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# Developing Instructional Mathematical Physics Book Based on Inquiry Approach to Improve Students' Mathematical Problem Solving Ability

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**Abstract.**The problem in this research is to know how the process of developing mathematics physics instructional book based on inquiry approach and its supporting documents to improve students' mathematical problem-solving ability. The purpose of this research is to provide mathematical physics instruction based on inquiry approach and its supporting documents (semester learning activity plan, lesson plan and mathematical problem-solving test) to improve students' mathematical problem-solving ability. The development of textbook refers to the ADDIE model, including analysis, design, development, implementation, and evaluation. The validation result from the expert team shows that the textbook and its supporting documents are valid. The test results of the mathematical problem-solving skills show that all test questions are valid and reliable. The result of the incorporation of the textbook in teaching and learning process revealed that students' mathematical problem-solving ability using mathematical physics instruction based on inquiry approach book was better than the students who use the regular book.

Keywords**:** Instructional Book;Mathematical Problem Solving Ability; Inquiry Approach

## I. INTRODUCTION

The curriculum at IKIP PGRI Pontianak requires the students of Physics education program to master some basic physics courses, one of which is mathematical physics. In learning physics, the students are required to master mathematics, this is because in learning physics the students are not only required to learn the concept of physics but also required to formulate a mathematical concept formulated in the form of a mathematical law or formula. In addition, students also learn how to use math to discuss physics problems. Wanhar [1], states that mathematics plays a main role in physics, to solve physics problems from the simple to the most complex. In addition, mathematics is also very helpful in reasoning someone in tracing the complexity learning physics.

Nevertheless, the students consider mathematical physics as one of the difficult subjects. This is shown from the results of the final examination of mathematical physics course given to students of IKIP-PGRI Pontianak in the academic year of 2010/2011 with an average score below 60, as well as in the academic year of 2011/2012 the average scores below 65. From these two sets of data it can be seen that the percentage of students who have difficulty working on mathematical physics problems is still quite large, especially on the question that requires a mathematical concept; for example, in kinematics material with vector analysis, in learning the concept the student experienced difficulties to solve the problems because they did not master integrals and derivatives. In fact, this course is a prerequisite course for students to take the next courses including modern physics courses, statistical physics, and quantum physics.

Based on the results of interviews with physics lecturers and some students of Physics education study program, it is revealed that the students' difficulties in studying mathematical physics due to the low ability of problem-solving mathematics. The results of the researchers' initial tests on students' mathematical problem-solving skills showed that most of the students were still difficult in solving mathematical problems. The mistakes made by students include: (1) 29% of students could not identify the data or information needed to solve mathematical problems, (2) 61% of students did not use effective strategies and lead to solutions to solve mathematical problems, and (3) 83% of students did not provide an explanation of the strategies, related concepts, and mathematical procedures; not using mathematical representations to solve problems and did not interpret and communicate solutions of mathematical problem solving obtained.

The low ability of mathematical problem solving caused by several factors, among others, lecturers still use lessons with lectures and less independent in learning. The lessons used by the lecturer with the sequence explaining, giving examples, asking questions, exercises, and assigning

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tasks to make the students accustomed to accept the concept directly from the lecturer without trying to find out the process of finding the concept. Therefore, it is required a learning model that can improve students' independence learning and train students in solving problems that require mathematical concepts.

According to Santyasa [2] the efforts to improve the quality of process and learning outcomes are through the implementation of constructivist learning paradigm. The change in the paradigm of learning leads to a change of learning focus from learner-centered learning into student-centered learning. Learning conditions that make the students only receive the material from the teacher, record, and memorize it must be converted into knowledge sharing, inquiry, find knowledge actively so that there is an increase of understanding not memorizing. In addition, learning based on constructivist paradigms focuses on solving problems, developing concepts, constructing solutions and algorithms rather than memorizing procedures and using them to get one correct answer. The appropriate approach for this demand is inquiry approach.

An inquiry approach is a form of teaching that emphasizes the active role of students both physically and mentally in the learning process. Kindsvatter, Wilen, and Ishler in Suparno [3] explain that inquiry is a teaching model that involves students' critical thinking skills for systematically analysing and solving problems. Through inquiry, can train students ability in solving problems both in solving problems and problems encountered in everyday life.

