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ORIGINAL RESEARCH

Characteristics of science process skills instruments for high school students in elasticity and Hooke's law based on analysis of item response theory

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Abstract

This study aims to analyze the characteristic of a science process skills test instrument on elasticity and Hooke's law of physics subjects in high school using item response theory. The characteristic of the instrument analyzed are the suitable logistic model, validity, reliability, discrimination index, difficulty, and pseudo guessing. The methode of this study is a quantitative descriptive and the design used is a one-shot design. The participant of this study are 121 high school students who have studied elasticity and Hooke's law. The instrumen used in this study is 20 multiple-choice question with five answer choiches. The results of validity analysis using Aiken's V index show that the instrument is valid. Based on logistic parameter model, the most suitable model for this instrument is 3-PL model with informastion function about 21,02. The reliability of the instrument shows that it is reliabel to be givento students with low to very high ability levels with ability scores -1,33 to 2,73. The overall discrimination index considered as good with a = 1,43, as for difficulty levels considered as good with b = 0,9, and pseudo guessing factor also considered as good with c = 0,17. The result show that the science process skill instrument of elasticity and Hooke's law is valid and reliable.

Keywords: *Test characteristic · Science Process Skills · Item Response Theory*

INTRODUCTION

Learning science requires students to be active in the learning process, starting from how to think, how to investigate, how to collect information, how to draw conclusions from an invention, and how to relate these findings to technological advances in society (Ramlawati et.al., 2019). The involvement of students in the learning process is very important for constructing knowledge, investigating problems, processing and finding solutions (Fajriyati et.al., 2021). One of the characteristics of learning with a scientific approach is involving science process skills in building concepts, laws or principles (Hosnan, 2014).

Science process skills are skills used to develop knowledge and problem-solving (Mutlu, 2020). These skills are thought processes by scientists in discovering and constructing knowledge to solve problems and formulate results that occur naturally and spontaneously in our minds (Herda et.al., 2020). Through these science process skills, students are expected to

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be able to discover and develop the knowledge they gain independently in accordance with the demands of the 2013 curriculum, namely student-centered learning (student centered) with the teacher acting as a facilitator (Putri et.al., 2019).

Science process skills are divided into two categories, namely basic skills and integrated skills (Riani & Ramalis, 2020). Basic skills include observing, classifying, predicting, concluding, measuring, and communicating skills. While integrated skills include skills in controlling variables, defining operationally, submitting hypotheses, interpreting data, conducting experiments, and creating models (Fugarasti et.al., 2019).

Science process skills in learning physics play an important role in discovering and understanding concepts (Siswono, 2017). Physics as a branch of science emerges and develops through observation, problem formulation, hypothesis formulation, hypothesis testing, conclusion drawing, and theoretical discovery which includes product, process, and attitude aspects (Putri et.al., 2019). Physics has nature as a product, process, and attitude. Physics as a product, namely physics as a result of empirical knowledge and experience arranged in the form of facts, concepts, laws, and theories (Murdani, 2020) . Physics as an attitude is a picture of a scientific attitude when doing research and discovering a knowledge or concept. Physics as a process shows the skills used by scientists to acquire and develop knowledge. These skills are known as science process skills. Therefore learning physics as a process is expected to develop process skills in students (Mahmudah et.al., 2020).

Science process skills are not only used as an approach in the learning process. However, it must be supported by instruments that can measure students' science process skills. The existence of this instrument is expected to provide honest and complete information on students' science process skills (Darmawan et.al., 2020). In a preliminary study conducted by the author of five high school teachers who taught physics, 60% stated that the measurement of student learning outcomes focused more on evaluating aspects of the product in the form of knowledge, which was carried out through practice questions, quizzes, oral exams, and test tests. Although all respondents are aware of the importance of measuring students' science process skills, this activity is still rarely carried out for several reasons. First, practicum activities as a means of carrying out assessments on students' science process skills are rarely carried out. Second, teachers do not yet have test instruments to measure science process skills because of a lack of reference questions and no guide in making science process skills questions.

