

Analysis and Design of Modules to Generate Students' Mathematical Communication Skills through Problem Based Learning Models

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Abstract The ability of mathematical communication is the ability of students to express mathematical ideas both oral and written in the form of language, symbols, and mathematical notations that are easier for students to understand mathematical problems. Problem based learning is a learning model that can be used to improve students' mathematical communication. In implementing the Problem Based Learning (PBL) model, teachers need appropriate modules. This study analyzes and designs teaching materials in the form of modules, based on the Problem Based Learning approach, allowing improving mathematical communication skills. The subjects of this study were students of class XI SMK Muhammadiyah 1 Sentolo, Kulonprogo. This type of research is research and development with the ADDIE development model. The collection instruments used were interview guides, classroom observations, and tests. Data analysis uses data reduction, data presentation, and drawing conclusions. This research produces an module needs analysis and module design according to the needs analysis. Modules are designed according to Problem Based Learning (PBL). Modules are designed to improve students' mathematical

communication skills. The results of the study can be used as a guide when the teacher develops a learning module for a problem-based learning model. The novelty of this research is the integration of mathematical communication skills into module design.

Keywords Mathematical Communication, Problem Based Learning, Modules Design

1. Introduction

Mathematical communication is the ability of students to express ideas in mathematics both oral and written in the form of language, symbols, and mathematical notations that are easier for students to understand and mathematical problems [1]. According to the National Council of Teachers of Mathematics (NCTM) and Wahyudin, mathematical communication is the ability to reflect real objects, images or mathematical ideas; deliver orally, in writing, using real objects, graphics, and algebra; use the

ability to read, write and analyze to translate and interpret mathematical ideas, symbols, terms, and information; and answer various problems of mathematical ideas [2]. Mathematical communication can be interpreted as the ability of students to convey something that students know through dialogue or reciprocal events that occur in the classroom environment, where there is a transfer of messages, where the message transferred contains mathematical material being studied, such as concepts, formulas, or solving strategies problem [3].

Mathematical communication has two important roles, namely: mathematics is a fundamental language that is not only a tool for thinking, solving problems, or concluding but also has limited value for expressing various ideas clearly, thoroughly and precisely; and learning mathematics is part of human social activities, as in learning there is the interaction between students and teachers [4]. Mathematical communication is the main key of students in creating mathematical concepts and strategies and to explore scientific inquiry which includes finding, exchanging opinions, assessing, and honing ideas to convince others [5]. Communication skills are used to determine whether a student understands the material being taught [6].

Based on the results of the 2018 International for Student Assessment Program (PISA), the average score of mathematics literacy scores, Indonesia ranked 76 out of 79 participating countries [7]. Communication skills are part of the aspects assessed in PISA [8]. This also happened at Vocational High School Muhammadiyah 1 Sentolo, Kulonprogo, in the 2019/2020 academic year. Based on interviews and observations it was found that learning resources/media are difficult for students to understand because the sentences are too formal and the learning model used is monotonous and conventional. Some of these, become one of the causes of the lack of students' mathematical communication skills.

Several studies have conducted research related to mathematical communication skills. The results of research conducted by Atika, Roza, and Murni (2020) show that the use of Problem Based Learning (PBL) can improve students' mathematical communication skills [9]. Similar research by Rahmantiwi and Rosnawati (2018) results in mathematical communication skills being improved through Problem Based Learning (PBL)[10]. And according to Sitopu, Saragih and Hasratuddin (2019) on the result [12] their research concluded that there is an influence of the Problem Based Learning (PBL) learning model on improving mathematical communication skills [11].

Problem Based Learning (PBL) model is a learning strategy that encourages students to be active and become confident in learning, and the Problem Based Learning (PBL) strategy model can encourage active students so that they can improve students' mathematical communication skills [12]. Problem Based Learning (PBL) is one of the learning models that is suitable for active

learning and independent learning [13]. Problem-Based Learning (PBL) can make learning mathematics more effective and innovative because students tend to focus on their interests and talents and are more active in the learning process [14]. Problem Based Learning (PBL) which can improve learning, students who experience difficulties in learning [15]. Problem Based Learning (PBL) can help the students to find learning problems with planning and problem solving [16]. The Problem Based Learning (PBL) approach is effective in preparing students for their future learning [17]. One solution to learning, mathematics learning must be accompanied by the use of teaching materials [6]. Teaching material with the right learning approach will support learning objectives [18]. Teaching materials in the form of modules can be considered as one of the right reasons [19]. Modules are teaching materials that are arranged systematically and are easily mastered by students according to their level of understanding and age so that they can learn independently with minimal assistance from the teacher [20].

