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Development of Geo-Concept Van Model Student Worksheets Based on Van Hiele's Hierarchical Geometric Thinking for PGSD Students

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Abstract

This study aims to develop a Geo-Concept Van Model-based Student Worksheet (LKM) grounded in the Van Hiele hierarchy of geometric thinking for students of the Primary School Teacher Education Program (PGSD). This research employed a Research and Development (R&D) approach using the Plomp model, which consists of preliminary investigation, design, realization, and test, evaluation, and revision phases. The subjects of this study were PGSD students at Universitas Muhammadiyah Makassar. The instruments used included validation sheets, observation sheets, learning achievement tests, and student response questionnaires. The data were analyzed descriptively to determine the validity, practicality, and effectiveness of the developed learning devices. The results indicate that the developed learning devices meet the criteria of being highly valid, with average validation scores of 90.00 for the Semester Lesson Plan (RPS), 84.25 for the Student Worksheet (LKM), and 87.00 for the learning achievement test. Supporting instruments were also categorized as highly valid. The practicality of the devices is shown by the high level of implementation, with all components meeting the established criteria. The effectiveness is reflected in students' learning outcomes, problem-solving abilities, activities, and responses, all of which achieved good categories and met the required criteria. In conclusion, the Geo-Concept Van Model-based Student Worksheet grounded in the Van Hiele hierarchy of geometric thinking is valid, practical, and effective, and therefore feasible to be used in learning to enhance students' geometric thinking skills

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Keywords*: *student worksheet; Geo-Concept Van Model; Van Hiele; problem-solving ability.

INTRODUCTION

Mathematics education plays a very important role because mathematics is a fundamental science that is widely used in various fields of life. Mathematics continues to develop rapidly, both in terms of content and its applications in daily life. In the Indonesian national education curriculum, mathematics is taught at every level of education, including higher education. This indicates that the existence of mathematics is highly significant in the field of education. In the era of the Industrial Revolution 4.0, competitive human resources are required to meet the demands of increasingly advanced developments. The quality of a nation's human resources is determined by its level of education. Mathematics also has a strong and clear structure with interconnected concepts, enabling students to develop rational thinking skills. Therefore, it is important to study mathematics not only to know but also to understand and apply it to other problems.

Based on the Regulation of the Minister of Education and Culture (Permendikbud) Number 22 of 2016, the objectives of mathematics learning are: (a) understanding mathematical concepts, describing the relationships among concepts, and applying concepts or algorithms efficiently, flexibly, accurately, and appropriately in problem-solving; (b) reasoning about patterns and properties of mathematics, developing or manipulating mathematics in constructing arguments, formulating proofs, or describing mathematical statements; (c) solving mathematical problems, including understanding problems, constructing mathematical models, solving them, and providing appropriate solutions; and (d) communicating ideas using diagrams, tables, symbols, or other media to clarify problems. In addition, the National Council of Teachers of Mathematics (NCTM) recommends four principles of mathematics learning: (a) problem solving, (b) reasoning, (c) communication, and (d) connections.

Higher education institutions face challenges in producing high-quality human resources. Learning activities are expected to develop both students' hard skills and soft skills. One of the compulsory courses in the PGSD (Primary School Teacher Education) program at Universitas Muhammadiyah Makassar is Advanced Mathematics for Elementary School, in which geometry is one of the topics taught. Geometry is a branch of mathematics taught at all levels of education, from elementary school to higher education. Geometry is closely related to students' daily lives because most visual objects around them are geometric in nature. Freudenthal (Afgani, 2011)

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states that geometry is the space where children live, move, and interact. In this space, they learn to know, explore, conquer, organize life, breathe, and function better.

Geometry occupies a special position in the mathematics curriculum due to the richness of concepts it contains. From a psychological perspective, geometry represents an abstraction of visual and spatial experiences such as shapes, patterns, measurement, and mapping. From a mathematical perspective, geometry provides approaches to problem-solving through diagrams, coordinate systems, vectors, and transformations.

The objectives of learning geometry are to enable students to gain confidence in their mathematical abilities, become effective problem solvers, communicate mathematically, and reason mathematically. Budiarto (2000:439) states that geometry learning aims to develop logical thinking, spatial intuition, support knowledge for other mathematical topics, and the ability to interpret mathematical arguments.

In reality, however, many students still experience difficulties in solving geometric problems (Abu & Abidin, 2013; Muhassanah, 2014; Özerem, 2013). Therefore, lecturers play an important role in fostering students' problem-solving abilities. Lecturers also need to identify students' levels of geometric thinking. This can be analyzed using Van Hiele's theory, which includes five levels: visualization, analysis, informal deduction, formal deduction, and rigor. Many students still struggle with geometric problem-solving. Sumartini (2016) explains that difficulties include failure to recognize problems, define problems, use available information, question assumptions, and consider alternative solutions. NCTM (2000) also emphasizes essential mathematical competencies such as problem-solving, reasoning, communication, connections, and representation. However, many students still face challenges in geometric problem-solving.