A good test instrument can be identified through the characteristics of the test which can be obtained through an analysis of both the items and the test as a whole, so that the test items are good, not good, or not good. Test characteristics become a characteristic of a test and test analysis is needed to determine the quality of the test (Permata et.al., 2020). An analysis of the items (item analysis) is a systematic procedure that provides very specific information on the items that have been made (Daryanto, 2010) . In general, analysis of test instruments can be carried out using classical test theory (Classical Test Theory/CTT) and item response theory (Item Response Theory). Classical test theory excels in its easy use, but this theory has limitations that depend on the characteristics of the test takers (group dependent) and the characteristics of the items (item dependent) (Putri et.al., 2019). Another alternative to classical test theory is the item response theory. This theory was developed to overcome weaknesses in the classical test theory, which is not independent of the group taking the test or the test being tested (Daryanto, 2010). Item response theory is one way to assess item eligibility

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by comparing the average item performance to the estimated group performance evidence (Sarea & Ruslan, 2019). The item response theory shows the relationship between the abilities measured by the instrument and item responses (Brzezinska, 2018).

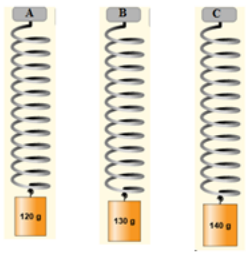
The purpose of this study was to analyze the characteristics of the science process skills test instrument on elasticity and Hooke's law using item response theory analysis. The characteristics of the instruments analyzed in this study were validity, reliability, discriminating power, level of difficulty, and quasi-guessing factors.

METHODS

The method used in this research is a descriptive research method using a quantitative approach. The research design used is *a one-shot design*. The population in this study were students who had studied elasticity and Hooke's law in high school. The sample in this study was 121 students of class XII majoring in science in Bandung City, Padang Panjang City, and Tasik Malaya City. Sampling in this study used a *convenience sampling technique*. *Convenience sampling* is choosing a group of individuals who are willing to be research subjects (Fraenkel et.al., 2012).

To obtain the necessary data, the instrument used was a science process skills test instrument consisting of 20 multiple-choice questions with five answer choices. Aspects of science process skills are observing, classifying, predicting, interpreting, communicating, asking questions, posing hypotheses, planning experiments, using tools and materials, and applying concepts (Rustaman, 2015). The following presents a matter of science process skills on elasticity and Hooke's law.

Perhatikan Gambar 6 berikut!



Gambar 6. Tiga buah pegas identik dengtan massa beban berbeda

Gambar 6 menunjukkan tiga buah pegas identik dengan panjang awal (x_0) yang sama. Pada pegas A, pegas B, dan pegas C secara berurutan digantungkan beban sebesar 120 g, 130 g, dan 140 g. Jika konstanta masing-masing pegas sama, maka pernyataan hipotesis yang benar adalah….

A. Perubahan panjang (Δx) setiap pegas bernilai sama
B. Pegas dengan massa beban paling kecil mengalami perubahan panjang (Δx) paling besar
C. Pegas dengan massa beban paling besar mengalami perubahan panjang (Δx) paling kecil
D. Pegas dengan massa beban paling kecil mengalami perubahan panjang (Δx) paling kecil
E. Pegas tidak mengalami perubahan panjang (Δx)

Figure 1. Example questions on the aspect of submitting a hypothesis

The validity of the instrument was obtained through the *judgment of* five experts on a validation sheet consisting of nine validation indicators for each item. Then the validation results will be processed using the Aiken V formula. The Aiken formula is as follows.

$$V = \frac{\sum r - l_0}{[n(c-1)]} = \frac{\sum s}{[n(c-1)]} \quad (1)$$

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where V is Aiken content validity index, r is score given by expert, c is score of the highest validity assessment, l_0 the lowest validity assessment score, N is the number of experts. The Aiken table based on the number of validators and the number of assessment categories is shown in Figure 2.

