

Developing Circle Module Based on Van Hiele Theory

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Abstract

The van Hiele theory offers learning phases as an effective way to be applied in geometry classes. Because there is the difference of students' ability in solving circle geometry problems, a module can be used to deal with. This article describes the developing process and validating of circle module based on van Hiele theory. The developing model was Plomp model. The module was developed by five phases of van Hiele theory, namely inquiry, guided orientation, explication, free orientation, and integration. In addition, this circle module was developed in seven sections, those were elements and parts of the circle; the value of Pi and the perimeter of circle; the area of circle; the central angle and the inscribed angle; arc length, area of sector and area of segment; the properties of tangents; and the direct common tangent of two circles and the indirect common tangent of two circles. Based on the result of validation from expert, field trial in the class, and the legibility tryout of the module, the circle module based on van Hiele theory was declared valid to be used as learning resources.

Keywords: Circle Module, Learning Module, Van Hiele Theory

1. Introduction

Geometry is a vital of mathematical study of the aspects of life. Properly organized school geometry learning will give a positive impact on student success in other mathematical studies [1]. One of the geometry materials that must be mastered well by students is a circle. Unfortunately, the facts in Indonesia, especially in Surakarta City, there are many students have difficulty in studying geometry, especially the circle material.

Based on the National Examination Result of 2016 from BSNP, the percentage of mastery in mathematics materials about the relationship of line and the angle, the concept of quadrilateral and triangle, Pythagoras theorem, the circle elements, the elements of plane and curved side space, only stand at 50.39%. This presentation is relatively lower than the percentage of

other basic materials. The percentage of mastery in material about numbers reach 56.80%; in algebra material reach 53.42%; as well as statistical materials and opportunities reach 52.12%. Furthermore, the result of interview with mathematics teacher at SMP Muhammadiyah Surakarta states that students have difficulties and weaknesses in learning mathematics about circle, although the ideas about the circle has actually been known by students in everyday life.

Piere Marie Van Hiele and Dina Van Hiele-Geldof introduce how to organize learning of school geometry. When studying geometry, students will go through five stages. Those are recognition, analysis, order, deduction and rigor. It starts from the students recognizing geometric objects until students are able to understand the geometry deductively in formal [2]. Van Hiele gives

a detailed explanation about how teachers should teach geometry in order to guide students from one level to the next. The progress from one level to the next will through five stages: information, guided orientation, explication, free orientation, and integration [3]. Those stages lead to a high-level thinking. In addition, the learning of geometry by adopting Van Hiele instruction can give a great influence in the learning result of geometry [4].

Moreover, interview with teacher at SMP Muhammadiyah Surakarta state that geometry learning about plane geometry is still use lecture method. Teacher only use the existing Student Worksheets that consist of a lot of exercises. This Worksheets has not been referring to Van Hiele's theory. One of the teaching materials that give students the opportunity to learn according to their own ability is a module. Learning by using module will give opportunities for students to learn individually because each student uses different techniques to solve a given problem and each student could not achieve the same results at the same time [5].

Based on the explanation above, it is necessary an effort to develop a mathematics learning module based on Van Hiele theory on circle material to improve students' geometry abilities. The formulation of the problem in this research is how the validity quality of mathematics learning module based on Van Hiele theory on circle material? Therefore, this research aims to produce and describe mathematics learning module based on Van Hiele theory on circle material which has validity criteria.

2. Theoretical Review

2.1. Van Hiele Theory of Geometry

One of the the best way for learning geometry was using Van Hiele theory by classified students based on their Van Hiele level geometry [6]. By using this method, the objective and accomplishment each group of students could be determined and teacher could give special treatment appropriate with student's abilities on geometry. In addition, this research also showed that there was no diversification result significantly based on gender by implementing Van Hiele theory for learning geometry. It presented that Van Hiele theory-based learning for geometry could be well applied for men and female students. Besides, for improving Van Hiele

thinking level, teachers should make consideration about language, words, and statement that was used have to suitable for learning contents [7].

Moreover, geometry learning which adopted from Van Hiele instruction could give great influence on learning outcomes [4]. Besides, it was suggested that Van Hiele theory-based learning for geometry could become consideration on curriculum [4]. The research from [8] about the influences of implementation Van Hiele model toward geometry understanding of junior high school students at first level showed: 1) instruction in learning model of Van Hiele was meaningful learning because it was based on student's understanding and relation of ideas on geometry, 2) there was diversification result significantly between students that taught by learning model of Van Hiele and students that taught by transferring of knowledge, and 3) student's concept understanding of geometry gave positive impact for students and the students could be used their abilities in their life. Another research from [9] about the effectiveness of learning equipment based on Van Hiele theory toward student's achievement at senior high school had results: 1) the rate of student's achievement at experiment class reached the learning objective appropriately, 2) score of pre-test and post-test increased significantly at experiment class and it was different with control class which the score of pre-test and post-test was not different significantly.

