A Didactical Design of Problem Based Learning Teaching Materials to Overcome Students Learning Obstacles on Calculus

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Abstract. This study aims to develop a didactical design for Calculus subject teaching materials using Problem Based Learning. The research method used in this study was didactical design research. The research steps taken are didactic situation analysis, to see the student learning obstacle that appears in calculus courses. The subjects taken were students who had received Calculus I courses, namely 5 people in class 2015, 5 people in 2016, and 5 people in 2017. The results of the didactic situation analysis were difficulties in understanding students in the initial calculus material, so the special emphasis was placed on - Initial calculus material with problem-based learning. Based on the results of the learning obstacle, a problem-based calculus teaching material was developed and validated. Metapedidaktic analysis, at this stage a limited trial was conducted on students who were taking calculus courses in class 2018. Retrospective analysis revised teaching materials and linked the learning obstacle with student responses and observations during learning. The results of this study are learning tools used in calculus learning with problem-based learning. The didactic design developed received positive responses from students.

1. Introduction
Calculus is one of the subjects that must be taken by students in the Mathematics Education Study Program at IKIP Siliwangi, this course is given to students starting in semester 2. Concepts in calculus play a very important role in the development of Indonesian educational innovations in the face of resource development humans in this Industrial 4.0 era. Some development of innovations from calculus can be utilized in the fields of mechanical engineering, architectural, engineering, industrial engineering, civil engineering, agriculture, medicine, pharmacy and there are still many uses of calculus in other fields. Some development of innovations from calculus can be utilized in the fields of mechanical engineering, architectural, engineering, industrial engineering, civil engineering, agriculture, medicine, pharmacy and there are still many uses of calculus in other fields [1].

Currently many students are unprepared to study calculus and fail the calculus course [2]. Based on the experience of researchers in teaching calculus courses, it turns out calculus is a subject that is felt difficult by most students. Student learning outcomes in the even semester of the 2017/2018 academic year shows that there are still many masteries of concepts in calculus courses. With still a lot of mastery of unfinished calculus concepts will result in inhibition of student mastery in the next material that requires calculus as prerequisite courses such as courses in differential equations, algebraic structures, real analysis and vector analysis. Mastery of the concept of a low calculus is caused by abstract calculus.
Study by Lamichhane & Belbase [3], found that mathematics is difficult and abstract, not contextual, mysterious subjects, but can be applied in various fields of science.

Many factors influence the success of students in mastering concepts of calculus, therefore it is necessary to know the causes of students experiencing learning obstacles in calculus courses. A new strategy is needed that is able to create learning to be more meaningful by giving problems with contexts related to everyday life. Learning that gives rise to the provision of problems with the context relating to daily life is learning Problem Based Learning [4]. A didactic design of teaching materials based on Problem Based Learning, is needed that is able to overcome student learning obstacles in understanding calculus concepts. Based on the background of the problem described above, the purpose of this study is to develop a didactic design of calculus subject matter materials with Problem Based Learning.

2. Method

The research method used in this research is Didactical Design Research with a qualitative approach to overcome student learning difficulties in calculus courses. The researcher will describe the steps to overcome the learning obstacle by using didactic design. This research focuses on designing and compiling didactic designs in the form of Problem Based Learning materials in calculus courses based on the identification of learning obstacles for some students who have studied the concept.

The steps of the research to be carried out according to [5]: 1) Analysis of the Didactic Situation, the activities are as follows, a) Analyzing and determining the material to be used as research, b) Developing test instruments to identify learning obstacles that will appear in calculus courses, c) Test the instruments that have been prepared for students at various semester levels and have studied the material, d) Analyzing data obtained from the test results of instruments, e) Making conclusions about learning obstacles that appear based on the results of instrument testing, f) Arrange didactic design in the form of problem-based learning based material that will minimize learning obstacles found, g) Conduct validation of teaching materials that have been compiled by several predetermined validators, h) Revise the teaching material after validation. 2) Metapedaddidactic (Meta Pedagogic Didactic) Analysis, with activities as follows: a) Conduct testing of didactic designs that have been prepared, b) Conduct observations during learning, c) Analyze the results of didactic design tests based on student responses. 3) Retrospective Analysis, with activities as follows: a) Revising teaching materials based on observations during learning and predicting student responses, b) Linking the learning obstacle with student responses and observations during learning.

