Developing calculus textbook model that supported with GeoGebra to enhancing students’ mathematical problem solving and mathematical representation

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Abstract. The main purpose of this research is developing and produces a Calculus textbook model that supported with GeoGebra. This book was designed to enhancing students’ mathematical problem solving and mathematical representation. There were three stages in this research i.e. define, design, and develop. The textbooks consisted of 6 chapters which each chapter contains introduction, core materials and include examples and exercises. The textbook developed phase begins with the early stages of designed the book (draft 1) which then validated by experts. Revision of draft 1 produced draft 2. The data were analyzed with descriptive statistics. The analysis showed that the Calculus textbook model that supported with GeoGebra, valid and fill up the criteria of practicality.

1. Introduction
To study the differential calculus requires the mathematical thinking ability. Differential calculus content involves many graphics functions and images that manually require a long time to make it. For that required software that can be used for to help make the graphic and image display of material concept functions, limits and derivatives.

Mathematical problem solving and mathematical representation are abilities that must be considered in differential calculus learning. Mathematical problem solving is a common goal in learning mathematics and even as the heart of mathematics [3,8]. If students have a good mathematical problem solving, students will have good analytical power to apply in a variety of situations.

Mathematical representation is the expression of mathematical ideas in an attempt to find a solution of problem [11]. The role of mathematical representation is important in learning mathematics because it can be a means of students to solve a problem. Indicator of mathematical representation in this research that student can present problem into mathematical idea which can be picture, diagram, and mathematical expression. Therefore, students need media that can be used to assist in developing their mathematical representation abilities. One of the media is GeoGebra.

GeoGebra is a software of dynamic geometry and algebra system. GeoGebra has ability to solve various problems related to functions, such as extreme points, optimization and others. GeoGebra can be obtained easily and free on the internet. In addition GeoGebra can also be used online without installing on the computer.

Based on the above description can be known about the importance differential calculus both in the mathematics scope and in other scopes, and the importance of mathematical problem solving skills and mathematical representation to be developed in students, and GeoGebra software can be effectively used.
in differential calculus learning. Therefore it is deemed necessary to develop and produce a Calculus textbook model that supported with GeoGebra to enhancing students’ mathematical problem solving and mathematical representation.

2. Review Of Related Literature

2.1 Mathematical Problem Solving
Mathematical problem solving and mathematical representation are abilities that must be considered in differential calculus learning. Mathematical problem solving is a common goal in learning mathematics and even as the heart of mathematics [8,9]. If students have a good mathematical problem solving, students will have good analytical power to apply in a variety of situations.

Mathematical problem solving indicators are Understand the problem; Choosing the right strategy to solve the problem; Implementing the chosen strategy for solving the problem; and Reviewing the correctness of problem solving obtained using the strategy chosen [6,7].

2.2 Mathematical Representation
Mathematical representation is the expression of mathematical ideas in an attempt to find a solution of problem [11]. The role of mathematical representation is important in learning mathematics because it can be a means of students to solve a problem.

According to [1] there are several reasons for necessity of mathematical representation, namely to fluency in building a strong and flexible concept and mathematical thinking. Mathematical representation can make concrete mathematical ideas and can help students to solve a complex problem becomes simpler problem. Therefore, mathematical representation should be owned by students in order to solve mathematical problems and can build a concept in learning mathematics. Mathematical representation indicators are can present the problem into mathematical ideas that can be images, diagrams, mathematical expressions, as well as written words or texts.

2.3 GeoGebra
GeoGebra was developed by Markus Hohenwarter in 2001. Markus Hohenwarter makes GeoGebra that can be used for learning mathematics from school to college level. GeoGebra can solve the particular mathematical problems, geometry, algebra and calculus. This software has a simple display that allows users to apply it.

GeoGebra is a software of dynamic geometry and algebra system. GeoGebra has ability to solve various problems related to functions, such as extreme points, optimization and others. GeoGebra can be obtained easily and free on the internet. In addition GeoGebra can also be used online without installing on the computer. Therefore, the software used in develop a Calculus textbook model is GeoGebra. According to [2], in order to understand the definitions and theorems of Calculus, students need to handle symbolic and graphical representations. With GeoGebra, it is possible to create different interactive applications that can be used as teaching tools.

