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LEARNING MODULE ANALYSIS OF PYTHAGOREAN THEOREM BASED ON SCIENTIFIC APPROACH

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Abstract

One of the basic competencies in class VIII contains the Pythagorean theorem. Surveys on students who have studied it, they still remember that the proposition is related to a right triangle. Interviews with students who understand the theorem show that they have a formulation of the relationship between the length of the hypotenuse and the side of the right angle. In detail they do not understand why this relationship can occur. That's because they memorized the formula instead of understanding it. For this reason, using the ADDIE development model, through this research a Scientific Learning-Based learning module was developed. This module was developed with the aim of helping self-study students to find their understanding of the Pythagorean theorem. Before being distributed, this module is analyzed to determine the validity and practicality of the module. The results of the study indicate that the module is valid, in accordance with the material, language and also there are scientific learning steps. Then, this module is said to be practical because through observation and interviews, the propositional module has met the criteria for practice assessment including, self-instructional, self-contained, stand-alone, adaptive, and user friendly.

Keywords: *Pythagorean Theorem, scientific, hypotenuse, right side*

INTRODUCTION

The Pythagorean theorem has strategic role for the future both in mathematics and other sciences even in everyday life. In other words, there is a connection among them. Diagonal determination of flat shape or building space, the slope of the rooftop of house, all of them using these theorem in their calculations. The connection of this proposition to other sciences has also been revealed by many researchers, for example in music (Caleon & Ramanathan, 2008;

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Cranmore & Tunks, 2010; Cuomo et al., 2014).

Material of Pythagorean Theorem is taught in junior high school students, precisely in class VIII (Kemendikbud, 2018). The material is explicitly stated in Basic Competencies Numbers 3.5 and 4.5 for knowledge competencies and skills competencies. The formulation of the theorem is expressed as a^2+b^2=c^2 where a and b are the right sides of a right triangle and c is the hypotenuse (Anon, 2008; Lin, 2007; Mestre & Marrows, 2007; Sunaryo & Sunardi, 2016). The proposition that was first proposed 4000 years ago by Pythagoras Von Samos, a Greek mathematician, was used as the basis for constructing a right triangle and designing the triangle (Rifai & Prihatnani, 2020). The design of the construction is done by dividing the length of a rope that has a size according to the length of the circumference of a right triangle into twelve parts of the same size. As a result, the first side has three parts, the second side has four parts, and the third side has five parts.

The Minister of Education and Culture, said that students are expected to be able to understand and apply the Pythagorean theorem in solving problems related to it (Kemendikbud, 2018). This material is a prerequisite material that must be mastered by students before discussing the material of flat shapes, curved side spaces, and so on. Research results from Zaerani et al. (2017) showed that mastery of this material has an effect on students' ability to solve problems related to flat-sided shapes. Study conducted by Muchyidin & Amin (2012) also concluded that students with good mastery of the Pythagorean concept could solve the tangent line material problem well too. It means that students need to master the concept of the Pythagorean theorem so that they do not experience difficulties in learning more advanced material.

Studies on students' difficulties in applying the Pythagorean theorem have been carried out by many researchers (Rudi et al., 2020). Generally, the difficulties experienced by students relate to the definition, use and proof of these propositions. The results of this study are in accordance with a survey conducted on class VIII school students. In general they said that they were familiar with the term proposition but generally were unable to explain it. For students who understand the Pythagorean theorem, they only know but do not know how to determine the truth value of the theorem. The results of the preliminary survey also found that students only memorized the formulation of the relationship between the length of the hypotenuse and the length of the right side of a right triangle. Students have not been able to understand in detail why this relationship can occur. As a result, students incorrectly apply the formulas of the Pythagorean theorem when solving problems related to the theorem (Fitriyani & Sugiman, 2014; Zaerani et al., 2017).

