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Development Of Problem-Solving Measuring Instrument In Motion Topic Using the Testlet Model

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Abstract: This research aims to produce the Testlets' model instrument test that measures the problem-solving abilities of high school students in West Kalimantan on motion topics. The study employed A.D.D.I.E.'s development model, which consists of analysis, design, development, implementation, and evaluation stages. Three hundred four students from three different cities in West Kalimantan were involved as respondents in this study. The researchers collected data through test techniques and documentation since this study focused on the characteristics of the test. The instrument test of problem-solving abilities is designed to follow Heller's solution stages, namely focusing on the problem, describing physics, planning a solution, implementing the plan, and evaluating the answer. The results of this study are the availability of 20 multiple-choice questions, with five main questions and four testlets. The assessment instrument developed had the characteristics of validity up to 0.90 (high), reliability through Cronbach's Alpha Reliability analysis: 0.83 (very good), person reliability: 0,84 (high) and item reliability: 0.98 (excellent). The test developed is theoretically and practically feasible so that high school physics teachers can use it to measure students' problem-solving abilities more quickly because it uses a multiple-choice test.

Keywords: Assesment; Motion; Problem-solving; Testlet

Introduction

21st-century education requires students to have 4C abilities: Critical Thinking and Problem-Solving, Creativity, Communication, and Collaboration. So, problem-solving ability is a skill students must prepare for the future. (Khairani & Prodjosantoso, 2024; Suharlan et al., 2023). Apart from that, changes in the implementation of the curriculum direct learning to be centered on students (student center); through the student center, it is hoped that students will have problem-solving abilities as an application (learning to do) to build their mindset (Silitonga & Sirait, 2016; Yana et al., 2022). Apart from that, education in the 21st century requires facing various challenges of increasingly advanced developments and industrial needs with a high level of generalization tasks. Therefore, understanding and problem-solving skills are needed in each student.

However, based on the results of interviews with Physics teachers who are members of the Physics M.G.M.P. in Pontianak City, it was found that most students consider physics to be one of the most challenging subjects to understand. As a result, many students still need to complete or achieve the Minimum Completion Criteria (K.K.M.) score for physics lessons. Further interviews with several physics teachers revealed that one form of student learning difficulty is the students' low ability to solve questions to be able to solve problems. The low problem-solving abilities of students in physics learning were also found due to research (Kurniawan et al., 2023; Maison et al., 2020). One of the skills that are important in students' success in learning physics is problem-solving ability because students' abilities not only reach mastery of concepts but

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apply them to solve physics problems (P. K. R. Heller & Anderson, 1992).

Apart from that, questions that require high-level thinking or HOTS can also include questions on problem-solving ability. Even though students' problem-solving abilities also refer to HOTS. Low HOTS can be caused by learning models or methods that cannot develop students' HOTS (Retnawati et al., 2018; Shin Yen & Hajar Halili, 2015). Apart from that, according to Rahayuningsih & Jayanti (2019), low HOTS can be caused by students who need to get used to working on HOTS-based questions.

One form of action taken to reveal students' difficulties is by giving tests to measure students' problem-solving abilities. Five steps in the problem-solving model by Heller & Heller (2000) will be used to reveal students' abilities in solving problems. The steps for solving physics problems (problem-solving) by Heller & Heller (2000) used in this research are 1) Focus on the problem; in this step, you can use qualitative descriptions by determining questions, writing down what is known and being asked in the problem and sketching pictures to help students find the main problem; 2) Describe the Physics, in this step you can describe diagrams, define symbols, and state quantitative relationships. 3) Plan a Solution; in this step, create an equation framework based on the physics explanation in the previous step to obtain another equation. 4) Execute the Plan; in this step, solve the problem in the equation and enter the known values or numbers so that the student can solve the algebra problem according to the target problem. 5) Evaluate the Answer: In this step, evaluate the solution and check the answer, as well as check for errors that occur so that an appropriate and correct answer is obtained.

Diagnostic tests are used to determine students' weaknesses or identify which learning targets a student has not mastered (Arikunto, 2018) (Nitko, 2001). The benefit of the results from diagnostic tests is that teachers can plan learning better to overcome difficulties experienced by students (Fariyani et al., 2015).