The research development about learning activities use software Geometry Sketch Pad based on learning phase of Van Hiele got positive respond from experts [10]. There was other research development about instrument to detect errors on understanding geometry based on Van Hiele learning model and it could be applied on classical and IT based-learning [11]. Van Hiele stated that students had different abilities to understand on learning geometry, thus students had variety of thinking level [2]. In addition, Van Hiele theory consist of three aspect, those are existence of levels, properties of levels, and movement from one level to the next [12].

Van Hiele explained that there were 5 levels on understanding geometry which students could not reach a level without pass the previous level. Those levels were recognition, analysis, order, deduction, and rigor. At recognition level, students were identifying, giving name, comparing, and doing operation on geometry. At analysis level, students were analyzing about relation between components or attributes and classifying the object. Then, at order level, students could connect the

attributes with informal argument. The next, at deduction level, students could proof theorem deductively and determine the relation between theorems. The last, at rigor level, student were explaining theorem as different system of postulate and analyzing or comparing the system.

Moreover, Van Hiele theory stated that student's understanding in geometry needed to pass the level consecutively and it had properties of levels that consist of fixed sequences, adjacency, distinction, separation, and attainment. Fixed sequences mean that students could not reach a level without passed the $n-1$ level. Adjacency property mean that what was intrinsic on the previous levels became extrinsic at the next level, while distinction property mean that every level had its symbols and relation among the symbols. Then, separation property mean that although two people at the same level, they could not understand each other. The last, attainment property mean that process of learning brought to higher understanding and had 5 ordinary level, they are inquiry, directed orientation, explanation, free orientation, and integration.

2.2. Learning Module

Van Hiele explained the detail how teacher should teach from one level to the next level for making students understand. There were five phases of Van Hiele theory, those are inquiry, guided orientation, explanation, free orientation, and integration [13]. At inquiry phase, students was recognizing concept that would be learned. Then, at guided orientation phase, students was doing some tasks that used relation from different concept, while at explanation phases, students was understanding about relation and trying to figure as statement based on topic. After that, at free orientation phase, students was studying to do complex task and determining the properties of concept that they learned. The last, students was resuming the material, figuring relation among the concept, and implementing at mathematics problems.

Module was an alternative of learning resources that presented systematically. Thus, the users could study with or without instructor or teacher [14], [15]. The main purpose of developing module was students could study autonomous with or without guidance from teacher. Ballstaedt explained that there were some concerning on developing module, those were: (1) layout arrangement on module should easy organized, the title was concise, there was list of content, the cognitive structure was clear, there was resume, and

there was task for readers [14]. (2) The language was easy to understand. (3) There was content to examine the readers. (4) It was recommended to give any stimulation that push the reader for thinking. (5) Module should easy to read, such the font was not too small or large, text structure, and the font was easy to read. (6) Content of module including material and worksheet should appropriate with the aim of learning.

In addition, there were 5 characteristics of module to motivate students for learning. Those were self-instruction, self-contained, stand alone, adaptive, and user friendly [16]. The developing module was done consecutively and the phases were: (1) analyzing main and basic competition, (2) determining the title of module, (3) giving module code to make organize easier, (4) writing module that consist of formulating basic competition, determining instrument of evaluation, material, sequences of learning, and completeness of module structure [14]. Moreover, the quality of module should be evaluated based on 4 components, those were properness of content, validity, presentation, and graphic.

3. Research Method

This research was research and development research that focus on developing circle module based on Van Hiele theory. The subject were teachers and students grade 8 at SMP Muhammadiyah 7 Surakarta. This model of research was preliminary research phase, development or prototyping phase, and assessment phase [17]. At this preliminary research phase, identifying and investigating about student's condition, module of geometry learning at school, and student's abilities on geometry was conducted by the researchers. The data was collected by observation, interview, documentation, and forum group discussion. At the development phase, developing and validating circle module based on Van Hiele theory was done. The validation process consisted of three aspects, those were content, presentation, and language. The content consisted of element of module and presentation, the presentation had five indicators, those were conformity between picture and table, clarity of text, conformity of colors, compatibility of layout, and attractiveness of the presentation. The Criteria of language consisted of clarity, convenience, and use of language. The last stage was legibility tryout by giving questionnaire for students and practicality test by giving questionnaire for teacher.

4. Result and Discussion

4.1. Product Development

The circle module based on van Hiele theory had been developed with special characteristics, namely inquiry, guided orientation, explication, free orientation, and integration. The main activities at the inquiry phase were the introduction of concepts through the association of information with concrete objects, contextual issues related to the material, as well as information related to the concept. Then, the main activities at guided orientation were related to construct students' concepts and basic concepts, find formulas, or deal with problem solving algorithms. After that, content used in explication phase was an explanation related activities to find concepts that students do by explaining the formula formally and explaining the material in depth. Then, free orientation phase had main activities, namely concept application in a given problem or further invention based on initial findings. The last, the activities at integration phase were summarizing the material, making concept maps, discussions, and presentations. The module was also developed by national council criteria, those were self-instruction, self-contained, stand alone, adaptive, and

user friendly. The circle module which developed consisted of seven section modules, those were elements and parts of the circle; the value of Pi and the perimeter of circle; the area of circle; the central angle and the inscribed angle; arc length, area of sector and area of segment; the properties of tangents; and the direct common tangent of two circles and the indirect common tangent of two circles.