Based on a research results, from student’s tests, answers in the questionnaire and in the interview, it can be concluded that GeoGebra has enabled an easier learning of Calculus material. The GeoGebra package enables the students to check whether each step in the process of solving a task was correctly done or not [10].

2.4 Relation between Calculus Textbook Model that Supported that GeoGebra of Students’ Mathematical Problem Solving and Representation
Calculus Textbook Supported with GeoGebra is designed to enhance students’ mathematical problem solving and representation in addition to enhance students’ outcome. The design of developed Calculus textbook will give chance to students to understand more about differential calculus. In this book there are any various problems both in mathematics and in other fields. In the process of problem solving with
GeoGebra, mathematical representation and mathematical problem solving will be developed. Students can create graphs, drawings, diagrams, and mathematical expressions with GeoGebra, for later use in problem-solving processes. In this case, students are trained to represent the problems given for later sought solutions and represented back to the original problem.

3. Research Methodology
The main purpose of this research is developing and producing a Calculus textbook model that supported with GeoGebra. This book was designed to enhance students’ mathematical problem solving and mathematical representation. This research was conducted in the mathematics department of one of universities in Central Java. This research was conducted by using development research steps developed by S. Thagarajan, Dorothy S. Semmel, dan Melvyn I. Semmel [4] that is 4-D model consists of four main stages, i.e.: (1) define, (2) design, (3) develop, and (4) disseminate.

3.1. Stage 1: Defining
This stage consists of front-end analysis, student analysis, concept and task analysis, and also formulation of objectives.

3.2. Stage 2: Designing
This stage consists of selection of format draft and textbook preliminary design.

3.3. Stage 3: Developing
This stage consists of evaluators’ assessment, readability test, and limited trials of designed textbook.

3.4. Stage 4: Limited Dissemination
Dissemination to the field is conducted at this stage by doing application research of the use of textbook to Statistics students.

But, in this research, the step used is only until the third stage that is define, design, and develop, because this research is conducted to produce calculus textbook that has been through expert validation of the book.

4. Result of the Research

4.1. Define
Several preliminary studies that had been carried out in this research were doing the steps in defining stage. Such steps are as follows:

4.1.1. Front-end Analysis
The result of this stage is development of a Calculus textbook model that supported with GeoGebra for to improve the result of study and also the students’ mathematical problem solving and representation.

4.1.2. Student Analysis
Based on the students analysis result, we selected software GeoGebra to support a Calculus textbook model.

4.1.3. Material Analysis
The material that would be discussed in this research was the material in differential calculus subject which Real Number System, Limit, and Differential

4.1.4. Task Analysis
Based on the task analysis result, giving the task in learning was done either individually or in group. The task given was designed to enhance students’ mathematical problem solving and mathematical representation.
4.1.5. Specification of Learning Objectives

Based on the specification of learning objectives result, the concept and task analysis to be learning objectives (Competency Standard, Basic Competency, and Competency Achievement Indicator) which were the basic in forming test and design of textbook.

4.2. Design

This stage was developed the textbook based on the competency standard, basic competency, and competency achievement indicator in differential calculus subject and it was corresponded with the learning objectives. One of the research objectives was to enhance the students’ mathematical problem solving and representation.

The material designed in the textbook was corresponded with standard competency of Differential Calculus subject which comprises of Introduction, Calculus with GeoGebra, Pre-Calculus, Functions, Limits, The Derivative, and Applications of The Derivative. The material was organized into 7 chapters; each chapter consisted of the learning main material, examples in accordance with the main material, and was also equipped with exercises. The examples of cases and exercises given were made by referring to the indicator of the students’ mathematical problem solving and mathematical representation.

The textbook designed with GeoGebra support, so that in each material ends with a detailed explanation of the steps of using GeoGebra in the material. The textbook developed phase begins with the early stages of designed the book (draft 1) which then validated by experts in developing stage.