No. of Items (*m*) or Raters (*n*)	Number of Rating Categories (c) 2		3		4		5		6		7	
	V	p	V	p	V	p	V	p	V	p	V	p
2							1.00	.040	1.00	.028	1.00	.020
3							1.00	.008	1.00	.005	1.00	.003
3			1.00	.037	1.00	.016	.92	.032	.87	.046	.89	.029
4					1.00	.004	.94	.008	.95	.004	.92	.006
4			1.00	.012	.92	.020	.88	.024	.85	.027	.83	.029
5			1.00	.004	.93	.006	.90	.007	.88	.007	.87	.007
5	1.00	.031	.90	.025	.87	.021	.80	.040	.80	.032	.77	.047
6			.92	.010	.89	.007	.88	.005	.83	.010	.83	.008
6	1.00	.016	.83	.038	.78	.050	.79	.029	.77	.036	.75	.041
7			.93	.004	.86	.007	.82	.010	.83	.006	.81	.008
7	1.00	.008	.86	.016	.76	.045	.75	.041	.74	.038	.74	.036
8	1.00	.004	.88	.007	.83	.007	.81	.008	.80	.007	.79	.007
8	.88	.035	.81	.024	.75	.040	.75	.030	.72	.039	.71	.047
9	1.00	.002	.89	.003	.81	.007	.81	.006	.78	.009	.78	.007
9	.89	.020	.78	.032	.74	.036	.72	.038	.71	.039	.70	.040
10	1.00	.001	.85	.005	.80	.007	.78	.008	.76	.009	.75	.010
10	.90	.001	.75	.040	.73	.032	.70	.047	.70	.039	.68	.048

Figure 2. Aiken table

Based on the Aiken table in Figure 1, if there are three assessment categories with a total of five validators or raters, then the Aiken validity coefficient value can be declared valid if it has a minimum value of 0.90.

The analysis technique used is item response theory or IRT. The IRT model used is a three-variable logistic model (3-PL), which takes into account three item parameters, namely discriminating power, level of difficulty, and pseudo guessing factor. This model was chosen because it shows the highest information value compared to the 1-PL and 2-PL models.

RESULT AND DISCUSSION

The characteristics of the science process skills instrument on elasticity and Hooke's law were obtained from IRT analysis using the eirt 2.0.0 software.

Validity

Judgment process by experts consisting of three lecturers from the Department of Physics Education and two high school physics teachers to assess and provide input on the science process skills instruments that had been created. The validator fills out the validation sheet with the provision that he puts a check mark (V) for each validation indicator in the categories valid without revision (VTR), valid with revision (VR), and invalid (TV). Each validation indicator is given a value of 3 for the valid category without revision (VTR), 2 for the valid category with revision (VR), and 1 for the invalid category (TV). Based on the assessment given by the expert, several suggestions for improvement were obtained both in terms of material, construct, and language. The results of the assessment were analyzed using the Aiken V index according to equation 1 and then interpreted according to the Aiken table in Figure 2. An item can be said to be valid if it has a minimum value of 0.90. Overall, the validation results of science process skills instruments for material aspects, language aspects, and construction aspects are presented in Table 1 .

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Table 1. Instrument Validation Results Science Process Skills Test

Validation Aspect	Validation Indicator	Aiken V index	Interpretation
Material	The suitability of the items with the question indicators	0.99	Valid
	The suitability of the items with the aspects of science process skills	0.99	Valid
	The accuracy of the items to measure science process skills	0.98	Valid
Language	The use of language in accordance with the rules of the Indonesian language	0.99	Valid
	The use of language that is easily understood by students	0.99	Valid
Construction	Choice of answers and reasons homogeneous and logical in terms of material	0.98	Valid
	There is only one answer key	0.99	Valid
	The questions do not give clues to the correct answer	0.99	Valid
	Answer choices do not use the statement "all answers are correct" or "all answers are wrong"	0.99	Valid
Overall grade point average		0.98	Valid

Identification of Logistics Parameter Models

This identification was carried out to find out the logistic parameter model in accordance with the material science process skills skills test instrument elasticity and Hooke's law that had been made. The data available in *Microsoft excel* were then analyzed using the 1-PL, 2-PL, and 3-PL models with the help of *eirt* version 2.0.0 software. Information for each model can be known through the information function or *information function* which indicates the extent to which the model is able to provide information about *trait-level estimation* along the ability scale. The higher the peak of the information function, the more informative the model is in explaining the ability of the test takers (Ramalis & Rusdiana, 2015).