Each country has a different emphasis on learning. Teachers in Hong Kong and Shanghai put more emphasis on exploring proof of theorems while teachers in Checo verify theorems (Huang & Leung, 2002). Because the Pythagorean theorem has been proven to be true, to teach this material more emphasis is placed on how to verify the truth value of this theorem. There are various

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approaches or learning strategies that can be used in designing learning. Design with lesson study is done by Cooper (2013) and PMRI conducted by Mulyatna (2019) to make students better understand the concept of the Pythagorean theorem. Cooperative learning model of NHT, jigsaw, *problem posing*, *inquiry*, and STAD also able to improve students' ability to solve problems related to Pythagoras (Novia et al., 2017; Layn, 2018; Rahmadani et al., 2018; Syahrin et al., 2019; Ulandari et al., 2019).

The Pythagorean theorem has been proven true (Sunaryo & Sunardi, 2016; Treeby, 2017), but in the world of education it is necessary to show students that the proposition is indeed true. Therefore, this research is more focused on using the media module to teach and guide students in understanding the concept of the Pythagorean theorem. The module developed as a learning medium also puts forward a scientific approach in learning activities. Previously Lasmiyati & Harta (2014) has researched the use of modules to improve understanding of concepts and learning interest of junior high school students on flat-shaped materials. The development of the module shows an increase in students' understanding of concepts and interest in learning the material being studied. Because the Pythagorean theorem is a prerequisite material for studying the concept of flat shapes, this research is intended to continue the development of modules in understanding the fundamental concepts of the flat shape material, namely the Pythagorean theorem.

METHODS

Research Type

The ADDIE development model is used as a guide in designing this Research and Development-based research. The development model contains five stages of development, including the Analysis, Design, Development, Implementation, and Evaluation stages. The Implementation and Evaluation stages have not been carried out in this study because of the condition of schools that are still implementing the Distance Learning (PJJ) system.

Module Development Procedure

1. Analysis Stage (*Analysis*)

Analysis of problems in the field is carried out on teachers participating in PPG (Professional Teacher Education) in positions. The results show that Pythagorean learning is carried out without the help of media. The teacher explains through pictures and continues with practice questions. The truth of the Pythagorean theorem is also not shown, but rather how to use the theorem. This shows the need for a means / media to teach the material the Pythagorean theorem correctly in accordance with the mandate of the 2013 curriculum, which is to provide learning experiences to students.

2. Design Stage (*Design*)

Referring to the analysis stage, it is necessary to design a learning media that is able to provide a student learning experience. The module design is intended to provide a learning experience for students in studying the Pythagorean theorem material. Each learning component in this module is arranged in a coherent manner so that students can understand the truth value of the

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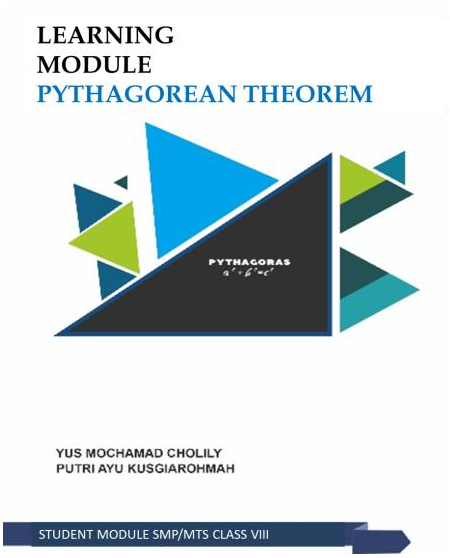
Pythagorean theorem. The components in this module are described as follows.

a. The title of modul

This module is entitled "The Pythagorean Theorem Learning Module". The title is pinned on the cover of the module accompanied by the identity of the author, the level of education that is the target of the module implementation, and the symbol of a right triangle along with the notation of the general formula of the Pythagorean Theorem.



Learning Module Cover

b. Student Identity

This section is located on the first page of the module. Student identity contains information about the name and serial number of students. Giving an identity page on the module aims so that the modules used by each student are not confused.