Based on the problems and previous research results above, then to improve mathematical communication skills the authors provide solutions to use modules based on Problem Based Learning (PBL). The purpose of this study is the analysis and design of modules to generate students' mathematical communication skills through the Problem Based Learning (PBL) model.

2. Materials and Methods

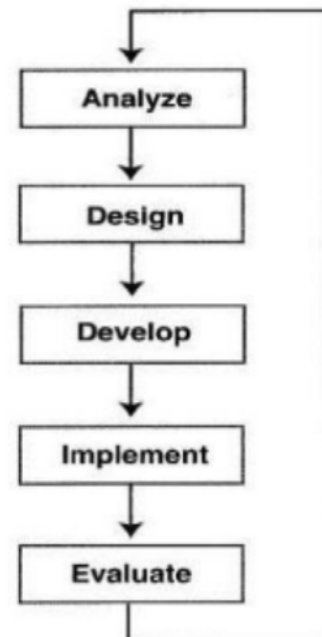


Figure 1. Development Process

This study uses ²⁰ ADDIE model. ADDIE is a research model that consists of several stages, namely: analysis, design, development, implementation, and evaluation [21], [22], [23]. Visually the ADDIE stages can be seen in Figure 1.

In this study, the authors limit to two stages, namely: the stages of analysis and design. The resulting product is a Problem Based Learning (PBL) based module designed to improve mathematical communication.

The analysis phase consists of curriculum analysis, material, student characteristics, and student achievement. While the research design stage is carried out through a framework of preparatory activities in the media and design of media learning. Products in the form of instructional media design are validated by experts. Design validation is carried out to determine the assessment and input from experts as a revision material so that the design of the development of good quality learning media.

Research subjects were all students of class XI semester 1 (one) Vocational High School Muhammadiyah 1 Sentolo, Kulonprogo, in the academic year 2019/2020. The type of data used is qualitative and quantitative. Data collection instruments include interview guides and classroom observations. Interview guidelines are used to interview teachers or students about the use of teaching materials used in the learning process, while the classroom observation guidelines are used to observe or know learning models that can improve students' mathematical communication skills. Data were analyzed using Huberman's Miles consisting of data reduction, data presentation, and conclusion drawing [24].

This research was conducted by designing problem-based learning in the XI grade mathematics

learning module at Vocational High School Muhammadiyah 1 Sentolo, Kulonprogo. The following are the results of design development through the analysis phase and the ADDIE design phase.

2.1. Final Stage

2.1.1. Curriculum Analysis

Based on observations of the curriculum used in the learning material book by students following the Core Competencies, Basic Competencies, and Indicators of Achievement of Competencies in the 2013 curriculum. Whereas in the learning process it still uses conventional means that the teacher becomes the center of learning activities. The following are Core Competencies, Basic Competencies, and Indicators of Competency Achievement in Table 1 and Table 2.

Table 1. Core Competencies

No	43 Core Competencies
1	Respect and appreciate the teachings of the religion they
2	Appreciate and appreciate honest behavior, discipline, responsibility, care (tolerance, cooperation), polite, confident, in interacting effectively with the social and natural environment within the reach of relationships and their existence
3	Understanding knowledge (factual, conceptual, and procedural) based on curiosity about science, technology, and culture related to phenomena and events seen in the eye
4	Trying, processing, and presenting in the real of concrete (using, unraveling, composing, modifying, and making) as well as abstract domains (writing, reading, calculating, drawing, composing) following what is learned in school and other sources in the sama perspective/theory.