4.2. Revision of Module

Table 1. Validation Score of Circle Module Based on van Hiele Theory

Aspect	Score	Criteria
Content	141	Very Valid
Presentation	55	Very Valid
Language	39	Very Valid

The circle module was validated by validator from mathematics lecturer and mathematics teacher. The validation was divided into three aspect that consisted of content, presentation, and language. The validation score of the circle module can be seen at Table 1. Moreover, there were some suggestions from the expert which presented at Table 2.

Table 2. Validation Score of Circle Module Based on van Hiele Theory

Expert Recommendation	Revision
The use mathematics symbol should be right and did not overlap each other. For instance, the symbol of arc was similar with the symbol of circle section.	There was no overlap symbol between arc and circle section.
Key answer of the problem could help students study independently and it was very good. But, it should not be placed at the end of the problems as it could disturb students. It would be better that the key answer was placed at the end of module.	The key answer was placed at the end of each section of module.
Circle problems should be sort by easier to harder.	The problems had been arranged from the easiest.
At the section three of module, students should cut the picture of circle and patched them at the next page. The activities was good as students could find the formula of area of circle directly. However, it could make the module broken and the presentation was not good.	The instruction was changing. Students should imitate the picture first before they cut it. So, the module was not broken.
It was better to present contextual material in each section of module.	The real content or contextual material had been added.
At the conclusion, it was better to use open-ended statement.	The statement at conclusion was changed by open statement.

4.3. Result of Try Out The Module

The first tryout was aimed to identify legibility of the module. The draft module was tried out at students of class 8C at SMP Muhammadiyah 7 Surakarta. This school was selected because of the students condition, students ability, and learning method that used. The try out was conducted three times with material about elements and parts of the circle; the value of Pi and the perimeter of circle; the area of circle. Based on the observation result, teacher only explained the main content and did not explore the content deeply. By using circle module, students focused on their module, listen the explanation from teacher, and wrote the essential content. It made learning more effective. When students did the exercise, many of them still confused about the problems, thus they need illustration about the problems. However, the students were enjoying discover the formula of circle area as they did activity by cutting and sticking the circle.

After using circle module in mathematics learning, the module was analyzed by students to identify the legibility. There were some comments from the students. (1) The size of geometry object was not draw exactly. When students arranged the section of circle become parallelogram form, the result was exceeds from the papers. So, the circle that drawn before was too big. (2) There was a problem which has multi interpretations. The students had different understanding about the same problems. It was because there was no picture at the problems. (3) Space to write the answer was minimalist so, students could not write the solution under the problems. Based on the legibility, the module was revised the layout and presentation.

Based on the result of validation from expert, field trial in the class, and the legibility of the module, the circle module based on van Hiele theory was declared valid to be used as learning resources.

4.4. Discussion

The result of this research supported the previous development research that has been conducted by other researchers. The research from [18] stated that the learning modules built using Google Sketch Up were potential in assisting to progress through the respective Van Hiele's levels of geometry thinking. The result of this research also supported other research from [19] that aimed produce learning instruments of mathematics material geometry based on Van Hiele learning theory

to develop characters which are valid, practical and effective criteria. The research from [19] indicated that the developed of learning instruments were in valid category.

The research development about learning activities use software GSP (Geometry Sketch Pad) based on learning phase of Van Hiele got positive respond from experts [10]. The other research development about instrument to detect errors on understanding geometry based on Van Hiele learning model concluded that the instrument could be applied on classical and IT based-learning [11].

Furthermore, the other research from [20] also affirmed this research. The students' level of Van Hiele geometrical thinking can be improved by using an educational video based on Van Hiele learning model. According to the result of the research, this tool was helpful in improving the Van Hiele geometry thinking level among the SMP graduates. The research from [21] about the development of Learning Strategy for 3-Dimensional Plan and Elevation using Sketch Up Make (LSPE-SUM) integrated into Van Hiele levels of geometry thinking was also affirmed this development research. The result showed that LSPE-SUM was well constructed in the context of incorporating visual spatial skills and Van Hiele levels of geometry thinking. Based on experts and students' evaluation agreed that LSPE-SUM was appropriate to be used in the classrooms.

5. Conclusion

This study was a series of development research with the main result was circle module based on Van Hiele theory. This research had 3 phases on developing module, they were of the preliminary research phase, development or prototyping phase, and assessment phase. This study only focused on development phase. The result was a Van Hiele-based module on circle material which had valid criteria. This module consisted of seven sections and each section consisted of Van Hiele phases namely inquiry, guided orientation, explanation, free orientation, and integration. Based on validation of expert, the module was very valid and the recommendation from expert had been done. Then, at the field trial, based on observation result, the teacher can explain the material easily and the student more enjoy on learning. In addition, the result of legibility tryout, the module can be used with some revisions. In conclusion, this module can be used as a learning resource.

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