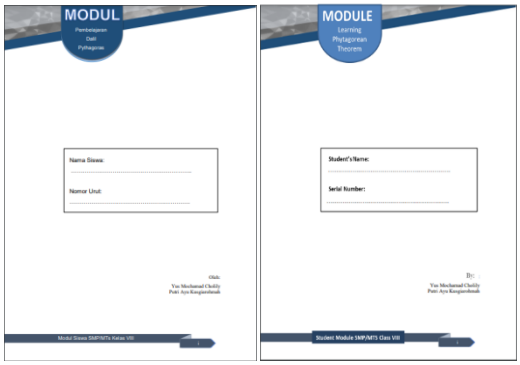


Figure 2. Student identity sheet

c. Foreword

The author's goals and expectations are stated in the Foreword. In addition, this section also explains that the author needs criticism and suggestions from users as well as media and material experts to improve the module in the future.

d. Table of Contents

The table of contents contains the topics covered in this learning module.

e. Basic Competencies

This module refers to the 2013 curriculum which contains four competencies. The four competencies to be achieved include spiritual attitude competence, social attitude competence, knowledge competence, and skills competence. While the core competencies and basic competencies contained in the 2013 curriculum regarding the Pythagorean theorem contain knowledge and skill competencies which are explained as follows:

1) Core competencies

The core competencies of knowledge in the 2013 curriculum expect students to be able to understand and apply knowledge

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(factual, conceptual, and procedural) based on their curiosity about science, technology, art, culture related to visible phenomena and events. As for the basic competence skills, students are expected to be able to process, present, and reason in the concrete realm (using, assembling, parsing, modifying, and creating) and abstract realms (writing, reading, counting, drawing, and composing) in accordance with what is learned in class. schools and other sources that are the same in a certain point of view/theory.

2) Basic competencies

The basic knowledge competence in the 2013 curriculum expects students to be able to explain and prove the Pythagorean theorem and Pythagorean triples. Meanwhile, for basic competence skills, students expect students to be able to solve problems related to the Pythagorean theorem and Pythagorean triples.

f. Achievement Indicator

This module in determining achievement indicators refers to the revised Bloom's taxonomy. There are twelve indicators of achievement that are classified into C1, C3, and C4. This means that while using this module, students have honed their cognitive abilities in the aspects of understanding, applying, and analyzing (Hyder & Bhamani, 2017).

g. Introduction or Overview of flat shapes

The introduction in this module discusses the concept of plane shapes, specifically triangles and squares. The area of a square is used as a supporting concept in teaching the concept of the Pythagorean theorem.

h. Material Description

The Pythagorean Theorem learning module contains three activities in the description of the material. The first activity contains material on the Pythagorean theorem which is compiled using a scientific approach. In this activity students are given two congruent squares with different partitions. Next, students are asked to determine the area of each square and make similarities between the two to find the general form of the Pythagorean theorem. The second activity contains practice questions related to the Pythagorean theorem and Pythagorean triples. The third activity is enrichment. The enrichment section contains 15 questions about the Pythagorean theorem and the Pythagorean triple. Advanced Training

The follow-up exercise contains ten questions with a higher level of difficulty than the enrichment activity. The problems contained in this section are the application of the concept of the Pythagorean theorem and the Pythagorean triple in everyday life.

i. Answer Sheet

Since the purpose of this module is to help students learn independently, this module is equipped with an answer key from the enrichment section and advanced exercises. The goal is that students can measure the extent of their understanding after studying the concept of the Pythagorean theorem with the help of the Pythagorean Theorem Learning Module.