To diagnose students' difficulties in solving problems. Testlets are given on motion material because among several areas of physics study, namely motion (mechanics); optics and waves; heat and thermodynamics; electricity and magnetism; modern physics; and the solar system, it was found that problem-solving abilities in the field of motion (mechanics) were most researched because they are contextual.

Testet is a form of test developed and designed to represent problem descriptions into a group of related questions. Each question represents a step in solving the problem (Slepkov & Shiell, 2014). Items in the Testlet model test consist of main questions and supporting questions. These questions are designed to provide information for other supporting questions. Supporting items are created to have a level of resolution of the main problem so that they are expected to help teachers diagnose students' learning difficulties (Muna et al., 2017).

Based on Afifah et al. (2021), testlets have pedagogical characteristics that stimulate qualitative analysis in solving physics problems. Testlet is a test model combining multiple choice and essay questions tests (Trinovitasari et al., 2022). The items are conceptually related to the tiered multiple-choice model (Kusumaningrum et al., 2015). Wahyuni et al. (2015) explained that the testlet model is a test that combines the advantages of objective questions and descriptive questions. Each question item developed has a relationship that supports each other. The question items developed have a level of completion of the main questions given to help teachers effectively measure students' problem-solving abilities.

Many Testlet model assessment instruments have been developed, one of which is the development carried out by Aloysius Rabata & Koes (2016). Other research has also been carried out by (Muna et al., 2017), who succeeded in developing a Testlet model test instrument to detect student learning difficulties on buffer solutions. (Damayanti, 2017) developed a Testlet model assessment instrument to measure the high-level thinking abilities of high school students in electrochemical material. Indicators of higher-order thinking skills are the skills to analyze, evaluate, create, think critically, and think logically.

Based on this description, it is necessary to develop an instrument to measure the problem-solving abilities of high school students by using Heller problem-solving steps in the form of testlets on motion material.

Method

The research and development method is used in this research. This type of research is different from other educational research because the aim is to develop a product based on trials and then revise it to produce a suitable product. Borg and Gall (Sugiyono, 2012) state that development research is used to develop and validate products in education and learning. Development in this research uses the ADDIE model. According to (Branch, 2009), who developed this product, the stages based on the ADDIE model are as follows Figure 1.

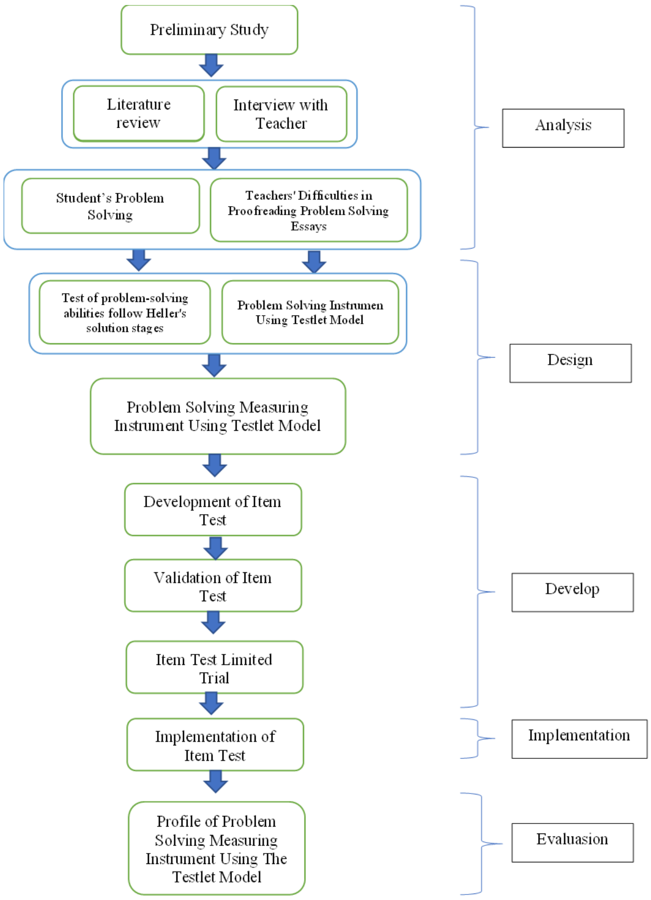

Figure 1. Procedures of Instrument Development

The stages of the ADDIE development model in this research consist of the Analysis, Design, Development, Implementation, and Evaluation stages. At the analysis stage, a preliminary study was carried out through literature review and interviews with high school physics teachers in West Kalimantan to identify problems felt by teachers related to measuring students' problem-solving abilities. The problems students face, especially in problem-solving, impact students' low physics learning outcomes, so students' problem-solving difficulties need to be identified. However, teachers also need help examining students' problem-solving results, generally in the form of essay questions.