Table 2. ¹⁶ Basic Competencies and Competency Achievement Indicators

Basic Competencies	Indicators of Competency Achievement	Information
3.6 Explain the composition operations on functions and inverse operations on inverse functions and their properties and determine their existence	3.6.1 Explain the concept on function	Support
	3.6.2 Explain operations on function	Key
	3.6.3 Explain composition operations on function	Key
	3.6.4 Explain the operating properties of compositions on function	Key
	3.6.5 Explains the inverse operatin on the inverse function	Key
	3.6.6 Explain the properties of inverse operations on the inverse function	Key
	3.6.7 Determine the existence of an inverse operation on an inverse function	Key
4.6 Solve problems related to composition operations and inverse operations of a function	4.6.1 Express ideas related to contextual problems related to the function	Support
	4.6.2 Resolve problems related to operating composition functions	Key
	4.6.3 Resolve problems related to the inverse operations of a function	Key

2.1.2. Material Analysis

Based on observations of the material contained in the learning tool used is less efficient, because it uses sentences or formal mathematical language. Also, teaching materials are not following the demands of 21st century learning to achieve the Basic Competencies to be achieved and do not meet the indicators of mathematical communication skills.

Students experience boredom in monotonous teaching materials, so students are less interested in studying teaching materials and do not understand the real flow of the material being taught. Some students only memorize the material or formula given by the teacher without knowing the process of the formula obtained, so there are often mistakes in applying the formula to solve problems. Thus, the flow of real activities needs to be developed chronologically so students can understand the material and objectives of learning. So students need modules that can help students improve mathematical communication.

2.1.3. Analysis of Student Characteristics

Students cannot understand the material well, resulting in a student's difficulty in working on problems that mostly come from everyday life. Based on interviews with Mr. Fachrul Rozi as a mathematics teacher in class XI mentioned the lack of mathematical communication skills of students of Vocational High School Muhammadiyah Sentolo, among the reasons for making students unable to understand mathematics well, students need modules that can help students understand the concept of the material well.

2.1.4. Analysis of Learning Achievement

Based on the results of interviews with teachers, it also obtained information that the lack of mathematical communication skills in students seen by the low learning

achievement that is less than expected. This can all be seen in the mathematics test scores of students who have not yet reached the individual Minimum completeness Criteria of 70, so teachers must take remedial exams. Also, students can not be maximized in doing the tasks given, because learning tools do not support to understand the material provided, so we need learning tools that can support learning well.

Based on the above analysis, the researcher concludes that students and teachers need learning media in the form of modules that can help students improve mathematical communication skills so that the teaching and learning process is more effective and efficient.

2.2. Design Phase

In the design phase, the module will be designed in the form of Problem Based Learning (PBL) based mathematics learning modules to improve the mathematical communication skills of students in class XI of Vocational High School Muhammadiyah 1 Sentolo, Kulon Progo. Based on the description above, the module design has been made as follows.

2.2.1. Opening Section

2.2.1.1. Cover

The cover of the mathematics learning module based on Problem Based Learning (PBL) is entitled "Modul 35 Pembelajaran Matematika Komposisi dan Invers Fungsi Berbasis Problem Based Learning (PBL) untuk Meningkatkan Kemampuan Siswa Kelas XI SMK". The cover is completed by the author's name, the origin of the university, and the subject matter contained in this module. Following is the module cover design in Figure 2