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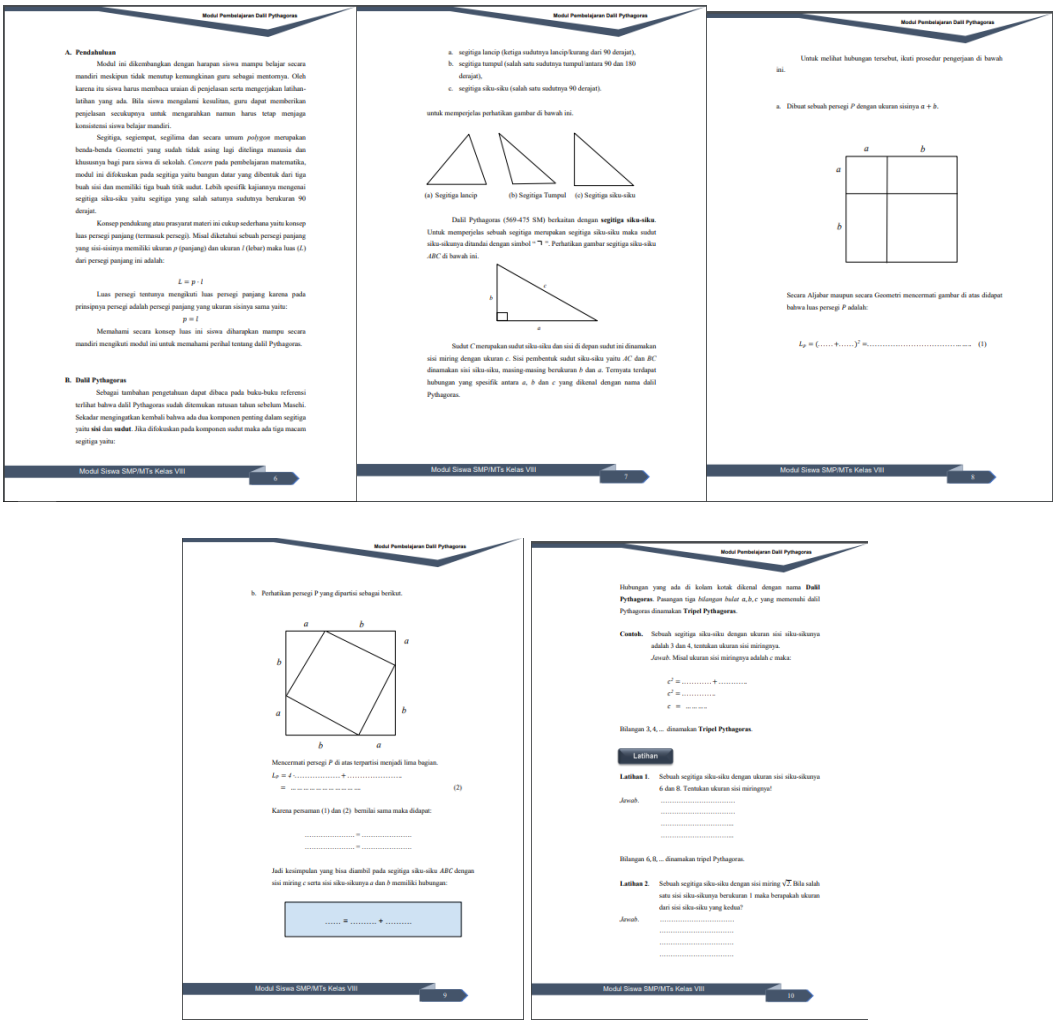

Figure 3. Material description

3. Development Stage (*Development*)

Before mass use, it is necessary to determine whether the module is suitable for use. The module feasibility test is carried out at this stage. Researchers conducted validity and practicality tests to determine the Pythagorean Theorem Learning Module suitable for use.

a. Validity Test

The validity in this study refers to the validity standards set out in table 1. The validity test data was obtained through a Forum Discussion with PPG lecturers and students in positions in two classes and each class had an average of 20 students. PPG students in positions are chosen because they are teachers of mathematics subjects in their respective schools. Indirectly, the validity test is carried out by practitioners (teachers) and material experts (lecturers). The discussion is carried out by referring to the validity indicators contained in table 1. The results of the discussion are used to correct the module deficiencies so that the module can be said to be valid.

