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IDENTIFICATION PRE-SERVICE ELEMENTARY TEACHERS' MATHEMATICAL KNOWLEDGE FOR 3-DIMENSIONAL GEOMETRY LEARNING

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ABSTRACT
This study reports the results of the initial identification of the knowledge of prospective elementary school teachers related to 3-dimensional (3D) geometry learning. A total of 32 students of the pre-service elementary school teacher education study program were used as research subjects and given 15 questions related to van Hiele's geometric thinking level and related to the concepts of Teachers' Geometry Content Knowledge (GCK), Knowledge of Geometry and Students (KGS), and Knowledge of Geometry and Teaching (KGT). Data were analyzed descriptively using the percentage of correct answers in each question item. The study results showed that most of the pre-service elementary school teachers who were the study subjects still had misconceptions about several 3-dimensional geometry concepts, and the subjects of the study had not fully mastered the application of van Hiele's geometric thinking level in learning 3-dimensional geometry.
Keywords: 3-dimensional geometry; pre-service elementary teachers; van hiele

ABSTRAK
Penelitian ini melaporkan hasil identifikasi awal terhadap pengetahuan calon guru sekolah dasar terkait pembelajaran geometri dimensi tiga (3D). Sebanyak 32 mahasiswa program studi Pendidikan Guru Sekolah Dasar (PGSD) dijadikan subjek penelitian dan diberikan 15 pertanyaan yang dikaitkan dengan level berpikir geometri van Hiele, serta dikaitkan dengan konsep Teachers' Geometry Content Knowledge (GCK), Knowledge of Geometry and Students (KGS), dan Knowledge of Geometry and Teaching (KGT). Data dianalisis secara deskriptif menggunakan persentase jawaban benar di setiap butir pertanyaan. Hasil penelitian menunjukkan bahwa sebagian besar mahasiswa calon guru sekolah dasar yang menjadi subjek penelitian masih mengalami miskonsepsi terhadap beberapa konsep geometri dimensi tiga, serta subjek penelitian tersebut belum menguasai sepenuhnya penerapan level berpikir geometri van Hiele dalam pembelajaran geometri dimensi tiga.
Kata kunci: *calon guru sekolah dasar; geometri tiga dimensi; van hiele*

Introduction

Mathematics teachers who have good competence will be able to carry out learning optimally. Ball et al. (2008) explained that teachers need to master the material that will be taught to students and master how to teach it to students. One of the branches of mathematics that students must learn is Geometry. Geometry can provide an essential foundation for studying other areas of mathematics and understanding other subjects such as art, engineering, science, and social sciences

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(NCTM, 2000). Geometry should be studied by students in elementary school, middle school, high school, and university because its goal is to develop logical thinking (Sudihartinih & Purniati, 2016).

Van Hiele's theory (van Hiele, 1984) provides ideas about the individual development of students' geometric thinking and has essential implications for geometry teaching. There are five levels of geometric thinking according to van Hiele's theory, namely: level 0 (visualization), students can recognize geometric shapes only from their appearance, not from their parts or properties; level 1 (analysis), students begin to see the characteristics of shapes and recognize their properties; level 2 (informal deduction), students begin to understand the reciprocal relationships of properties within a shape (for example, in a triangle, if two sides are congruent, then the opposite angles on the sides are congruent) and between different shapes (for example, a square is a rhombus because it has all the properties of a rhombus); level 3 (deduction), students can see the role and relationship of axioms, postulates, theorems, and proofs and understand the interaction between necessary and sufficient conditions; level 4 (rigor), students can understand and compare mathematical systems with different sets of axioms, such as Euclidean geometry and non-Euclidean geometry (Crowley, 1987). According to van Hiele's theory, if students and teachers reason at different levels, they cannot communicate with each other (van Hiele, 1984). According to Hoffer (1981), when students transition through various levels, they must master lower-level skills to advance to the next higher level. However, there are still elementary school students who have difficulty learning geometry, such as difficulty in using concepts, difficulty in using principles, and difficulty in solving verbal problems (Fauzi & Arisetyawan, 2020). Meanwhile, from the teacher's perception, students still find it difficult to calculate when solving geometry-related problems given by the teacher (Fauzi & Haeriah, 2021). The causes of low student achievement in measurement and geometry materials include teacher preparation that is not optimal in teaching the material (Bleeker et al., 2013; Browning et al., 2014; Sulistiowati, 2022).

Based on the information above, there needs to be a study related to the geometric knowledge of pre-service elementary school teachers because these pre-service teachers will later become teachers in existing schools. However, elementary school teachers are still at a low level, according to van Hiele's theory (Rafianti, 2016; Najwa, 2022). In fact, for elementary school students, it is possible to be at level 0, level 1, or level 2 (Yi et al., 2022), so elementary school teachers should have mastered van Hiele's geometric thinking level and its application in learning.