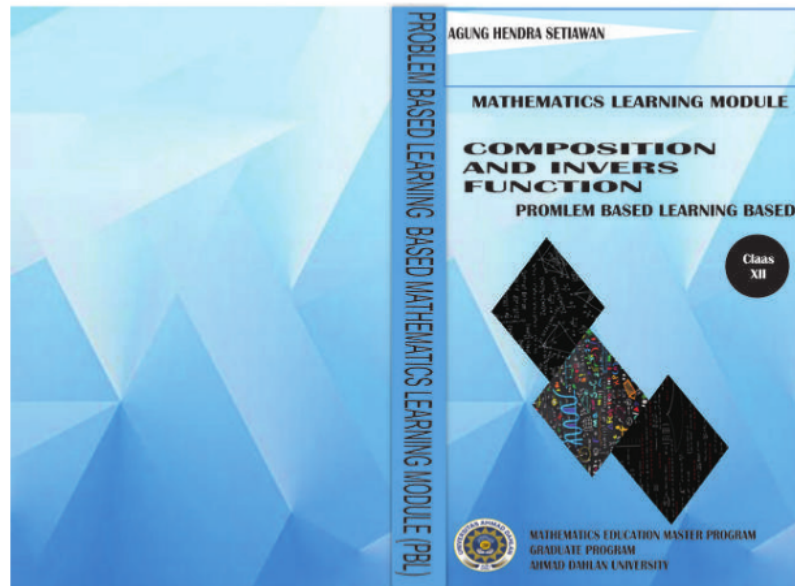


Figure 2. Display Cover

2.2.1.1. Foreword

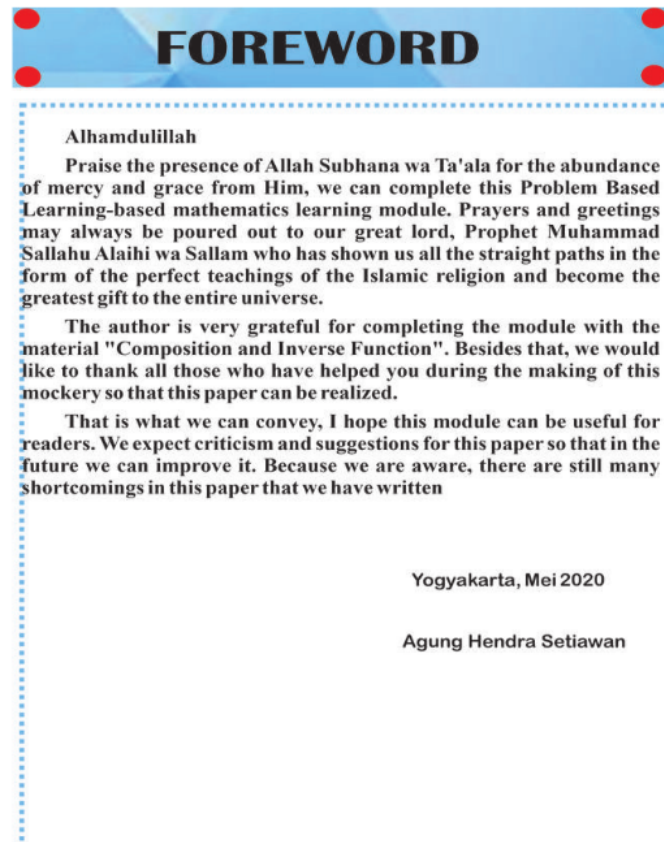


Figure 3. Display Preface

The introduction in the Problem Based Learning (PBL) module expresses gratitude to Allah Ta'ala and to those who have helped in the formation of this module and their apologies and suggestions. The following is the preface design that was created in Figure 3.

2.2.1.2. List of Competency Objectives

List of competency objectives in the Problem Based Learning (PBL) module contains what knowledge, attitudes, or skills can be mastered after completing learning. The following is a list of the designs of Core Competencies and Basic Competencies that have been created in Figure 4.