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Table 1. Validity test indicator

Assessment Component	Description
Content Eligibility	Module compatibility with BC
	Material delivered is in accordance with the learning objectives
	Material is presented systematically
Language	Language used in module is communicative and easy to understand
	Languages used is in accordance with KBBI
	Language used does'nt cause multiple interpretations (ambiguous)
Scietific Approach	The modules created can guide students to observe (read, hear, see, or listen) the facts that are being observed (**Observe**)
	The module created can guide students to ask questions based on the facts being observed (**Asking**)
	The module created can guide students to carry out object observation activities to obtain authentic learning outcomes (**Gathering Data**)
	The module created can guide students to process the data from observations that have been collected (**Associating**)
	The modules created can guide students to communicate the results of observations in writing (**Communicating**)
	The modules created can guide students to be directly involved in learning activities

b. Practical Test

The module that has been declared valid is tested on class VIII students to determine the level of practicality in helping students learn the concept of the Pythagorean theorem. The module is said to be practical if it meets the practical standards contained in table 2 below. The practicality test in this study refers to the module development rules set by Departemen Pendidikan Nasional (2009).

Table 2. Practical tes indicator

Assesment Component	Description	Method of Collecting Data
Self Instructional	There are clearly defined learning objectives The material is presented into more specific units The material is presented clearly and uses language that is easy for students to understand Loading examples and practice questions	Interview

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Assesment Component	Description	Method of Collecting Data
	Contains assessment instruments and feedback for students	
Self Contained	Containing material in one competency	Observation
Stand Alone	Easy to use Does not require other media in learning the concepts being taught	Observation and Interview
Adaptive	Modules can be used for a long time following the development of science and technology	Observation
User Friendly	Use simple and communicative language Containing clear instructions Using common terms	Interview

If in the first trial the module has not been declared valid, then criticism and suggestions from students are used to make improvements to the module. Furthermore, the module that has been repaired will go through the validity test phase and if it is declared valid it will be tested again. The process will continue to repeat until the module can be declared practical to use.

RESULTS AND DISCUSSION

Validity of Modul

The Forum Discussion conducted with PPG lecturers and students stated that the material contained in the Pythagorean theorem learning module was in accordance with the Basic Competencies set out in the 2013 Curriculum. There were two basic competencies developed in this module, including 1) explaining and proving the Pythagorean theorem and Pythagorean triples (Knowledge) and 2) solve problems related to the Pythagorean theorem and Pythagorean triples (Skills). The material presented in this module also leads to the achievement of students' cognitive abilities in aspects of C1, C3, and C4. These three aspects are in accordance with the learning objectives to be achieved in this module. This means that the modules designed are in accordance with the learning objectives to be achieved. The material in this module is also structured deductively. Students are introduced first to flat shapes, especially triangles and squares. Students are also introduced to how to find the area of a square. Through these two knowledges, students are asked to compare the area of two squares with different partitions to find the length of the hypotenuse of a right triangle. It shows that the material in this module has been arranged systematically.

The sentences used in this module are communicative. If you learn to use this module, students can understand the commands contained in it. The words used in this module are also in accordance with KBBI and do not contain ambiguous sentences. This shows that this module has met the linguistic requirements to be said to be valid.

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This module is arranged systematically so that it can guide students to understand the concept of the Pythagorean theorem independently. In the first step, students are asked to observe the area of two congruent squares but have different partitions. This step shows that the module created can guide students to observe the facts being studied. Observing the two squares will trigger students to ask "What is the relationship of the two squares congruent with the different partitions they are observing?", "What is the relationship between the area of the square and the Pythagorean theorem?" and other questions. The activeness of students in asking questions after making observations shows that the modules made can guide students to ask questions based on the facts being observed. Furthermore, in this module, students are asked to write down the equations obtained from the two squares. Since the two squares are congruent, they have the same area. This step shows that the module created can guide students to carry out object observation activities to obtain authentic learning outcomes. The information they have obtained regarding the relationship between the two areas of the square can be used to process the observed data. Students are asked to make the similarities of the two equations they have obtained previously. By writing these similarities and performing calculation procedures by applying algebraic rules, students can find the relationship between the area of two squares that is congruent with the Pythagorean theorem. This step shows that the module created can guide students to process data from observations that have been made. This module also provides a place for students to write conclusions from the observations they have made. This shows that the module created can guide students to communicate the results of their observations in writing. Each step of the work made in this module requires students to be directly involved in finding the concept of the Pythagorean theorem, meaning that the module created can guide students to be directly involved in learning activities.