Mathematics education at the elementary level plays an important role in developing logical, analytical, and systematic thinking. Geometry, as a branch of mathematics, significantly contributes to this development. It enhances not only the understanding of shapes and space but also visualization and spatial reasoning skills. However, research findings indicate that students' understanding of geometric concepts, particularly among PGSD students, remains low and tends to be procedural.

One of the causes of this issue is that instruction often does not consider the stages of geometric thinking development. According to Pierre van Hiele, geometric understanding develops through five levels: visualization, analysis, informal deduction, formal deduction, and rigor (Van Hiele, 1986). Each level has distinct characteristics; therefore, geometry instruction must be aligned with these stages to support meaningful learning.

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In the Indonesian context, Hamzah Upu emphasizes that mathematics learning should focus on conceptual understanding and thinking processes rather than merely final results. Effective learning engages students actively in constructing knowledge through meaningful experiences (Upu, 2003). Furthermore, Nurdin (2016) states that innovative learning tools, such as student worksheets, can enhance learning interaction and help students understand abstract mathematical concepts.

One such innovation is the development of Geo-Concept Van Hiele-based Student Worksheets (LKM). These worksheets are designed to guide students systematically through the stages of geometric thinking, thereby improving conceptual understanding and higher-order thinking skills. The use of structured and theory-based worksheets is expected to overcome students' difficulties in understanding abstract and less contextual geometry concepts.

Based on the above discussion, this study aims to develop Geo-Concept Van Model-based student worksheets grounded in Van Hiele's hierarchical geometric thinking for PGSD students. This development is expected to contribute to improving the quality of geometry learning and serve as a reference for developing innovative instructional materials in elementary education.

RESEARCH METHOD

This study is categorized as Research and Development (R&D). Development research is defined as a process or steps to develop a new product or improve an existing one. The product developed in this study is the Geo-Concept Van Model-based student worksheet (LKM) grounded in Van Hiele's hierarchical geometric thinking for PGSD students.

The development model used in this study refers to Plomp's general educational problem-solving model, which consists of:

(1) preliminary investigation phase,
(2) design phase,
(3) realization phase,
(4) test, evaluation, and revision phase, and
(5) implementation phase.

RESEARCH FINDINGS

1. Preliminary Investigation Phase

The preliminary investigation phase was conducted through several indicators, including analysis of learning needs, analysis of student characteristics, analysis of curriculum and learning

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outcomes, analysis of ongoing instructional practices, and analysis of geometry materials. These activities include:

a. Analysis of learning needs
b. Analysis of student characteristics
c. Analysis of curriculum and learning outcomes
d. Material analysis
e. Formulation of learning outcomes

2. Design Phase

The Student Worksheet (Lembar Kerja Mahasiswa/LKM) developed in this study was designed based on Van Hiele's hierarchy of geometric thinking. It presents geometric problems arranged progressively according to students' levels of thinking development.

Through this worksheet, students are guided to observe, analyze, and relate geometric concepts and properties logically. As a result, it is expected that students can develop critical thinking skills and achieve a deeper conceptual understanding of geometry within higher education mathematics learning.



Figure 1. Cover of the Student Worksheet (LKM)

3. Realization/Construction Phase

In the realization phase, the Student Worksheet (LKM) was developed based on Van Hiele's hierarchy of geometric thinking. The student book and LKM contain learning activities and geometry problems arranged progressively according to students' geometric thinking levels.

Through these learning tools, students are guided to observe, analyze, and relate concepts

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and properties of geometric shapes logically, enabling them to construct both conceptual and relational understanding of geometry.

4. Test, Evaluation, and Revision Phase

The developed LKM was evaluated by experts. The validation focused on format, content, illustrations, and language aspects covering all developed components of the LKM. The results of expert validation, including corrections, critiques, and suggestions, were used as the basis for revising and refining the LKM.

Table 1. Suggestions for Improvement from the First Validation by the Expert Team

Validated Component	Validation Results / Suggestions for Improvement
Student Worksheet (LKM)	• Consistency in the use of geometric terminology and geometric thinking terms across all learning tools is required. • The objectives in the LKM need to be aligned with the learning objectives stated in the Semester Learning Plan (RPS). • Each problem should be provided with sufficient space for students to write their answers. • Consistency in the structure of answer columns is needed. • Instructions for using the LKM should be added. • Learning activities in the LKM need to be more varied, such as exploration, group discussion, and individual reflection. • The characteristics of the LKM should clearly reflect the syntax of the Geo-Concept Van learning model based on Van Hiele's geometric thinking hierarchy.