At the design stage, an instrument could measure students' problem-solving abilities using five steps in Heller's problem-solving model in the form of multiple-choice questions with five main problems and four testlets. Testlet model questions have more practicality than descriptive tests because the assessment can be carried out objectively and is polyatomic.

In the development stage, 20 questions were developed in multiple choice form with five main problems and 4 tests on uniform straight motion material. Next, validation is carried out by validators consisting of lecturers and physics teachers. Validation results are processed through Aiken's V validation analysis. Guidelines for Categorizing Validation with Aiken's V are follows the guidelines in Table 1 .

Table 1. Guidelines for Validation Categorization with Aiken's V

Index Validity	Criteria
$0 \leq V \leq 0.4$	Low
$0.4 < V \leq 0.8$	Medium
$0.8 < V \leq 1$	High

Next, trials were carried out on 304 students at three high schools in three regions in West Kalimantan. Next, the results were analyzed using Rasch model analysis using Winstep 5.1.4.0.

The first is to test the level of item fit by looking at the Outfit Mean Square (MNSQ) value received: 0.5<MNSQ<1.5; Accepted Outfit Z-Standard (ZSTD) value: -2.0<ZSTD<+2.0 ; and Point Measure Correlation (Pt Mean Corr): 0.4<Pt Measure Corr<0.85.

The second is the item reliability test with Cronbach's alpha reliability. The reliability criteria are follows the guidelines in Table 2.

Table 2. Cronbach's alpha reliability criteria

Alpha Cronbach' value	Interpretation	Reliability Value	Information
$0.90 \leq r \leq 1.00$	Very good	<0.67	Weak
$0.70 \leq r \leq 0.90$	Good	0.67 – 0.80	Enough
$0.40 \leq r \leq 0.70$	Pretty good	0.80 – 0.90	Good
$0.20 \leq r \leq 0.40$	Bad	0.91 – 0.94	Very good
$r < 0.20$	Very bad	>0.94	Special

Third, test the level of difficulty of the questions from the logit measure value with the following categories.

Table 3. Question Item Difficulty Level Criteria

Measure value (Logit)	Category
< -1.17	Very easy
-1.17 – 0	Easy
0 – 1.17	Difficult
>1.17	Very difficult

Next, improvements to the test were carried out based on the several stages above. The test was assembled into appropriate questions to measure the problem-solving abilities of high school students in the form of tests on movement material. The questions that had been declared appropriate were then given to 304 10th grade high school students in three cities in West Kalimantan province, namely Pontianak City, Sambas Regency, and Bengkayang.

The results of the analysis and trial of test items are used to determine the feasibility and characteristics of the resulting test in measuring the Profile of Problem Solving Measuring Instrument Using the Testlet Model.

Result and Discussion

The research aims to produce a test in the form of a Testlet, which can be used to measure students' problem-solving abilities in Movement material at the 10th grade high school level. There were 20 questions in multiple-choice form with five main problems and four testlets on the uniform rectilinear motion. Problem-solving questions refer to the problem-solving steps by Heller & Heller (2000), namely focusing on the problem, describing the physics, planning a solution, executing the plan, and evaluating the answer. These five solution steps become a reference for students in developing strategies for solving physics problems presented in the questions being developed. The questions were designed based on the revision of national curriculum's competency in 10th grade. Table 4 shows the questions indicators based on the Heller problem solving steps.