Several studies have shown that the inquiry approach is well applied in learning. Brickman, et al [4] suggests that the inquiry approach can develop student skills, increase self-confidence and scientific skills. In addition, McBride, et al [5] found that physics teachers were more successful in teaching their students through an inquiry approach. Kurniawati, et al [6] showed that mastery of concept and critical thinking ability of students who learn with inquiry learning guided peer instruction integration higher than conventional learning. Similarly, Wahyudin, et al [7] concluded multimedia-assisted learning using guided inquiry can increase students' interest and understanding.

This study uses an inquiry approach to improve students' mathematical problem-solving skill in mathematical physics course. To carry out teaching and learning process using inquiry approach, a textbook that is oriented to the approach is needed. Therefore, this research aims to develop a textbook of physics mathematics-based inquiry approach, in order to improve students' mathematical problem-solving skill. Besides developing textbooks, this research also develops supporting documents such as Semester Learning Activity Plan (SLAP), Lesson Plan (LP), and Mathematical ProblemSolving (MPS) test.

## II. RESEARCH METHOD

This research is a research and development approach (R & D) which aims to develop a product of physics-based mathematics instructional books inquiry approach. The textbook development process uses the ADDIE model consisting of four stages: analysis phase, design stage, development, and production stage, implementation stage, and evaluation stage [8]. This research uses descriptive, evaluative, and experimental methods. Descriptive methods are used to describe the initial analysis of existing conditions. Evaluative methods are used to evaluate the product validation and testing process. The experimental method is used to test the efficacy of the resulting product.

The sample of this research was two classes of Physics education study program of IKIP PGRI Pontianak selected as control class (Class A) and experiment class (Class B). For the experimental class, it is done using mathematical physics instruction based on inquiry approach. While the control class using Mathematical Physics textbook which was not based on inquiry approach.

In the analysis phase, it describes the needs analysis of textbooks. From the results of preliminary studies on the need for textbooks to improve the problem-solving skills of mathematics has taken the action of designing textbook of mathematical physics based on inquiry approach. At this stage of design is also designed supporting document for a textbook. Furthermore, after going through the stage of analysis and design, the next stage was the development stage. At this stage, it is described the quality of physics-based mathematics instruction book based on an inquiry approach assessed by a team of experts and improvements made by researchers based on experts input.

The aspects assessed from the textbook consist of five such as: (1) the accuracy of the scope of the content, including the suitability of the textbook content to the purpose of the lecture to be achieved, and the breadth or depth of the textbook content, (2) the textbook digestibility, Systematic, orderly and consistent format, (3) language usage, such as language or editorial used in clear, proper, and communicative textbooks, (4) the appearance of the textbook, and (5) the use of clear illustrations and right.

In addition to being asked to assess the quality of textbooks, the experts were also required to assess the quality of SLAP and LP. SLAP and LP were arranged based on course with reference to the standard format established by the instructional analysis development centre. Assessment in SLAP consists of five aspects: (1) development of the course identity, (2) development of learning activities, (3) time allocation, (4) library resources, and (5) language use.

Aspects of assessment for the LP were four aspects: (1) development of expected end-capabilities and indicators based on inquiry approach, (2) development of inquiry-based learning activities, (3) development of assessment based on inquiry approach, and (4) LP.The assessment of each aspect in textbooks, SLAP and LP was done using Likert scale, namely SB (very good), B (good), C (enough), K (less) and SK (very less). Very well worth 5, good 4, enough 3, less 2, and very less 1. Next is calculated the average value of each aspect assessment of all expert team assessment and categorized with the provisions: the value of textbook quality /SLAP/LP was very good if 4<value<5; good if 3<value< 4; enough if 2<value<3, less if 1 <value< 2.

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The research instrument was developed in this research to assess the effectiveness of the lecture by using mathematical physics instructional book based on inquiry approach in improving students' problem-solving abilities in mathematics. The instrument was a set of MPS test. MPS test was analysed quantitatively through a try-out to 39 students of Physics education study program that have taken the subject of mathematical physics. Quantitative analyses of MPS tests include empirical validity, distinguishing power, difficulty index and reliability test.

Results obtained from validation have been followed up with revisions of validation results. Furthermore, in the development stage, a limited trial conducted on some of the subjects of the textbook. Similar to the validation stages, these test results were reviewed and followed up with revisions. In order to improve the product trial result, the implementation of the textbook in the experimental class (23 students) and compared with the control class (19 students) using the textbook used by the lecturer in the mathematics physics lecture. At this stage was also conducted MPS test to determine the problem-solving ability of mathematical students after obtaining learning by using developed textbook.