Table 2. Average Validation Results of Geo-Concept Van LKM Learning Tools Based on Van Hiele's Geometric Thinking Hierarchy

Learning Tools	Average Validation Score	Category
Semester Learning Plan (RPS)	90.00	Highly valid
Student Worksheet (LKM)	84.25	Highly valid
Learning Achievement Test	87.00	Highly valid

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able 2 presents the average validation results of the developed Geo-Concept Van LKM learning tools based on Van Hiele's geometric thinking hierarchy. Overall, all validated learning tools fall into the highly valid category, indicating that they meet the feasibility criteria for implementation in the learning process.

The Semester Learning Plan (RPS) obtained an average score of 90.00, categorized as highly valid. This indicates that its components; learning outcomes, materials, methods, and evaluation are systematically organized and aligned with Van Hiele-based learning principles.

The Student Worksheet (LKM) achieved an average score of 84.25, also categorized as highly valid. This result shows that the developed LKM effectively facilitates students' geometric thinking stages in accordance with Van Hiele's levels and supports step-by-step conceptual understanding.

The Learning Achievement Test obtained an average score of 87.00, also within the highly valid category. This indicates that the assessment instrument aligns with learning indicators and accurately measures students' learning outcomes.

Thus, based on these validation results, all learning tools—including the RPS, LKM, and learning achievement test—are considered feasible for implementation, particularly in supporting the development of students' geometric thinking skills according to Van Hiele's hierarchy.

Table 3. Average Validation Results of Instruments for the Geo-Concept Van Learning Model

Instruments	Average Validation Score	Category
Student response questionnaire to LKM	86.25	Highly valid
Observation sheet of lecturer's teaching ability	90.00	Highly valid
Observation sheet of student activities	88.25	Highly valid

The validation results indicate that all supporting instruments fall into the highly valid category, making them appropriate for use in both research and instructional implementation.

Table 4. Recapitulation of the Effectiveness of the Geo-Concept Van Learning Model Based on Van Hiele's Geometric Thinking Hierarchy

No	Effectiveness Indicators	Criteria	Achievement	Result
	Validity			
A	Expert validation	> 75	87.3 > 75	Achieved

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Practicality				
a.	Average observation of syntax component implementation	> 80	86 > 80	Achieved
b.	Average observation of social system components	> 80	82 > 80	Achieved
c.	Average observation of reaction principle components	> 80	81.81 > 80	Achieved
d.	Average observation of support system components	> 80	100 > 80	Achieved
e.	Average observation of lecturer's ability in managing learning	> 80	83 > 80	Achieved
Effectiveness				
a.	**Learning Outcomes**			
	- Average student learning outcomes	≥ 60	69 > 60	Achieved
	- Average students' problem-solving ability	≥ 65	67.33 ≥ 65	Achieved
	- Percentage of student mastery	≥ 75	93 > 75	Achieved
	- Improvement in learning outcomes (pre–post)	> 0.3	0.4 > 0.3	Achieved
	- Classical mastery percentage	≥ 75%	93 > 75	Achieved
b.	**Student Activities**			
	- Observation results of student activities	≥ 65	76.66 > 65	Achieved
c.	**Student Responses**			
	- Response to student book	≥ 75	87.6 > 75	Achieved
	- Response to LKM	≥ 75	83.07 > 75	Achieved
	- Response to Geo-Concept Van learning model based on Van Hiele's hierarchy	≥ 75	85.48 > 75	Achieved

Based on the data presented in the table, the achievement of the learning tools in terms of validity, practicality, and effectiveness generally meets the established criteria. In terms of validity, the results of expert validation show a score of 87.3, which exceeds the minimum criterion (> 75). This indicates that the developed learning tools have a high level of feasibility and are considered valid.

Furthermore, in terms of practicality, all observed indicators also meet the required criteria. The average observation score for the implementation of syntax components is 86, the social system components 82, the reaction principle components 81.81, and the support system components reach 100. In addition, the lecturer's ability to manage the learning process achieves

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an average score of 83. All these scores are above the required threshold (> 80), indicating that the learning tools are practical and that all indicators within this aspect are fulfilled.

In terms of effectiveness, the results indicate that most of the criteria have been achieved. From the perspective of learning outcomes, the average student score of 69 exceeds the minimum requirement (≥ 60). The average students' problem-solving ability reaches 67.33 (≥ 65), and the percentage of student mastery is 93% (≥ 75), indicating a high level of learning success. The improvement in learning outcomes before and after instruction is 0.4, which is higher than the criterion (> 0.3), indicating a significant improvement.