Table 4. Questions Indicators with Heller Problem Solving Steps

Heller problem solving	Indicators	Questions
Focus on the Problem	Visualizing the problem	1, 13
	Draw graphics of the problem	5, 9, 17
Describe the problem in terms of Physics	Selecting the correct Physics terms	2, 6, 10, 14, 18
Plan a Solution	Planning steps to solve the problem	3, 7, 11, 15, 19
Execute the Plan	Analyzing the problem	4
	Calculating	8, 16,20
	Predicting	12

This is an example of part one on question number 2, which has been developed from indicators on the Heller problem-solving step one, "focus on the problem" on the indicator "draw graphics of the problem".

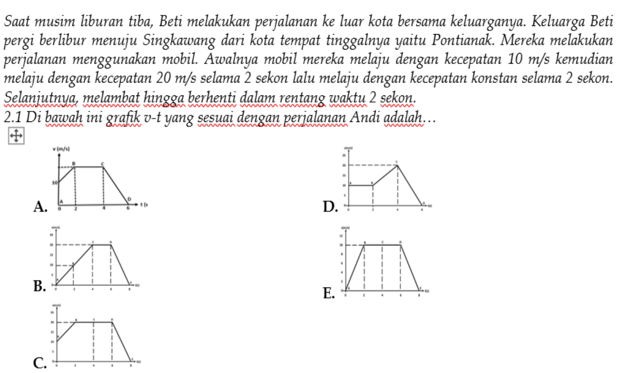

Figure 2. An example of question

The draft questions were validated by lecturers and physics teachers involved in the research as partners and then revised and tested in partner schools. The validation results were analyzed using Aiken's V Validation Categorization Guidelines in Table 1, which shows the following results.

Table 5. Item Validation

Aspect	Expert			Score	V	Category
	1	2	3	Max		
Substance	299	317	278	320	0.90	High
Construct	379	393	351	400	0.91	High
Language	211	229	209	240	0.86	High
Average					0.90	High

Table 5 shows Aiken coefficients of questions based on the aspects measured which are substance, construction, and language. It shows that the questions developed has an average Aiken V' coefficients of validity of 0.90, so the questions are valid in high category. In terms of material, the questions developed are valid in high category with an average Aiken V' coefficient of 0.90. This indicate that the substances tested on the questions are corresponding to the expected learning outcomes, the questions indicator, cognitive dimension, and suits for high school students. In addition, the construction of the questions is also valid in high category with an average Aiken V' coefficient of 0.91. This shows that the questions developed were constructed based on Heller problem solving steps and the testlet correspond to the main problem given. Furthermore, this category also shows that the pictures or diagrams given were clear, the questions only have one answer and the other answer choices are homogenous and logical with the substance. Linguistically, the questions developed were also valid in high category with an average Aiken V' coefficient of 0,86. This shows that the questions are communicative, follows the KBBI rules, and do not cause double interpretation.

After the questions developed are validated, it was tested on 304 10th grade high school students from three districts/cities of West Kalimantan, namely Pontianak, Sambas, and Bengkayang. The test results were then analyzed to determine the validity and reliability of the test using Rasch model analysis using Winstep to determine the level of suitability of the question items.

First, the item fit of the questions shows information about whether the items usually function or not in carrying out measurements. A question is considered fit if it meets the Outfit Mean Square (MNSQ) score, Outfit Z-Standart (ZSTD) score, and Point Measure Correlation (Pt. Mean Coor) score criteria. Sumintono & Widhiarso (2015) stated that the valid parameter of those criteria is the value of the Outfit Mean Square (MNSQ) is

0.5<MNSQ<1.5; the value of Outfit Z-Standart (ZSTD) is -2.0<ZSTD<+2.0; and the value of Point Measure Correlation (Pt Measure Corr) is 0,4<Pt Measure Corr<0,85. A question item is said to be valid, so it does not need to be removed or replaced if it meets two of the three criteria above. The results of the analysis of the level of suitability of the questions using Winstep are as follows.