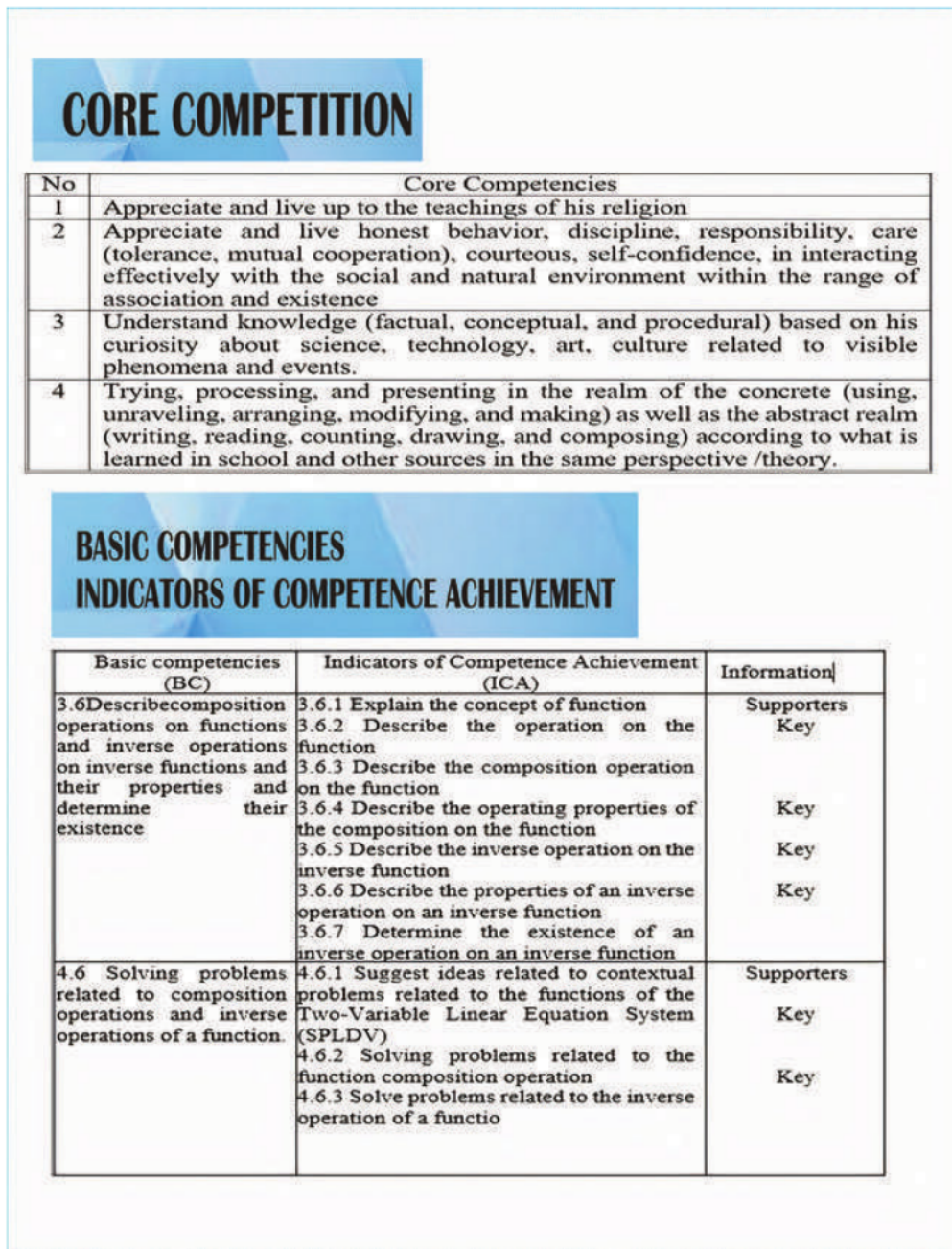


Figure 4. Display Competency Objectives

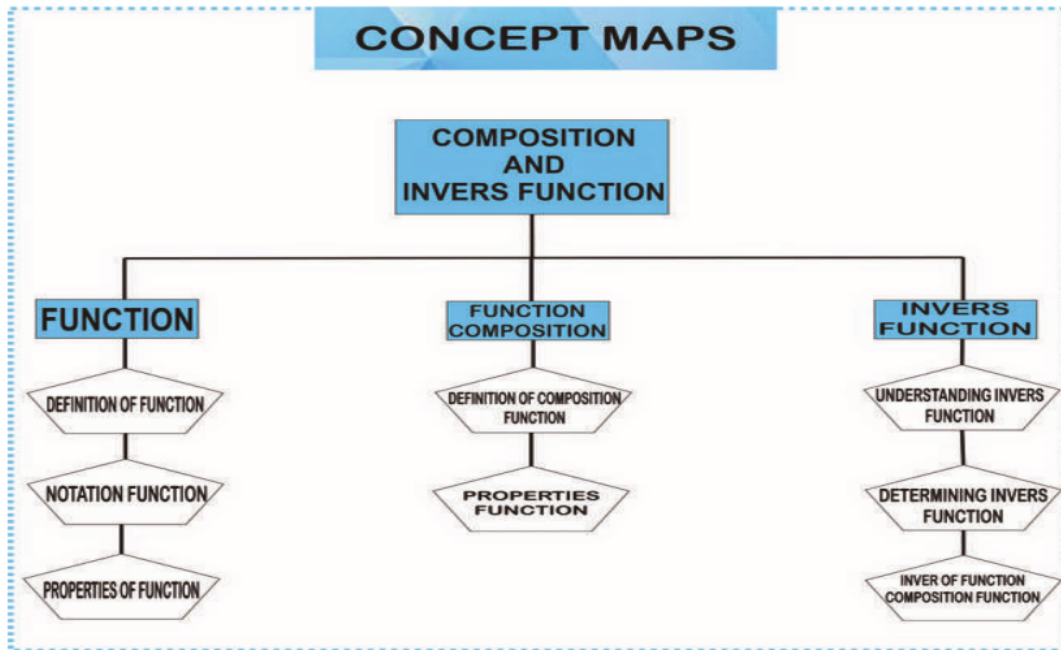



Figure 5. Concept Map Display

Function

Definition of Function



Before discussing the material about internal functions math, try to pay attention to the problem of function contained in everyday life. Of course is very much an example of a request function and supply function. If you shop at supermarkets, give it a try Observe all bekanjaan must have a label code respectively. By using a coded tool which is directed at the code label, cashier or you can know the prices of these items. Ever you wonder what process applies in coded? Does a certain function take place in it? To find out the answer from problem above, let us study this materi

Figure 6. Display Material

2.2.1.3. Concept Maps

The concept map in the Problem Based Learning (PBL) module contains topics to be studied in the module and shows the interrelationships between topics in the module. The following concept map designs have been created in

Figure 5.

2.2.2. Core Section

2.2.2.1. Theory

The material in the Problem Based Learning (PBL)

module contains detailed explanations of the subjects that are delivered sequentially and systematically so that students easily master the learning material. In this module, several Learning Activities contain a description of the material, assignments, and summaries of each sub-chapter discussed. Next is the material design that has been made in Figure 6.

2.2.2.2. Theory

The task in this Problem Based Learning (PBL) module, contains exercises that need to be completed by students which are tasks to increase the competency students must have. Designing the following task has been made in Figure 7.

THEORY

A. PROBLEM ESSAY

1. Given that the sets $V = \{r, s, t\}$ and $W = \{12, 15, 17, 19\}$. The function is determined by $f = \{(r, 12), (s, 15), (t, 17)\}$.
 - a) Write that the inverse f is $g: W \rightarrow V$ as the set of pairs sequentially.
 - b) Show f and g with the arrow diagram.
 - c) Is the inverse f , i.e. g , a function? Explain your reasons!

2. Based on the image below which is a graph of the functions $f(x)$ and $g(x)$

3. Determine the composition of the function $(f \circ g)(3)$ from the graph of the function is

