, 2017). By knowing this, teachers will be able to better design learning. It is essential to formulate learning strategies by teachers before implementing learning. It is necessary to reformat them if they are not by class conditions, class situations, characteristics of students encountered, and the material to be taught (Barlian, 2013).

To map students' initial knowledge and basic concepts, the most accessible activity is to hold a test (Rusilowati, 2015). With the information that is believed, the teacher can identify the fundamental knowledge and variations in the basic concepts of students in the study group as supporting knowledge. Learning a lesson requires supporting knowledge. If this supporting knowledge is not yet possessed, treatment must be carried out to follow the experience (Mardapi, 2003). To carry out special treatment, it is necessary to have a plan covering certain materials/ topics that must be discussed and the methods and strategies used.

Knowing the initial ability or prior knowledge, in this case, the basic concepts of students, is an essential step in the learning process. The basic concepts of students are the main factors that will affect the subsequent learning process (Astuti, 2015). The effect of basic concepts that students have not only implied how high or low their previous knowledge is but also means that the variation in knowledge in the study group will change over time (Simonsmeier, 2018). Because students' initial abilities will be related to the learning process (Razak, 2018). The study was conducted by developing test questions on geometric optics material. The basic conceptual test of geometric optics as an instrument for measuring the basic concepts of students in understanding optics, and serves as a model for conceptual development in other domains. This test has an impact on the teacher or all students because the test results clearly show the students' basic items and concepts regarding geometric optics.

Item response theory is a statistical approach that functions to evaluate actions, such as surveys, questionnaires, and achievement tests. Item response theory is often called modern psychometrics because it enforces the relationship between items and respondents, such as competition (Moutinho et al., 2014). This item analysis model involves latent variables for discrete responses to questionnaires or test questions to measure achievement, personality, attitudes, and so on (Maydeu-Olivares, 2013). It is developed to provide a detailed description of algorithms that can be used to estimate item or parameter abilities in various parameters grain response model.

Item analysis using item response theory is useful in the development and evaluation of assessments and in calculating standard student performance measures (Cardamone et al., 2012). This analytical model has been used in increasing the number of physics and astronomy education research, such as the analysis of vector concept understanding tests (Susac et al., 2018), which states that the test items function well. The analysis of basic mechanics tests (Cardamone et al., 2012) shows the quality of learning outcomes proportional to the quality of the test, Newton's Gravity concept (Williamson, 2013), tests on the concept of force (Han et al., 2015), students' reasoning tests on mechanics (Alifa & Ramalis, 2018) the results of the analysis state that the tests carried out are suitable and with students moderate to high ability. This fundamental conceptual analysis with the item response theory in physics education is carried out based on ideas for capturing and building concepts, diagnosing idea potential, finding meaning, producing conclusions about the size of knowledge on the topic of the nature of light, the Fermat principle, curved mirrors, refraction and refractive index, total internal reflection, prisms, plan parallel glass, curved surfaces, lens strength, luminosity, and optical tools, regarding basic geometric optics and follow-up plans (Wallace et al., 2018).

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conclusions about the size of knowledge on the topic of the nature of light, the Fermat principle, curved mirrors, refraction and refractive index, total internal reflection, prisms, plan parallel glass, curved surfaces, lens strength, luminosity, and optical tools, regarding basic geometric optics and follow-up plans (Wallace et al., 2018).

Item response theory is a development of the classical test theory. Thus, this theoretical model has a number of advantages over classical theory. The difference between these two theories is shown in the aspects of the model, level, assumptions, item stability, item invariance, statistics used and the number of samples determined in these two theories (Erguven, 2013). Item response theory has some advantages over CTT in terms of data analysis. CTT statistics do not predict students' baseline abilities, regardless of the response items (Hambleton & Jones, 1968). Likewise, IRT analysis can estimate students' skills and is independent of one another, so the difficulty of fulfilling the parallel test concept on CTT. The IRT statistical method can be overcome, which allows estimating SEM on test participants with different ability levels (OA & ERI, 2016).

In item response theory, the individual parameters (difficulty level, differentiation power) for each item or question match the item response model. This parameter provides a means of evaluating the test and offers a better level of student proficiency than the obtained raw test score because each skill count considers not only the number of questions answered correctly, but each individual of all questions answered. Here are presented the results of the basic concept tests of geometry optics for physics students at Unwira Kupang using grain parameters.

RESEARCH METHODS

The purpose of the test is to solve students' necessary abilities before the optics lecture is conducted. The analysis in this study used the Rasch model or the 1-PL model because the samples used were not as large as calibrating the polytomous data using the 2-PL or 3-PL models (Hambleton & Jones, 1968).

In this study, Winsteps software was used in the form of polytomous questions with four answer choices.