Table 6. Result of Item Fit

Item	Outfit MNSQ	Outfit ZSTD	Pt. Measure Corr
1	0.86	-0.21	0.44
2	0.88	-0.19	0.43
3	0.73	-0.22	0.53
4	0.66	-0.81	0.51
5	0.92	-0.61	0.50
6	0.80	-0.18	0.52
7	0.80	-1.68	0.58
8	1.47	3.29	0.43
9	0.94	-0.42	0.52
10	0.72	-0.65	0.50
11	1.46	2.19	0.45
12	2.31	7.07	0.43
13	0.87	-0.06	0.48
14	1.01	0.15	0.46
15	1.30	2.13	0.39
16	0.98	-0.09	0.53
17	1.71	3.27	0.47
18	1.19	1.49	0.48
19	0.81	-1.61	0.58
20	1.12	0.94	0.46

Table. 6 Results of analysis of the questions' suitability level using Winstep. The analysis results are then sorted based on question number to make it easier to analyze the question item suitability test results. Based on the test results data, it was found that several questions did not meet the Z.S.T.D. Outfit criteria, namely question items number 8, 11, 12, 15, 17. A ZSTD value < -2 indicates that the response variation is less than the model or closer to the Guttman than the Rasch model. A ZSTD value > 2 indicates that the response variation is more than the model, where the answers given by respondents cannot be predicted (Bond & Fox, 2020).

Apart from that, the data also shown a question item that did not meet the Point-measure correlation criteria, namely question item number 15. Point-measure correlation shows the correlation between the difficulty level of the question items and the difficulty of the test as an instrument. A point-measure correlation value of 1 indicates that all test participants with low ability answered the questions incorrectly, and all test participants with high ability answered correctly. However, if the point-measure correlation value is 0, it indicates no relationship between the question items and other tests; it is not related to the abilities (Planinic et al., 2019). After carrying out the analysis, it can be stated that 20 items met the criteria of item fit because even though items 15 and 17 show that they are out of the criteria because only 2 of the three criteria for the level of suitability of the questions do not meet the criteria, thus no items are dropped.

The reliability of the items developed is also analyzed. Based on the analysis of Table 2 alpha Cronbach's criteria, it was found that Cronbach's alpha reliability is 0.83 (good), person reliability is 0.84 (good), and item reliability is 0.98 (excellent). Person reliability shows how consistent the students' answers are. The person reliability reported is in good category with the value of 0,84. This indicates that the students will be able to reproduce the sequence of order if they are given a similar test (Chan et al., 2014; Susac et al., 2018). Furthermore, the item reliability reported is in excellent category with the value of 0,98. This indicates that the items will be placed in the same difficulty order if the test were administered to another similar sample of students (Susac et al., 2018).

The testlet developed is then tested for each question item's difficulty level. The values obtained are interpreted using the criteria for the difficulty level of the question items in Table 3. After interpreting the test results, the level of difficulty of the questions can be shown in the Table 7.

Table 7. Result the level of difficulty of each question item

Measure	Category	Item Number	Total
<-1.17	Very Easy	1,2,4,10,13,14	6
-1.17 – 0	Easy	3, 6	2
0 – 1.17	Hard	5,7,8,9,12,15,16,18,19,20	10
>1.17	Very Hard	11,17	2

Based on the item difficulty shown in Table 7, most of the questions developed are in the hard category with 10 items. The other questions are in very easy category with 6 items, easy and very hard category with 2 items each. The item difficulty in IRT is based on the probability of students to answer the question correctly based on their ability or trait level (Furr & Bacharach, 2007). The higher the item difficulty indicate that the higher trait level required in order for students to have 50/50 probability to answer the question correctly. Item difficulty of 0 indicates that students with average level trait have 50/50 chance to answer the question correctly. Thus, students the average trait have less probability to answer it correctly and the students with low trait level have even lower probability to answer the question correctly than the students with average level trait.

Conclusion

Based on the analysis of this research, the problem-solving test developed following the Testlets model assessment is feasible and practical for teachers to determine student's ability to solve problems on motion topics. The result showed that the instrument met the content validity and Rasch model analyzed. The characteristics of tests are Aiken validity up to 0.90 (very high), reliability through Cronbach's Alpha Reliability analysis: 0,83 (good), person reliability 0,84 (good), and item reliability: 0,98 (excellent). The test developed is theoretically and practically feasible so that high school physics teachers can use it to measure students' problem-solving abilities quickly because it uses a multiple-choice test. Further research is needed regarding testlets, so the suggested research topics are analyses of students' problem-solving abilities in physics subjects using testlets. Testlet instruments for other physics materials need to be developed.

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