Designing a Differential Calculus Textbook for Mathematical Guided Inquiry

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Abstract. This study aimed to develop a high-quality textbook for Differential Calculus and evaluate its effectiveness. The textbook was designed to support students learning using guided inquiry and to improve their mathematics thinking ability. The indicators of the high-quality textbook referred to three criteria offered by Nieveen: validity, practicality and effectiveness. The stages of development referred to the Four-D model by Thiagrajan, Semmel & Semmel. A field trial for the textbook was carried out and 23 students of an undergraduate educational school became subjects for the trial. The study results show that the developed textbook is valid to be used as a learning resource for differential calculus. The result shows that the developed textbook is valid due to expert validation and the readibility criteria also are met. The practicality aspect of the book development shows that the textbook can be used in differential calculus classroom with a guided inquiry approach. The development of the textbook is, however, just a starting point for creating a proper learning environment for students to learn using guided inquiry approach. In addition, the outcome of this research should be extended by further development of an accurate assessment method to evaluate the skill of students after using the textbook in the guided inquiry classroom.

Keyword : Differential calculus, guided inquiry and textbook

INTRODUCTION

Differential calculus discusses instantaneous rates of change [1]. Physics, astronomy, mathematics, engineering are all fields that use calculus in large portions. Calculus is used in a very wide range of disciplines as well as for a wide variety of purposes. Calculus is a powerful tool that can be used to see the relationship between variables in the fields that have been mentioned [2]. Differential calculus helps to solve problems in economics and exchange by seeking maximum benefit or minimal expense and the like [3].

In the Calculus course, students learn the concepts of limits which begin to involve complex arithmetic and advanced algebra. The concept of infinite, which is also studied in calculus, cannot be understood simply. It requires abstractions and indirect arguments to demonstrate its existence [4]. The use of complex arithmetic, advanced algebra, and the process of abstraction causes calculus to become one of the subjects in mathematics considered difficult by students. Most of the students only understand operational skills and difficulties in interpreting concepts [5]. Learning that makes students active must be developed one way is by learning to find concepts so students don't just memorize the material presented [6]. Guided discovery learning can build your own understanding and discover new knowledge [7].

Previous researchers have identified the difficulties students experience when studying calculus as well as working out solutions to these difficulties. Ferrer reported that students recognized their shortcomings in remembering trigonometric identities and in carrying out basic fundamental operations involving non-algebraic expressions, assisted by the results of the interview with the participants of this study. In general, learners have the fundamental knowledge of the integration process, but not the technical ability to control trigonometric functions [1]. Makgakga & Makwakwa reported that in locating the derivatives, learners performed more poorly using first principles than using the laws of differentiation. The poor performance was maybe due to the teaching methods of the teachers and the lack of procedural and conceptual experience of the learners [8]. To investigate the conditional reasoning of undergraduate students Alva et al. used the written responses of students and semi-structured interviews. They found two major logical errors that prevailed in the reasoning of the students: 1) the use of the invalid inference rejection of the antecedent, and 2) the incorrect use of conjunction negations involved in a form P->Q structure [9].

Inquiry is characterized as different activities where scientists investigate and analyze the environment on the basis of facts [10]. Using inquiry as a learning technique may encourages students to discover and use a range of knowledge and ideas to gain an appreciation of an issue, subject or issue. Inquiry is not alone; it includes students and desires, and calls them to link their environment to curricula. By means of guided inquiry, students are willing, during their learning phase and in compliance with the subject area curriculum standards, to use materials and resources for learning in [11]. Six phases (phases) of the guided inquiry research model are: (a) planning, (b) information management, (c) information processing, (d) information generation, (e) information communication and (f) assessment. Guided inquiry learning enables learners to independently construct and contribute to the development of understanding and science literacy for the concept of representative [12].

This research aimed at creating and evaluating the efficacy of a high quality textbook for Differential Calculus. The textbook was designed to enable students to learn through directed study and increase their ability to think mathematically.

METHOD

The textbook was developed using the 4-D model proposed by Thiagarajan [13][14] [15]which consists of four stages: (1) define, (2) design, (3) develop, and (4) disseminate. The define phase includes five phases: (a) front-end analysis; (b) learner analysis; (c) task analysis; (d) concept analysis; and (e) specifying instructional objectives. The design stage consists of four phases: (a) constructing criterion-referenced tests; (b) media selection; (c) format selection; and (d) initial design. The development stage includes two phases: (a) expert appraisal; and (b) developmental testing .

The define stage is carried out by conducting various analyzes related to the differential calculus course. Front-end analysis was carried out by examining STKIP Pamane Talino's curriculum and the relevant guided inquiry learning theory. In the learner analysis stage, student characteristics are examined in order to obtain an overview of the learning book design that is developed according to student characteristics. Task analysis is carried out to form the basis for the development of instructional material designs and evaluation tools. Concept analysis is carried out to examine what differential calculus material will be taught using the developed book. The design stage, which consisted of selecting the media, and choosing the format, resulted in an initial design of a differential calculus book that used the guided inquiry approach. The develop stage consists of expert validation, practicality testing, and device testing. The resulting mathematics learning device was revised based on input from experts and data obtained from the trial. The last stage is the dissemination stage which is carried out through summative evaluation before the teaching materials are officially used.

The research was conducted in the Department of Mathematics Education in an educational college in West Borneo, Indonesia. Twenty three students of the mathematics education program were determined as subjects for the field trial. Two non-test instruments were used for the data collection: expert validation and user questionnaire. An expert review of the book material was performed using a validation sheet and a questionnaire to assess a student group 's view of the book was used.