The Pythagorean theorem learning module has met all three aspects of the validity test, meaning that this module can be said to be valid. Valid modules can be used as learning media in the learning process (Nafsiah et al., 2019). This valid module can also be used to measure certain skills possessed by students (Harisman, 2016).

Modul practicality

Practicality test was conducted to see if the Pythagorean Theorem Learning Module was practical to help students learn the concepts of the Pythagorean theorem. The practicality test is carried out by referring to the module development rules that have been set by the Ministry of National Education. The following is a description of each component of the assessment.

a. Assesment Component of *Self Instructional*

The learning objectives that are expected to be achieved by students

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when learning to use this module have been written in a structured manner, starting from the lowest to the highest cognitive aspects. The learning objectives in this module have been summarized in the achievement indicators section.

The material presented in this module is divided into three units. First, the Introduction unit which contains a general description of the material regarding flat shapes. The second is the Pythagorean theorem unit which contains a description of the types of triangles and learning steps that can guide students to find the general concept and form of the Pythagorean theorem. The second unit also contains examples of the use of the theorem if the lengths of two sides of a triangle are known. The last is the advanced training unit which contains the application of the Pythagorean theorem concept in everyday life. Unfortunately, this module does not contain an assessment instrument and feedback that can be used by students to conduct an independent evaluation of their understanding only in the form of an answer key.

This module is designed to fulfill the basic competencies of explaining, proving and solving problems related to the Pythagorean theorem and Pythagorean triples. The material in this module has been prepared in accordance with the basic competencies to be achieved. It's just that the section on solving everyday problems related to the Pythagorean theorem and triple has not been given examples of problems and how to solve them. The problem solving given in this module is directly in the form of practice questions.

b. Assesment Component of *Stand Alone*

The test results of the module showed that students stated that this module was easy to use. The work steps are arranged systematically so that they can help students to understand their mathematical thinking. Students also do not need other media to understand the concept of the Pythagorean theorem because it is clearly presented in this module.

c. Assesment Component of *Adaptive*

In terms of content, this module can be used to follow the development of science and technology. It's just that this module is still in the form of print media. In the future this module can be developed in digital form.

d. Assesment Component of *User Friendly*

The language used in this module is structured simply by using common mathematical terms. So that students more easily understand the meaning of each description of the material. Instructions that are clearly expressed also make it easier for students to follow the observation procedure to find the general form of the Pythagorean theorem.

Referring to the explanation, this module can be said to have met the practicality test, so this module can be used as a learning resource (Kariman et al., 2016; Agustyaningrum & Gusmania, 2017). It's just that there are several aspects that need to be added to correct the shortcomings. In general, students stated that by using this module they could derive the formula from the area of a square to find the

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formula for the Pythagorean theorem without being accompanied by the teacher. This is in accordance with the results of the study conducted by Hamdunah, (2015) which stated that the use of modules in learning can help students understand concepts, instruction activities, and complete the exercises provided in the modules.

CONCLUSION AND RECOMMENDATION

The description of the Pythagorean Theorem Learning module material which was developed through the analysis (problem analysis), design (module design), and development (module development) stages is adjusted to KD and KI as well as learning objectives. The language used in this module is also made communicative. So that even though students study independently without being accompanied by a teacher, students can still understand the material of the Pythagorean theorem. Students learn independently through observing, asking questions, collecting data, associating and communicating which have been covered in this module. This shows that this module has met the eligibility criteria for content, language, and scientific approach and this module can be said to be valid. Therefore, this module can be used by students in understanding the concept of the Pythagorean theorem.

Then, based on observations and interviews with students by referring to the module development rules set by the Ministry of National Education, the Pythagorean theorem development module has met the practicality test. This is because the Pythagorean Theorem module has fulfilled the components of self-instructional, self-contained, stand-alone, adaptive, and user friendly. This means that this module is practical to use and can help students learn independently.

This module is only limited to validity and practicality tests, for that further research is expected to be able to test the effectiveness of the module. In addition, researchers, teachers, and stakeholders can carry out the implementation stage and carry out the evaluation stage in order to correct the deficiencies contained in the Pythagorean theorem learning module.

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