The graph of the information function for each model of the logistic parameter test for science process skills is presented in Figure 3 .

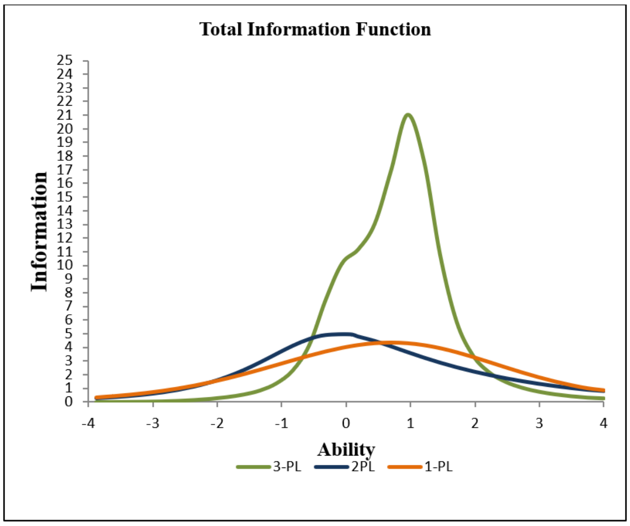

Figure 3. Graph of the information function of the 1-PL, 2-PL, and 3-PL models

Based on the graph of the total information function in Figure 1, it can be seen that the graph with the highest information peak is the 3-PL model with an information value of 21.02. Meanwhile, the information value at the top of the information function graph for the 1-PL and 2-PL models is 4.32 and 4.97, respectively. So it can be concluded that the logistic parameter model that corresponds to the science process skills test on elasticity and Hooke's law is the three-parameter logistic model (3-PL). According to Ramalis & Rusdiana (2015), this means that the 3-PL model can provide better information to show the relationship between the test takers' response patterns and the characteristics of each item.

Reliability

Instrument reliability was analyzed using item response theory. The model used is a three-parameter logistic model (3-PL). This model was chosen because it has the highest value of the information function (I). The higher the value of the information function, the more precise a model is in estimating the ability of the test takers (Ramalis & Rusdiana, 2015). The level of precision in the model used can be seen from the *Standard Error Measurement* (SEM) value. SEM is quadratic inversely proportional to the information function, the greater the value of the information function, the greater the SEM value and vice versa (Hambleton, Swaminathan, & Rogers, 1991). Instrument reliability can be identified by looking at the intersection of the total information function curve and the SEM curve. The information function curve and SEM for the 3-PL model are presented in Figure 4.

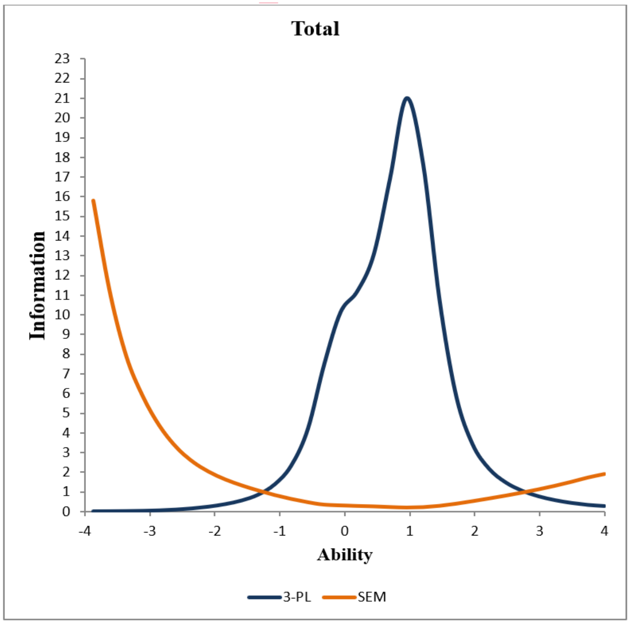

Figure 4. Information function curve and *Standard Error of Measurement* (SEM) 3-PL model