The student sample involved 35 students or 10% of the total number of physics students at the Unwira Kupang study program. The research instrument used was a matter of geometric optics' basic concepts, which consisted of 20 items of geometric optics basic concept tests.

RESULTS AND DISCUSSION

Qualitative Analysis of Optical Questions

In this case, qualitative analysis is that all the questions/items on the developed optical basic concept test items are reviewed first from the aspect of cognitive dimensions according to Cognitive Taxonomy. Each item was reviewed based on the breadth, depth, and difficulty of the test material. The results of the analysis are shown in Figure 1. The scope of the geometric optical test material includes the law of light reflection, Fermat's principle, objects between two flat mirrors, curved mirrors, the law of refraction and refractive index, total internal reflection, plan parallel glass, prisms, refraction on curved surfaces, lenses, and optical tools.

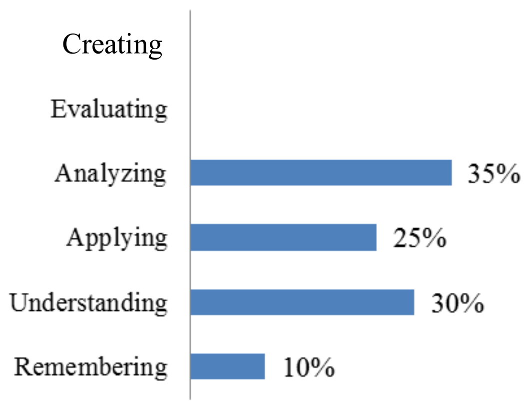

Figure 1. Diagram of the number of items in each cognitive aspect

All items on the concept of geometric optics, the distribution of the items' difficulty level were the highest at the level of the cognitive dimension to analyze. The items measure cognitive abilities in remembering, understanding, applying, and analyzing basic optical concepts. As many as 10% of the total items were items that measured students' memory, 30% of items contained understanding, 25% of items were application items, and 35% of items were analyzing. The distribution of these items was then tested on the fifth-semester physics students before the first optics lecture was held.

The following is an example of a question in a basic optical concept test instrument:

Analyze (C4): How do you position two mirrors so that regardless of the incidence angle, the rays coming to one mirror align with the reflected light from the other mirror?

Applying (C3): A magician shows an empty box to the audience, it looks empty, but when he opens the top of the box, a rabbit comes out. How to explain this?

Understanding (C2): Why do dentists use concave mirrors to examine small holes in teeth?

Given (C1): describe the process of forming images on mirrors and lenses using special rays! The interpretation of the results describing the students' initial abilities was analyzed using the Rasch model.

Table 1. Item difficulty level, rasch standard error, infit and MNSQ outfit and Z score point-measure correlation for each TUV item

Item	T. s	Measure	SE	Infit		Outfit		Correlation
				MNSQ	Z	MNSQ	Z	
15	0	4.94	1.84	Maximum measure				.00
19	0	4.94	1.84	Maximum measure				.00
14	2	2.98	.73	.99	.2	.76	.0	.16
6	4	2.21	.54	.98	.1	.86	.0	.19
13	5	1.95	.49	1.14	.5	1.91	1.5	-.14
8	8	1.35	.41	1.10	.5	1.23	.7	.07
16	8	1.35	.41	.89	-.5	.74	-.6	.38
18	9	1.18	.40	.98	-.1	2.86	3.8	.10
1	15	.35	.36	.91	-1.0	.84	-.8	.41
12	17	.09	.36	.81	-2.1	.78	-1.3	.53
20	17	.09	.36	1.50	4.7	1.55	2.8	-.31
2	18	-.03	.36	.76	-2.7	.72	-1.8	.61
10	20	-.29	.36	.88	-1.1	.83	-1.0	.48
7	21	-.42	.37	1.13	1.1	1.09	.6	.19
9	23	-.70	.38	.85	-1.0	.90	-.5	.50
4	25	-1.00	.40	1.19	1.0	1.32	1.3	.09
5	26	-1.17	.41	.98	.0	.98	.0	.38
11	34	-3.97	1.06	.56	-.3	.09	-.8	.67
17	34	-3.97	1.06	.56	-.3	.09	-.8	.67
3	35	-5.26	1.85	Manimum measure				.00
Mean	16.0	35.0	.23	.95	-.1	1.02	.2	
S.D	11.0	.0	2.58	.22	1.5	.63	1.4	

Quantitative Analysis of Optical Questions

Some parts of concern in item analysis with the Rasch model, with winstep software in item measurement (item measure) are the difficulty level of the item (which is stated in the item measure results) is the analysis result table that details the logit information of each item, the level of suitability. Item (item fit) and the possibility of bias in the arrangement of items. The item's difficulty is seen from the total score, which states the student's answer, the logit value of the item, the average logit value of each item, and the logit standard deviation. The item suitability criteria in this section are seen from the outfit mnsq and the ZSTD value (Sumintono, Bambang & Widhiarso, 2015), which is described in the analysis results Table 1.