3. To print x copies of newspapers a day, a printing machine is required. In fact, if you use x units of printing machines, the daily maintenance costs that must be spent are machine maintenance today of IDR 50,000.00, so many copies of the printed newspaper are

4. If it is known that $(x) = 5x - 7$ and the composition of the function $(g \circ f)(x) = 4x + 8$, then is it true that $(x) = -x + 7$? Show the truth / error of the statement above and then provide a conclusion

Figure 7. Task Display

2.2.3. Closing Section

2.2.3.1. Summary

Summary

- 1. The relation of set A to association B is the installation or correspondence between member A and member B**
- 2. A function of set A set B is a relation that pairs each member of set A with exactly one member of set B**
- 3. The conditions for a function are as follows:**
 - a) Each member A must be completely paired
 - b) Each member A is paired exactly one with member B
- 4. $f: x \rightarrow y$ (read: f means x to y) y is called the x image by the function f and is represented by $f(x)$**
- 5. The nature of a special function is as follows:**
 - a) One-to-one (injective) function
 - b) Function on (subjective)
 - c) One-to-one and on (wise) functions
 - d) Identity function
 - e) Constant function
- 6. The function $f \circ g(x)$ is the composition of the functions f and g, so that $f \circ g(x)$ is called the composition function**
- 7. The properties of the composition of the function, for example, determine the rules for the function f, the function g and the function h of R**
 - a) The composition operation is generally non-commutative meaning $(f \circ g) \neq (g \circ f)$
 - b) In the composition of the function the associative nature applies, namely $(f \circ g) \circ h = f \circ (g \circ h)$
 - c) Let I be the function $I(x) = x$ and satisfy $f \circ I = I \circ f = f$, then I is the identity function
- 8. A function $f: A, B$ has an inverse function $f^{-1}: B, A$ if f is an independent function or the sets A and B correspond one to one**

Figure 8. Summary Display

This summary in the Problem Based Learning (PBL) module examines the main points in the module discussed. The following summary design was created in Figure 8 .