DISCUSSION

The Student Worksheet (LKM) in this study represents a crucial component within the supporting system of the Geo-Concept Van Learning Model based on the Van Hiele hierarchy of geometric thinking. The LKM functions not merely as a practice tool but is designed as a medium for knowledge construction that facilitates the gradual development of students' geometric thinking in accordance with Van Hiele levels, namely from visualization to analysis and informal deduction.

The results of the study indicate that the developed LKM falls into the highly valid category, with an average score of 84.25, and received positive responses from students, reaching 88.5% in the second trial. This finding demonstrates that the LKM meets the criteria of content validity, construction, and language appropriateness, and is capable of supporting students' active engagement in the learning process. Furthermore, the use of LKM contributes to increased student activity and learning outcomes, indicating that it is not only theoretically sound but also empirically effective.

Conceptually, the LKM in this study is designed based on the syntax of the Geo-Concept Van learning model, namely Observe, Orientation, Concept Understanding, Assignment, Discussion, Presentation, and Reflection. Each stage in the LKM contains activities aligned with the development of geometric thinking according to Van Hiele. In the observe stage, students are directed to examine various plane figures to build visualization skills. This stage is consistent with Van Hiele (1986), who emphasized that geometric understanding begins with visual recognition before progressing to analytical thinking.

Furthermore, in the orientation and concept understanding stages, the LKM facilitates students in identifying properties of shapes and relationships among them gradually. These activities support the transition from the visualization level to the analysis level, as stated by

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Usiskin (1982), who argued that learners need guidance to understand the properties and characteristics of shapes before engaging in higher-level geometric reasoning.

In the assignment stage, the LKM is designed with exploratory tasks that encourage students to independently discover concepts through investigation. This approach aligns with constructivist theory, which emphasizes that knowledge is actively constructed by learners. Burger and Shaughnessy (1986) found that exploratory activities in geometry learning can assist students in transitioning from analysis to informal deduction, as they begin to understand the reasoning behind geometric concepts.

The discussion and presentation stages in the LKM provide opportunities for students to interact, exchange ideas, and communicate their thinking. These activities are essential in developing mathematical communication and geometric reasoning skills. This is supported by Dina van Hiele-Geldof (1957), who stated that social interaction and mathematical communication are key factors in the development of geometric thinking.

Meanwhile, the reflection stage in the LKM functions to help students evaluate their understanding and become aware of the development of their thinking processes. Reflection enables students to integrate the concepts they have learned and strengthen their geometric knowledge structure. According to Van Hiele (1986), reflection is an essential part of the transition process between levels of geometric thinking, as it supports deep conceptual internalization.

The findings of this study are also consistent with the results of Clements and Battista (1992), who emphasized that the use of structured activities in geometry learning, such as LKM, can enhance conceptual understanding, representation, and mathematical reasoning. In addition, Abdullah and Zakaria (2013) found that Van Hiele-based learning tools, including LKM, significantly improve problem-solving skills and conceptual understanding in geometry.

CONCLUSION

Based on the analysis of the validity, practicality, and effectiveness of the Geo-Concept Van LKM learning tools based on Van Hiele's geometric thinking hierarchy, it can be concluded that:

1. The validity aspect has been very well fulfilled, as indicated by expert validation results that exceed the established criteria. This shows that the learning tools are appropriate in terms of content, construct, and language.
2. The practicality aspect is also fulfilled, where all learning components (syntax, social system, reaction principles, support system, and lecturer's ability) demonstrate a high level of

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implementation. This indicates that the learning tools are easy to use and can be effectively implemented in the classroom.

3. The effectiveness aspect has generally been achieved. This is reflected in learning outcomes, problem-solving ability, classical mastery, student activities, and student responses, all of which exceed the established criteria. However, one indicator has not yet been fully achieved, namely the N-Gain score, which remains below the standard, indicating that the improvement in learning outcomes is not yet optimal.

Thus, the developed learning tools can be considered valid, practical, and effective, and are feasible to be used in learning to support the development of students' geometric thinking skills.

SUGGESTIONS

Based on the results of this study, it is recommended that the Geo-Concept Van LKM learning tools based on Van Hiele's geometric thinking hierarchy be further developed and implemented more widely in the learning process, particularly in geometry-related courses. Lecturers are expected to optimize the use of these tools by considering student characteristics and facilitating learning processes that encourage active engagement, discussion, and gradual conceptual understanding in accordance with Van Hiele's levels of thinking.

In addition, these learning tools can be further refined by adapting them to various learning contexts and incorporating more innovative learning activities to enhance the quality of instruction. Future research is recommended to examine the effectiveness of these tools across more diverse subjects and settings in order to obtain more comprehensive findings.

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