Estimating the difficulty of the items in Table 1 is done by looking at the entry number and total score (T.s). The items (item numbers) that were considered the most difficult in the geometric optics basic concept test instrument were items 15 and 19. None of the students answered the item correctly with a logit value of 4.94, namely the topic of discussion was lens strength, refraction on the curved surface, so that it correlated with the infit value. mnsq-z and the mnsq-z outfit value for this item reach the maximum value. The most accessible item is item 3; all students can answer with a logit value of -5.26; the topic of discussion in this item is optical properties. A high logit value indicates a high level of problem difficulty and corresponds to the total score value. The table's total score states the correct number of each item that was worked on (Sumintono, Bambang & Widhiarso, 2015). The material that is considered complicated, which is represented by the items in this test, becomes a note for the teacher to design strategies and learning models for the future. Because basically, the basic concepts of students will develop over time and the learning methods designed by the teacher (Simonsmeier, 2018).

The analysis results in Table 1, if connected with the previous descriptive analysis (Figure 1), can be ascertained that the item difficulty percentage is close to the same value. Items more difficult (to analyze) have a smaller total score than the total item score for application, comprehension and memory tests.

To check the item fit's suitability, we use the mnsq outfit value, the Z-standard outfit, and the correlation value. It is known that the items that are not fit, namely items 15, 19, and 18 matches the criteria used in checking the suitability of the items, as stated (Boone et al., 2014) and (Bond & Fox, 2003). The fit item index measures how accurately a series of item responses can be predicted by the test design model (Lai, Hollis & Gierl, Mark J & Cui, 2012). The items that are not fit are a note for the teacher to pay attention to the material related to items that are not fit so that there are no more misconceptions on these items.

Ability Analysis of Optics Topics Students

As with item difficulty, the table of student ability analysis results also has similar columns. Some information can be read from Table 2, starting from the student serial number, the total score of correct answers, the logit value that correlates with the number of correct answers (total score), to the student code used during the analysis. A high logit value indicates a high level of problem ability, and vice versa, a lower logit value indicates a lower student ability in solving basic geometrical optics problems.

Table 2. Student Ability Level, infit and outfit mnsq and Z score point-correlation

				Infit		Out fit		
N.S	T.s	Measure	SE	MNSQ	Z	MNSQ	Z	Correlation
27	12	1.02	.61	.94	-.1	.84	.2	.63
32	12	1.02	.61	.84	-.7	.64	.0	.67
2	11	.66	.59	.89	-.3	.80	.1	.65
6	11	.66	.59	1.05	.3	.96	.3	.61
9	11	.66	.59	1.00	.1	.82	.1	.63
13	11	.66	.59	1.00	.1	.82	.1	.63
30	11	.66	.59	1.00	.1	1.17	.5	.60
1	10	.31	.59	1.25	1.0	1.24	.5	.55
4	10	.31	.59	.67	-1.4	.52	-.5	.71
11	10	.31	.59	1.18	.7	.98	.2	.59
15	10	.31	.59	1.14	1.6	1.20	.5	.52
….	…	….	….	….	…	….	….	….
3	3	-3.14	1.00	2.78	2.0	5.24	2.0	.31
Mean	9.2	-.02	.61	1.03	.0	1.03	.1	
SD	1.9	.79	.07	.37	1.0	.82	.6	

Students' ability in this analysis is related to students' mastery of geometric optics topics as previously described. Students' ability in the item response theory (Rasch model) is expressed on a logit scale. Each student's logit can be seen in Table 2, the enormous logit value is 1.02, and the smallest logit value is -3.14. The distribution of logit values is mostly at 0 <logit <1, or more than 57% of students can be at logit values of 0 to 1.

CONCLUSION

The optical concept test is carried out in an optics course to know the extent of the students' ability to the optical concept and the test material's difficulty. The results of the studies' analysis illustrate that the geometric optical test material is spread from the memory test to the analysis level. Also, information was obtained that more than half of the participants in the geometry optics topic test had the ability to logit values between 0 and 1. The analysis results, which included item analysis and student ability analysis, became meaningful information for teachers to design courses such as choosing learning models/methods and strategies. - the project implementation strategy and the assessment carried out.

ACKNOWLEDGMENT

This publication is the output of physics education research funded by the 2020 Unwira Kupang Grant. For this reason, many thanks to LPPM Unwira Kupang for financing this research.

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