From the result of the application of textbook, evaluation of mathematics instruction book based on inquiry approach and effectiveness level on students' mathematical problem-solving ability.

## III. RESULT AND DISCUSSION

The results of the research presented in this paper are the results of each stage of development of physics mathematics textbooks based on inquiry approach and its supporting tools and research instruments, from the analysis phase to the evaluation stage.

Activities undertaken at the analysis phase are needs analysis, student analysis, context analysis, and task analysis. The activity in requirement analysis stage is to determine the basic problem that is needed in the development of textbook by conducting a study on the relevant curriculum and learning theory so that the description of the text book is considered appropriate. At this stage defined and defined the needs of the mathematical physics lecture is expected after following this course students can explain the concepts and principles of ordinary integral and integral folding, matrix, derivative, and differential equations, and can use it in various problem-solving process, both related issues Mathematics itself as well as related to the problems of physics.

Mathematical physics is not a new subject matter for the students. In Senior high school level, they have studied mathematical physics subject matter such as integral, differential function, and matrix, therefore, they already have initial knowledge about it. At the beginning of the semester, the students have also acquired basic physics courses which are a prerequisite for taking a course in mathematical physics. With their initial knowledge, it certainly enables students to analyse and solve problems systematically. This is in line with the inquiry approach since it is a learning approach that involves students' critical thinking skill to analyse and solve problems systematically [3].

Student analysis was a study of student characteristics in accordance with the development of the textbook model design. From the preliminary study that researcher conducted it was revealed that the initial ability of students in Physics education study program of IKIP PGRI Pontianak in the academic year of 2014/2015 classified as low. Based on the analysis of the students it is determined that lectures did not directly use the inquiry approach, but in each subject preceded by lectures using expository methods to explain the mathematical concepts, then on the application of problem-solving physics used inquiry approach.

Context analysis is an act of identifying, detailing, and systematically compiling relevant mathematical concepts to be formed into appropriate textbooks. From this analysis it is found that the composed teaching material consists of four subjects: (1) matrix consisting of three learning activities namely: definition, types, and matrix count operation, determinant and inverse matrix, and application of matrix in solution of problem physics; (2) a derivative consisting of three learning activities: algebraic functions and trigonometric functions, high-level derivatives, and derivative applications in the completion of physics; (3) partial differential consisting of four learning activities namely: partial differential definition, total differential and chain derivative, and implicit and extreme price function, and differential application in the completion of physics problem; and (4) the ordinary integral and folding integral consisting of four learning activities: the regular integral, the two-fold integral, the triple integral, and the integral application in the completion of the physics problem;

The activity in this task analysis is to identify the basic competency and standard competency that will be achieved through the mathematics physics lecture by using textbook based on inquiry approach. The last activity of the analysis phase was the conversion of standards competency and basic competency of task analysis and context analysis into lecture objectives. The purpose of the lecture is contained in every chapter and in every learning activity in the mathematics physics textbook.

The next is the design stage. This stage was an early stage of the design of textbooks of mathematical physics based on inquiry approach that was used in lectures. At this stage, an early draft of the textbook has been produced and used for fourteen times face to face. The designed textbook consisted of four chapters and fourteen learning activities. The textbook was embedded with SLAP and LP. In addition at this stage also has produced the initial draft of MPS test instrument.

The textbooks, supporting tools, and research instruments that have been designed at the design stage were validated by five experts who were deemed proficient in order to obtain information in the form of input, evaluation, and revision of the textbook model, supporting documents and research instruments that have been designed.

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The results of the textbook quality assessment on the five aspects of assessment by five experts are shown in Table I.