The research subjects taken in the preliminary study were 5 students in 2015, 5 students in 2016 and 5 students in 2017. While the trial subjects were students of class 2018. The instruments used in this study were a test and non-test instruments. Test instruments are arranged to see learning obstacles for students in calculus courses. The question is adjusted to the achievement indicators of derivative material. The non-test instruments used in this study were observation sheets and student response sheets. Non-test instruments are used to see the suitability of learning obstacles with the implementation of teaching materials during the learning process. Data analysis uses qualitative data analysis techniques. Qualitative analysis is carried out during the process of collecting data until the results of data collection.

3. Result and Discussion

3.1. Didactic Situation Analysis

The compilation of didactic design learning in calculus courses was carried out after the initial calculus ability test was carried out before students who had received calculus courses to identify the learning obstacle that appeared in the course. In this process, the research subjects were given 5 questions about the initial ability of calculus. After being given the initial ability question, each student was interviewed regarding the questions that had been done to get deeper information regarding the difficulties experienced by the research subject of the initial calculus ability test. Based on the results of the initial ability test, the obstacle learning identification results are obtained as follows:

a. Ontogonic learning obstacle type, that there is still a leap in the thinking process of students due to a mismatch between teaching materials and students' thinking power [6].
b. Epistemological learning obstacle type, students still lack understanding of the context and concepts provided by the lecturer, so students often turn upside down or do not know which concept to be able to solve the problem given [7].

c. Didactical learning obstacle type, that students is still focused on lecturers who explain, so students are fixated on what is explained by lecturer [8].

Based on the learning obstacle that has been identified, a learning device is prepared using the Problem Based Learning approach in calculus courses. This learning tool is in the form of a Learning Implementation Plan (RPP) and Student Activity Sheet (LAM). Table 1 is the draft RPP and LAM that has been prepared.

| Table 1. Phase of Problem Based Learning Approach related to Learning Student Obstacle |
|-------------------------------|---------------------------------|---------------------------------|
| Learning Obstacle              | Phase of PBL                    | Student Activities               |
| Ontogonis learning obstacle type, that there is still a leap in the thinking process of students due to a mismatch between teaching materials and students' thinking power. | Problem Orientation Phase | Students are given problems to explore student curiosity in the material to be studied |
|                                | Observes and asks Phase         | Students are asked to solve problems by collaborating in groups, asking one question that can help them to solve the above problems and answer them so that they can help students solve problems. |
| Epistemology learns the obstacle type, students still lack understanding of the context and concepts provided by the lecturer, so students often turn upside down or do not know which concept to be able to solve the problem given. | Research Phase | Students are asked to look for data and describe it so that it can help in solving problems |
| Didactical learning obstacle, that students is still focused on lecturers who explain, so students are fixated on what is explained by the lecturer. | Problem solving phase | Students are asked to identify a set of numbers that have the same members so that a set of parts can be seen from the others. |
| Concluding phase               |                                  | Students are asked to conclude the answer to the problem above from several steps that have been done. |

The RPP and LAM that have been compiled are validated by two expert lecturers. The LAM consideration sheet and RPP validation sheet are given to the two experts to provide an assessment of the RPP and LAM that have been prepared. The following are the results of LAM considerations and RPP validation. The assessment sheet contains several assessment indicators as seen on Table 2.

| Table 2. Validator Advice and Recommendations |
|-----------------------------------------------|-----------------------------------|
| Validator                                    | RPP advice and recommendations    | LAM advice and recommendations    |
| Validator 1                                  | RPP is good                       | Development questions need to be presented after solving a problem in order to construct a big problem. |
| Validator 2                                  | The lesson plan is good and is in accordance with the Problem-Based Learning approach | In general, LAM is good, which needs to be developed are pictures or graphs of functions that can represent the functions that exist so that students can more easily understand it. |

Based on the results of suggestions and recommendations from the validator, it was found that the RPP and LAM that had been prepared were feasible after revision.
3.2. Metapedidactics Analysis

Improvements from the validator produced the second draft RPP and LAM, then limited trials were conducted for students of class 2018 who were getting Calculus courses to see student responses to learning activities. The instrument used is the student response sheet on a 1-4 scale. The following are the results of student responses after learning is given:

| No | Statement                                                                 | Average of student response |
|----|---------------------------------------------------------------------------|------------------------------|
| 1  | Learning material has been presented in full at LAM                        | 2.50                         |
| 2  | The stage in PBL support in understanding the material                     | 3.57                         |
| 3  | Learning material is displayed sequentially according to the syllabus     | 3.17                         |
| 4  | The practice questions presented help understand the material             | 3.60                         |
| 5  | The overall layout and design of LAM is good                              | 3.53                         |
| 6  | Suitability for the use of the shape and size of letters in LAM            | 3.10                         |
| 7  | The appeal of LAM in presenting the material as a whole                   | 3.27                         |
| 8  | The consistency of the use of letterform, font size, spacing, and layout and systematic typing of LAM as a whole | 3.43                         |
| 9  | Suitability of the format used in LAM as a whole                          | 3.37                         |
| 10 | Clarity of Instructions and directions                                     | 3.47                         |
| 11 | The language used is communicative                                         | 3.33                         |
|    | Practical Quality                                                         |                              |
| 12 | The learning approach used by lecturers in calculus courses helps improve understanding of the material in learning | 3.59                         |
| 13 | The learning approach used by the lecturer makes it easier for me to do calculus practice questions | 3.40                         |
| 14 | The learning approach used by lecturers adds to my knowledge in learning Calculus Courses | 3.70                         |
| 15 | The learning approach used by lecturers increases my interest in learning | 3.33                         |
| 16 | The learning approach used by lecturers increases my motivation in understanding the material in learning | 3.40                         |

Based on Table 3, each statement points are mostly more than scale 3, which means the quality of LAM and the practical quality of the learning approach used in the good category.

3.3. Retrospective Analysis

The following is given the learning obstacle analysis and learning approach, linking the learning obstacle with student responses and observations during learning.

3.3.1. Obstacle Ontogenic Learning Type

There is still a leap in the thinking process of students because there is a mismatch between teaching materials and also the thinking of students resulting in difficulties for students in continuing to study calculus. In problem-based learning, students show an active response to lecturers when giving direction on several activities that students must follow. The problem orientation phase, the stage of observing and asking questions gives space for students to improve their literacy skills and thinking by connecting the initial knowledge they have learned. This is consistent with the results of research [9], mathematical literacy abilities of students who get learning with a problem-based learning model is better than students who get conventional learning. Through scaffolding the lecturer gives several questions to provoke student curiosity so that new questions are obtained from students. From the questions given by the lecturer, students carry out the stages of investigation and problem solving so that students' thinking power is systematic in solving problems. This is in accordance [10], mathematics learning achievement
using PBL with scaffolding techniques gave better results than mathematics learning achievement with direct learning.

3.3.2. Epistemological learning obstacle type
Students still do not understand the context and the concepts given by the lecturers, so students often turn upside down or do not know which concept to solve the problem given. The stages of problem-based learning, students' initial knowledge is used in introducing new material. The cases given in LAM provide a comparison between one question and another, so that students can adjust which concept is used to solve the problem. For example, in LAM 1.

![Figure 1. Example of LAM Contents](image)

Translation:
*Case 1: Can \( \sqrt{2} \) be expressed as the quotient of two integers \( \frac{m}{n} \)? Compare your answer with illustration below.*

Case 1 at LAM 1 in Figure 1 is an example, students answer problems based on initial knowledge about the numbers they have. Then the next comparison is given so that students understand the new concepts they will have. The results of the study [11], show that problem-based learning uses manipulative materials and problem-based learning, both effective in terms of students' cognitive abilities in learning mathematics. This study found that classes with problem-based learning using manipulative materials were more effective in terms of the cognitive abilities of students in mathematics. The cases given at the LAM can hone students' critical thinking skills in the learning process with the Problem Based Learning approach. This is consistent with the results of research [12], show that students' critical thinking skills, increase using the Problem Based Learning model, both student activities during the learning process.

3.3.3. Learning obstacle didactical type
Students are still focused on lecturers who explain, so students are fixated on what is explained by the lecturer. The stage of concluding from problem-solving activities bridges students in understanding the material and the lecturer directs to new concepts learned by students. The steps taken in PBL provide knowledge, experience for students so that they are not only fixated on the lecturers' explanations. This is consistent with the results of research [9], learning independence of students who get learning with problem-based learning models are better than students who get conventional learning.

The results of the analysis concluded that the didactic design made, effective calculus learning was implemented. This is in accordance with the research [13], the didactic design that has been made, is
able to change student learning habits and is quite capable of developing student competencies even though it is not optimal.

4. Conclusion
The didactic situation analysis that has been done shows that the students still do not use the initial knowledge they have to use in calculating learning. Furthermore, the didactic design was made using the problem-based learning approach that was adjusted to the characteristics of the learning obstacle in calculus courses to be further validated by expert validators. Metapedidaktic analysis, at this stage the trial was limited to students who were taking calculus courses and the results of student responses in good categories. Retrospective analysis revised teaching materials and linked the learning obstacle with student responses and observations during learning.

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