2.2.3.2. Glossaries

The glossary in the Problem Based Learning (PBL) module contains the concept definitions discussed in the module and summarized so students can easily understand and remember them. The following is a glossary design that was created in Figure 9.

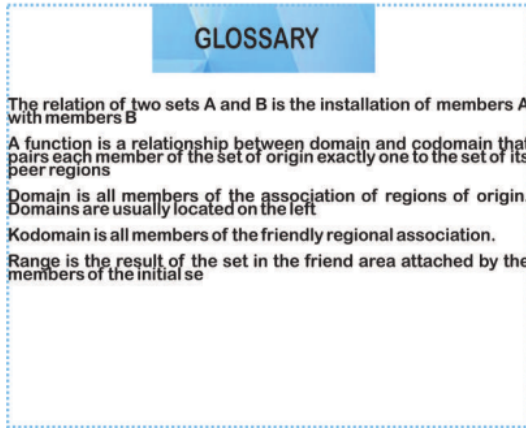


Figure 9. Glossary Display

2.2.3.3. Reference

This reference in this Problem Based Learning (PBL) module, contains sources of information about the contents of the module. The following reference designs have been created in Figure 10.

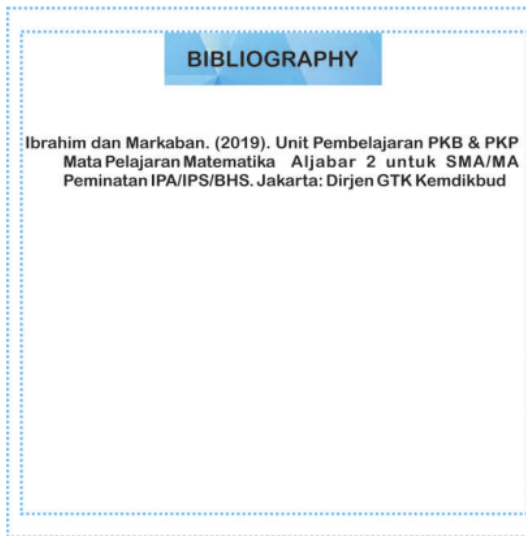


Figure 10. Display Bibliography

Further research can be continued at the development, implementation, and evaluation stages to produce products in the form of e modules that are valid, practical, and effective. Development contains module preparation

activities referring to the module design that has been made. At this stage of development, the module is also validated by media experts and material experts. This development stage aims to produce a valid module. Implementation contains activities using modules to obtain feedback from students on the developed modules. At this implementation stage, students' responses to the module were collected through a questionnaire. This implementation stage aims to produce a practical module. Evaluation contains activities to assess students' mathematical communication skills after students use the module. At this evaluation stage, the module is revised so that the objectives of module development can be achieved. This evaluation stage aims to measure the achievement of the module development objectives.

3. Conclusion

This research resulted in the design of module Problem Based Learning (PBL). In the analysis phase, researchers grouped the analysis into four types, namely: curriculum analysis, material, student characteristics, and learning achievement. In curriculum analysis, researchers found that the curriculum used was the 2013 curriculum following the government. In the analysis of the material, the researcher found that students had difficulties because sentences or language used formal mathematics that was difficult to understand for students. In analyzing students' characteristics, reseachers found that students had difficulty working on problems because students could not understand the material very well. Whereas in the analysis of learning achievement, the authors found that the majority of students' mathematics test scores had not yet reached the individual Minimum Completion Criteria of 70. At the design stage, the reseachers designed three outlines, namely: the opening part, the core part, and the closing part. The opening part consists of a cover, introduction, module description, list of competency objectives, concept maps, table of contents, and preliminary tests. The core part consists of an introduction, material, and assignments. The concluding part consists of the final test, summary, and glossary. Modules designed have advantages. Modules are designed to improve mathematical communication skills in the subject matter because each indicator of mathematical ability is included in the questions in the module. Also, the module is designed following the Problem Based Learning (PBL) approach.

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