Based on Figure 4.2 it can be seen that the total information peak of the 3-PL model is at an information value of 21.02 and an ability level θ= 0.95 with an estimation error (SEM) of 0.22. The intersection between the information function curve and the SEM curve is in the range -1.33 to 2.73. These data indicate that the science process skills instrument on elasticity and Hooke's law material in this study will be reliable if given to students with low to very high abilities.

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Discrimination, Difficulty Level, and Pseudo Guessing Factor

The discriminating power, level of difficulty, and the overall guess factor of an instrument in the analysis of item response theory can be seen from the *test characteristic curve* or TCC. The TCC curve in this study shows the scores obtained by students at each ability level after working on 20 items of science process skills on elasticity and Hooke's law. The total characteristic curve of the results of the analysis of item response theory model 3 logistic parameters is presented in Figure 5 .

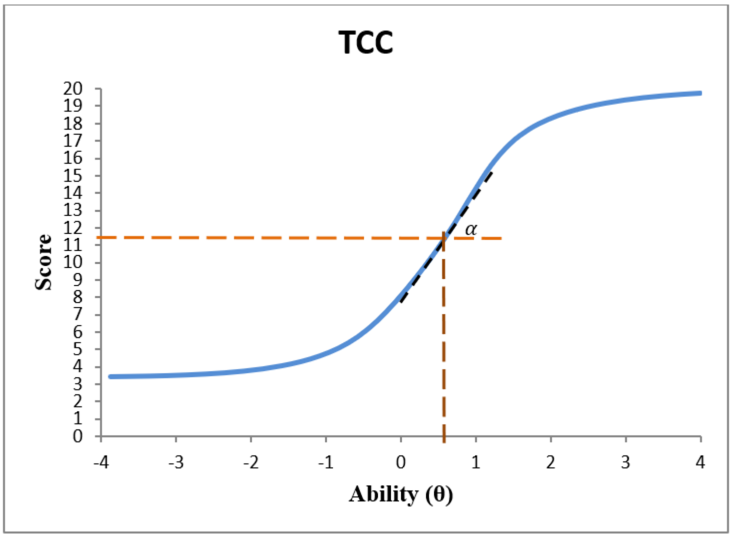

Figure 5 . The total characteristic curve of the 3-PL model

Based on Figure 3, students with a $\theta = -4$ (very low) ability level will get a score of 3.40 from an ideal maximum score of 24, meaning that the probability of 0 is at a score of 3.40. Whereas students with ability levels $\theta = -4$ will get a score of 19.74 out of an ideal maximum score of 20, meaning that probability 1 is at a score of 19.74. Then the probability of 0.5 is at a score of 11.57 on the total characteristic curve.

The value of parameter a (distinguishability) is obtained from the slope of the curve *or* it could also be from the results of $\tan\alpha$. Based on Figure 3 obtained $\tan\alpha = \tan 55° = 1{,}428$. Arikunto (2019) states that items that can be answered correctly by students in the upper and lower groups have poor discriminating power, similarly if students in the upper and lower groups cannot answer the item correctly then the item has high discriminating power. bad, good items are items that can be answered correctly by students in the upper group only. When viewed as a whole, the discriminating power of this science process skills instrument can be said to be good in distinguishing students from the upper and lower groups because it is still in the range 0 to 2 with a discriminating power value of 1.428. The following is an example of questions with good discriminating power.

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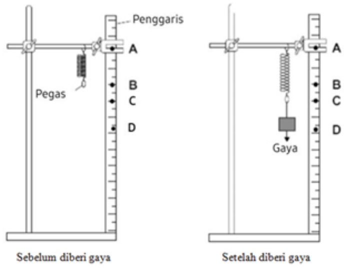
Gambar 4 menunjukkan keadaan pegas sebelum dan setelah diberi gaya pada percobaan hukum Hooke.