Table I
Result of Textbook Analysis by Expert Team

| No | Assessment aspects | Mean score | Mean of total score | Scoring criteria |
|---|---|---|---|---|
| 1 | The accuracy of content coverage | 4.30 | | |
| 2 | The legibility of textbook | 3.90 | | |
| 3 | The use of the language | 4.20 | 3.92 | Good |
| 4 | Cover/appearance | 3.20 | | |
| 5 | The use of illustration | 4.00 | | |

The result of the analysis shows that the developed textbook has anaverage score of assessment is 3.92 it belongs to thegood criterion. Belawati, et al [9] said that several factors that influence the quality of textbook, among others: the scope of textbook content, digestibility, language, appearance, and illustration. The quality of textbook developed is dependent on the accuracy of textbook developers in taking into account these factors in developing textbook. With the assessment of the quality of textbook by a team of experts who categorized well, this textbook prototype can be used in the next step of the development of field trials (implementation)

In general, the five experts stated that the mathematical physics textbook is well-constructed, but there were some things that need to be fixed before they are tested in the classroom. Some of the improvements that need to be improved include: (1) consistency in image numbering, examples, exercises, and competency tests; (2) error in typing;(3) error in calculation; (4) the exercise was put at the end of the activity; (5) textbook was equipped with key answer for odd-numbered / even-numbered questions; and (6) improvements in some graphic images.

The use of textbook will be more easily equipped with supporting documents such as SLAP and LP. The results of the SLAP quality assessment on the five assessment aspects are shown in table II.

Table II
The Result of SLAP Analysis by Expert Team

| No | Assessment aspects | Mean score | Mean of total score | Scoring criteria |
|---|---|---|---|---|
| 1 | The development of course identity | 4.20 | | |
| 2 | The development of learning activities | 4.40 | | |
| 3 | Time allocation in the design | 4.50 | 4.40 | Very good |
| 4 | The use of literature | 4.20 | | |
| 5 | Language aspects | 4.70 | | |

The results of the analysis show that the developed SLAP has an average score of each aspect of the assessment of more than four and a total average score of 4.40 is considered very good. Some expert team suggestions for SLAP are the addition of used literature sources and a more customized grammar with the format set by the instructional analysis development centre.

The results of the analysis on the LP by the expert team showed that overall the LP was also very well classified with a mean score of 4.15. The LP is designed based on an inquiry approach with four aspects of assessment. The result of the quality assessment of the LP by the expert team is presented in Table III. The suggestion from the expert team on the lesson plan is on the more detailed learning steps of the inquiry instruction syntax in the LP.

Table III
The Result of LPAnalysis by Experts Team

| No | Assessment aspects | Mean score | Total mean score | Scoring criteria |
|---|---|---|---|---|
| 1 | Expected capability development. | 4.40 | | |
| 2 | The development of learning activities | 3.95 | | |
| 3 | Development of assessment | 3.77 | 4.15 | Good |
| 4 | Language Usage | 4.50 | | |

A textbook that has been developed, of course, cannot be said well if not tested its use in the field, therefore this research develops research instruments to measure the effectiveness of the use of textbooks in classroom lectures. The developed instrument is the MPS test. This is in line with the opinion of Triyono [10] who said that the conclusions of a study were drawn based on empirical data collected. If the data collected does not provide a true picture of the actual situation, then the conclusion of the results of his research is also difficult to be trusted.

The results of the analysis by the expert team on the MPS test conclude that of the four MPS test questions given, three questions are declared valid and one is invalid. One problem with the valid category still needs to be fixed the redaction of the sentence is less clear. An invalid problem is replaced because it does not match the indicator of the grid problem. The replaced questions are then returned to the experts and are considered valid. After the next validated the problem is tested for being analysed.

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The MPS test results show that there is no validity with a low level of validity. The first question ($R_{xy}$ = 0.745), the third question ($R_{xy}$ = 0.808) and the fourth question ($R_{xy}$ = 0.758) have a high degree of validity while the second ($R_{xy}$ = 0.857) has a very high degree of validity. From the reliability test resulted the fourth reliability index question is 0.802 is high.

Analysis of distinguishing power and indices of difficulty on KMPS test questions indicates that the KMPS test has sufficient and good distinguishing features, as well as a moderate and easy difficulty index. The results of distinguishing power analysis and difficulty indices are presented in Table IV.

Table IV
The Result of Discriminating Power and Difficulty Index Analysis of MPS Test

| No MPS Test | Discriminating Power | | Difficulty Index | |
|---|---|---|---|---|
| | Score | Criteria | Score | Criteria |
| 1 | 0.311 | Good | 0.621 | Moderate |
| 2 | 0.304 | Good | 0.740 | Easy |
| 3 | 0.241 | Enough | 0.743 | Easy |
| 4 | 0.303 | Good | 0.604 | Moderate |

Problem number three has considerable distinguishing power with easy index indices. This issue will still be used but will be revised on the content aspect. Revisions made to keep in mind the indicators to be achieved in the test questions.