4.3. Develop

Before the designed textbook was valid and reliable and also could be used widely, it had to be validated by some experts first. Assessed textbook validity was about content validity related to the competency standard of the subject and also mathematical problem solving and representation that would be developed. There are three experts in Mathematics, Mathematics Education and Mathematics Evaluation as validator’s who gave consideration of Differential Calculus textbook validity with GeoGebra support. The validator consideration of textbook content validity with GeoGebra support was given to the main subject which in this research was arranged in the textbook chapter. Aspects observed on the textbook put by [5] and can be seen in Table 1.

| No | Aspects                                                                 |
|----|-------------------------------------------------------------------------|
| 1  | The book is in accordance with curriculum syllabus                      |
| 2  | The book is in accordance with expected basic curriculum                 |
| 3  | The book is relevant with material the students have to learn           |
| 4  | The material content has the correct and exact concept                   |
| 5  | The book helps explain the concept                                       |
| 6  | The book contains examples of question                                   |
| 7  | The book contains exercises                                              |
| 8  | The compatibility of the exercises with the explained material          |
| 9  | The compatibility of the examples and exercises with the developed abilities |
| 10 | The exercises have complied difficulty level proportion                 |
| 11 | The language used properly                                              |
| 12 | The language used is easy to understand                                 |
| 13 | The book display and arrangement is interesting                          |
| 14 | The Figure and table arrangement is interesting                         |
| 15 | The font size is obvious                                                |
| 16 | The students can use the book independently                             |

Table 1. Textbook content validity
Based on the consideration result of those three experts about 16 aspects observed from 6 chapters in differential calculus textbook, then analyse nonparametric statistical analysis using Q-Cochran test to know that the validator had the same consideration related to the content validity from the arranged textbook. The Q-Cochran test show Sig = 0.609 greater than \( \alpha = 0.05 \). So it is concluded that those three validator’s had the same consideration about textbook content validity.

4.4. Experts’ Consideration of Textbook Related to the Mathematical Problem Solving and Representation

The experts’ consideration about the validity of the content of Calculus textbook model that supported with GeoGebra based on the compatibility to the indicator of mathematical problem solving and representation was also given to each subject consists of 6 Chapters in a textbook. Some indicators of mathematical communication and connection ability observed in the textbook are “The compatibility of presented material, examples and exercises in a book with the enhanced mathematical problem solving and representation”.

From Q-Cochran test result, we can see that Sig = 0.109 is greater than the value of \( \alpha = 0.05 \). So it can be conclude that those three validators has the same consideration about the content validity of the textbook based on the indicator of mathematical problem solving on Chapter I. The same result was obtained for the content validity of the textbook on the other main subjects. So, the validators had the same consideration about the content validity of Differential Calculus textbook with GeoGebra support based on the indicators of mathematical problem solving and representation.

5. Conclusion

Based on the result of learning tools development, it was produced Differential Calculus textbook model designed with GeoGebra support. The developed Differential Calculus textbook with GeoGebra support is valid based on the expert validations and has met the practicality criteria, so that the developed textbook model can be used for Differential Calculus lecture.

Since this research is only developing textbook until validated by experts, so for the next stage it needs to textbook readability test, textbook trial to small class, and in disseminate stage needs expand a valid and reliable learning tools also instrument of mathematical problem solving and connection test as an evaluation tool to measure students’ ability after using a Calculus Textbook supported GeoGebra. Besides, it can be analyzed the students’ respond after using the textbook also conducting class experiment to test the textbook effectiveness.

References

[1] Banihashemi S 2014 Am J Educ Res 2 592
[2] Calogaris M G, Schivo M E and Romiti M R 2015 Procedia-Soc Behav Sci 174 1183
[3] Chang K E, Wu L J, Weng S E and Sung Y T 2012 Comput Educ 58 775
[4] Dewi N R and Kusumah Y S 2014 Int J Educ Res 2 101
[5] Hendikawati P and Arini F Y 2016 JPCS 693 012020
[6] Lester Jr F K 2013 Math Enthus 10 245
[7] McLeod D B and Adams V M 2012 Affect and mathematical problem solving: A new perspective (New York: Springer Science & Business Media)
[8] Schoenfeld A H 2016 J Educ 196 1
[9] Silver E A 2013 Teaching and learning mathematical problem solving: Multiple research perspectives (New York: Routledge)
[10] Takači D, Stankov G, and Milanovic I 2015 Comput Educ 82 421
[11] Wilson P H, Mojica G F and Confrey J 2013 J Math Behav 32 103