RESULT AND DISCUSSION

Define Stage

The first stage of developing the textbook was the define stage. In this stage, the analysis of front-end, student analysis, material, task and learning objectives were conducted. The front-end analysis was conducted by studying the curriculum of STKIP Pamane Talino's curriculum as well as observin the students' characteristis. The first stage resulted that the developed calculus textbook was designed for students in the first semester who was still in adaptation to the learning environment of a college degree. Thus, the textbook was designed to lead students' learning more independently rather than which in the high school. The material analysis resulted the most important part which should be thaught in differential calculus, which is the concept of limit. The task analysis narrowed the design process by specifying the learning objectives which resulted in the formulation of competency standard, basic competency, and competency achievement indicator.

TABLE 1. Shows the result of define stage

Learning Outcomes of Graduates (CPL)	1. Attitude a. Fidelity to the one and only god and able to show a religious attitude; b. Upholding human values in carrying out duties based on religion, morals and ethics; c. Contributing to improving the quality of life in society, nation, state, and advancement of civilization based on Pancasila; d. Acting as citizens who are proud and love the country, have nationalism and a sense of responsibility to the state and nation; e. Respect the diversity of cultures, views, religions and beliefs, as well as the original opinions or findings of others; 2. General Skills a. Able to apply logical, critical, systematic, and innovative thinking in the context of developing or implementing science and technology in accordance with their field of expertise; b. Pay attention to and apply humanities values in accordance with their field of expertise; c. Able to study the implications of the development or implementation of technological science that pays attention to and applies humanities values according to their expertise based on scientific principles, procedures and ethics in order to produce solutions, ideas, designs or art criticism, compile scientific descriptions of the results of their studies in the form of a thesis or final project report. , and upload it on the college page; 3. Special skills a. Providing educational learning services to students according to their characteristics; b. Facilitating the development of the potential of students optimally; c. Choosing approaches and learning models, using teaching materials and media, and assessments that are relevant to the characteristics of students for the benefit of learning; 4. Knowledge a. Mastering in depth the characteristics of learners from physical, psychological, social, and cultural aspects for the benefit of learning; b. Mastering the philosophical, juridical, historical, sociological, cultural, psychological and empirical foundations of education; c. Mastering the concepts, instrumentation, and praxis of educational psychology and guidance; d. Mastering learning theories and educational learning principles related to the subjects being taught; e. Mastering the objectives, content, learning experience, and assessment in the educational unit curriculum;
Subject Learning Outcomes (CPMK)	Students can understand all the topics given in the differential calculus course. Students can apply the understanding that has been obtained to work on problems both in the subject concerned and in the future. Students have a responsible attitude in completing assignments.

Design

Here we provide some basic advice for formatting your mathematics, but we do not attempt to define detailed styles or specifications for mathematical typesetting. You should use the standard styles, symbols, and conventions for the field/discipline you are writing about. In the Design stage, the textbook was designed based on the results of the define stage. The textbook was designed to contain four chapters, each of wich consists if the material description, examples of calculus problem as well as exercises. The material description was designed to give students opportunity to learn independently while the examples familiarize students with the calculus problems. The exercises in each chapter provide challenging problems which provoke students curiosities and therefore make them learn independently.

Development

The stage of development includes confirmation by some experts concerning the validity of the book material, regardless of whether or not it applies to the subject's competence level. An expert of calculus material was chosen to give their expert judgement for the textbook. The feasibility aspect of the material and how to present the material in textbooks got the score of 0.89 and 0.87 (out of 1), while the aspect of the appropriateness of the language used in the textbook got 0.89 out of 1. The next aspect which was evaluated is evaluation of learning which obtain 0.87. While the last material aspect which is the contextuality aspect got score of 0.88. Meanwhile, an expert of mathematics media was asked to give the judgement for the aspects related to layout of the the developed book. The textbook obtain the score of 1, 0.875, and 0.9 for the size of the textbook, the design of the cover, and the layout of the entire book, respectively. Table 2 shows the results of expert judgements.

TABLE 2. The result of the expert judgements

Material	Presenting Materials	Appropriateness of language	Evaluation aspect	Contextuality	Size of the textbook	design of the cover	layout of the entire book
0.89	0.87	0.89	0.87	0.88	1	0.875	0.9

The Practicality Aspect Of The Textbook

After the book had been judged by the experts, it then was tested to check the practicality. An observation sheet has been used to see whether the book can be used in the classroom activities. Three students have been chosen to give evaluators about the practicality of the textbook. The indicators of practicality were the ability of textbook to attract students, the materials used in the the textbook and the language aspects. The average score obtained by the book from three students was 0.76 out of 1. Table 3 shows the detail result of scores given by three students.

TABLE 3. The practicality aspect of the textbook

Aspect	Student 1	Student 2	Student 3
the ability of textbook to attract students	0.83	0.83	0.875
the materials used in the the textbook	0.875	0.83	0.83
the language aspects	0.8	0.67	0.8

The Effectifity Aspect Of The Textbook

The developed textbook then entered the stage of checking the effectifity aspect after had been tested in terms of its practicality. The effectifity aspect of the book was evaluated by using test. A test was designed to see the classical completeness as well as to measure the result of the classroom activities which used the developed textbook. The test resulted the percentage of 83% for the classical completeness and the average of students score was 72.8. Table 4 shows the detail results of the test.

TABLE 4. The effectifity aspect of the textbook

N	21
Total score	1.519,98
Average	72,38
Variance	469,07

CONCLUSION

The result shows that the developed textbook is valid due to expert validation and the readibility criteria also are met. The practicality aspect of the book development shows that the textbook can be used in differential calculus classroom with a guided inquiry approach. The development of the textbook is, however, just a starting point for creating a proper learning environment for students to learn using guided inquiry approach. In addition, the outcome of this research should be extended by further development of an accurate assessment method to evaluate the skill of students after using the textbook in the guided inquiry classroom.

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