Gambar 4.Keadaan pegas pada percobaan hukum Hooke

Berdasarkan Gambar 4, perubahan panjang pegas ditunjukkan oleh titik….

A. A-B
B. A-C
C. B-C
D. B-D
E. C-D

Figure 6. Item question no. 6

The value of parameter b (difficulty level) is obtained by drawing a horizontal line from the probability value of 0.5 at a score of 11.57 to the TCC curve, then from the point of intersection, a vertical line is drawn to the capability axis. Based on the total characteristic curve it is known that the value of b = 0.9 and is in the category of moderate difficulty level. Arikunto (2019) states that the items in the medium category are items that are neither too difficult nor too easy. A good question is one that is neither too difficult nor too easy. So based on this statement, most of the questions in this instrument can be said to be good in terms of difficulty level because they are neither too easy nor too difficult. The following is an example of a question with a moderate level of difficulty.

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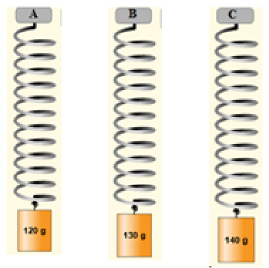

Gambar 6. Tiga buah pegas identik dengtan massa beban berbeda

Gambar 6 menunjukkan tiga buah pegas identik dengan panjang awal (x_0) yang sama. Pada pegas A, pegas B, dan pegas C secara berurutan digantungkan beban sebesar 120 g, 130 g, dan 140 g. Jika konstanta masing-masing pegas sama, maka pernyataan hipotesis yang benar adalah….

A. Perubahan panjang (Δx) setiap pegas bernilai sama
B. Pegas dengan massa beban paling kecil mengalami perubahan panjang (Δx) paling besar
C. Pegas dengan massa beban paling besar mengalami perubahan panjang (Δx) paling kecil
D. Pegas dengan massa beban paling kecil mengalami perubahan panjang (Δx) paling kecil
E. Pegas tidak mengalami perubahan panjang (Δx)

Figure 7. Question number 9

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The value of parameter c (false guess factor) is the lower asymptote of the total characteristic curve. Hullin in Retnawati (2014) states that an item can be said to be good if it has a c value of not more than 1/k where k is the number of answer choices. Based on the total characteristic curve, it is known that the value of c for the science process skills test is at a score of 3.40, so the probability is 0.17 and is categorized as good because the value of c is less than 1/k, which is 0.2.

CONCLUSION

In this study, 20 questions were produced on the material science process skills test on elasticity and Hooke's law in multiple choice form with five answer choices. Based on the findings and discussion, the following conclusions can be drawn:

The validity of the test instrument as a whole can be said to be valid based on the results of expert *judgment* with an average of 0.98 for all aspects of the assessment. Identification of the logistic parameter model obtained by comparing the information function curves of the three logistic parameter models shows that the best model to be used in analyzing the science process skills instrument on elasticity and Hooke's law is the 3-PL model with an information value test I = 21.02. The test instrument is reliable if it is tested on students with low to high abilities with an ability scale of -1.33 to 2.73. The parameters of the discriminating power test instrument in this study as a whole were good with a value = 1.43, the level of difficulty in the medium category with a value of b = 0.9, and a good guessing factor with a value of c = 0.17.

Based on the results of the research that has been described, the science process skills test instrument on elasticity and Hooke's law material that has been made can be used by educators and other parties to evaluate students' science process skills. In addition, the results of the characterization of this instrument can also be used as a reference to determine the characteristics of the multiple choice test using item response theory analysis.

Recommendations from this study for further research are as follows: Data collection in this study was carried out by distributing questions in the form of a *Google form* randomly to students who had studied the material on elasticity and Hooke's law, for further research it would be better if they collaborated with physics teachers at school so that the results of students' work could be used as grades. additional so that students can work in earnest. The test developed in this study uses elasticity and Hooke's law. For further research, other physics materials can be used.

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