From the overall analysis of MPS test results showed that all items on the MPS test can be used as research instruments.

From three stages of development has been produced prototype textbooks of physics mathematics-based approach inquiry and supporting documents. The next step is to test the prototype of the course to get input to refine the textbook before it is used more widely.

Mathematical physics lecture by using textbook based on inquiry approach done in one semester. The result of mathematical problem-solving ability is shown in Table V.

Table V
Student Mathematical Problem Solving Abilities

| Class | Mean | Standard Deviation |
|---|---|---|
| Exsperiment | 56.34 | 18.07 |
| Control | 4.20 | 15.29 |

The result of hypothesis testing shows that there is a difference of the problem-solving ability of amathematic student who gets the learning by using physics mathematics instructional book based on inquiry approach with students who get the learning by using a textbook which is used by the lecturer, with significance level 0.029 smaller than 0.05. Judging from the average problem-solving abilities, the experiment class is higher than the control class. This shows the result of learning of students who get the learning by using textbook of physics of mathematics based on inquiry approach better than a student who gets the learning by using a textbook which usually used by the lecturer.

The use of guided inquiry approach is very supportive in improving students 'mathematical problem-solving skills, in line with Kinsvatter, Wilen, and Islher[3] opinion that inquiry learning is a learning that involves students' critical thinking ability to analyse and solve problems systematically. In student inquiry learning is directed to answering questions and solving problems, learning is based on logical testing of facts and observations. Through inquiry learning, students can develop intellectual thinking and other abilities such as asking questions and skills to find answers that begin with their curiosity. This course can support the improvement of students' mathematical problem-solving skills

Usman [11] in his research concludes that in solving a problem, students need meta-cognition activities in the form of: (1) when understanding the problem, the subject performs meta-cognition activities, namely: realizing the importance of thinking about how to understand the problem, monitoring the understanding of the problem, and evaluating the understanding of the problem, (2) when making the completion plan, the subject performs meta-cognition activities, namely: be aware of the importance of planning the completion steps, monitoring the plan of completion steps, and re-evaluating the plan of completion plan steps, (3) Meta-cognition activities, namely: realizing the importance of thinking about the implementation of the completion plan, monitoring the implementation of the completion plan, and evaluating the implementation of the completion plan, (4) when re-examining the completion, the subject performing meta-cognition activities, Namely: realizing the importance of thinking about re-examining the settlement, monitoring the truth of the outcome, and evaluating the truth of the outcome.

These meta-cognition activities are most likely to be developed using inquiry learning, since inquiry learning has learning steps: the first stage is the orientation stage, creating a responsive atmosphere or learning climate. Students are conditioned to be ready to receive lessons. Students are stimulated to think about solving problems. This stage can develop a meta-cognition activity that is aware of the importance of thinking about how to understand the problem, monitor the understanding of the problem, and evaluate the understanding of the problem.

The second stage is the stage of problem formulation, which begins when asking questions of the phenomena learned at the beginning of the lesson so that it leads to the hypothesis (temporary answer to the problem under study). All students are entitled to submit a hypothesis but selected one of the hypotheses relevant to the concept being studied. At this stage meta-cognitive activities that can be developed are aware of the importance of thinking about the plan of completion steps, monitoring the plan of completion steps, and re-evaluate the steps of the settlement plan.

The third and fourth stages of inquiry learning are data collection and hypothesis testing. Data collection is an activity in gathering the information needed to test the

hypothesis. At this stage of data collection, students are given the freedom to experiment or study literature. The process of determining the answers based on data collection performed is called the hypothesis testing stage. At both stages, it can develop meta-cognition activities that are aware of the importance of thinking about implementing the completion plan, monitoring the implementation of the completion plan, and evaluating the implementation of the settlement action plan.

## IV. CONCLUSIONS

The product of this development research is a physics-based mathematics instruction book based on inquiry approach with its supporting documents in the form of SLAP, LP, and MPS test. The use of the textbook in teaching and learning process revealed that the use of mathematics physics textbook based on inquiry approach can improve students' mathematical problem-solving ability. For future improvement, it is necessary to evaluate the textbook by rearranging the textbook to make it simpler and easier to understand.

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