Most studies still describe the level of geometric thinking in teachers and students (Rafianti, 2016; Najwa, 2022; Unaenah et al., 2020; Demir et al., 2023), but there has not been much research related to the initial identification of teacher knowledge that is not only related to mastery of geometry material but also teacher understanding of their students' abilities in geometry and the teacher's ability to teach it. (Ball et al., 2008) developed the Mathematical Knowledge for Teaching (MKT) framework, which represents various domains of teacher knowledge that support students' mathematics learning. Furthermore, (Yi et al., 2022) adopted the framework by focusing on the content of two-dimensional (2D) geometry consisting of Geometry Content Knowledge (GCK), which is related to teachers' understanding of geometric concepts, properties, and relationships between geometry topics. Then, Knowledge of Geometry and Students (KGS) is related to teacher knowledge about the development of students' geometric thinking, including students' thinking methods, general conceptions, and misunderstandings about geometric content. Lastly, there is Knowledge of Geometry and Teaching (KGT), which is related to teachers' understanding of various methods, materials, and activities that support students' geometry learning.

Based on this, this study will identify the knowledge of pre-service elementary school teachers by adapting indicators developed by Ball et al. (2008) and Yi et al. (2022). The indicators from Ball et al. (2008) are still explained generally in mathematics, while in this study, they have focused on the realm of geometry. Yi et al. (2022) have also conducted relevant research, but their research focused on two-dimensional geometry, while this research focuses more on three-dimensional (3D) geometry.

Research Methods

This research is qualitative descriptive research that explains the actual conditions without special treatment to the research subjects. The stages of this research are preparing research instruments, giving instruments to research subjects, and then analyzing the data. The subjects of this research were 32 Elementary School Teacher Education students who had taken lectures in their third year, and the students had obtained material related to 3-dimensional geometry for elementary school and van Hiele's geometry learning theory. The research data were obtained through a test using a test sheet instrument containing questions with four answer choices. The instrument focuses on Geometry Content Knowledge (GCK), Knowledge of Geometry and Students (KGS), and Knowledge of Geometry and Teaching (KGT) (Yi et al., 2022). In addition, it also focuses on the level of geometric thinking from van Hiele for levels 0 - 2 because elementary school teachers must be ready to teach geometry material at that level. The instrument used consisted of 15 questions with the division, as shown in Table 1.

Table 1. Distribution of question items

Sub-Scale	Item	Concept	Van Hiele Levels
GCK	1	Properties of prisms	1
	2	Properties of pyramid	1
	3	Properties of cube	1
	4	Properties of cuboid	1
	5	The relationship between a cube and a prism	2
	6	The relationship between a cuboid and a cube	2
KGS	7	Students' understanding of prisms	0
	8	Students' understanding of pyramid	0
	9	Students' understanding of the cube	1
	10	Students' understanding of cuboid	1
	11	Students' understanding of a cube and a prism	2
	12	Students' understanding of a cuboid and a prism	2
KGT	13	Prism learning activities	0
	14	Pyramid learning activities	1
	15	Cube and cuboid learning activities	2

Students at level 0 can recognize geometric shapes only from their appearance, not their parts or properties. At level 1, students begin to see the characteristics of shapes and identify their properties. At level 2, students begin to understand the reciprocal relationships of properties within shapes and between different shapes (Crowley, 1987). The instrument was validated using content validity by experts who are Mathematics Education Lecturers and Lecturers who have experience teaching Elementary School Mathematics courses for decades in Elementary School Teacher Education. Furthermore, the test results were analyzed descriptively, namely by displaying the percentage of correct and incorrect responses from respondents and then describing the response parts that were quite extreme.

Results and Discussion

The answers from the research subjects in percentage form are in Table 2.

Table 2. Recapitulation of research subjects' answers

Item	Percentage of Correct Responses	Percentage of Not Correct Responses
1	18,8%	81,3%
2	65,6%	34,4%
3	68,8%	31,3%
4	34,4%	65,6%
5	18,8%	81,3%
6	37,5%	62,5%
7	43,8%	56,3%
8	53,1%	46,9%
9	31,3%	68,8%
10	59,4%	40,6%
11	62,5%	37,5%
12	25%	75%
13	43,8%	56,3%
14	40,6%	59,4%
15	31,3%	68,8%

The data in Table 2 provides information that the level of knowledge of prospective Elementary School teachers is still below 50%. For the GCK indicator, respondents who answered correctly only reached 40.6%, KGS 45.82%, and KGT 61.5 or even 38.5%. Furthermore, based on the data in Table 2, question items 1, 5, and 12 have the lowest percentage of correct answers. Item 1 is related to the properties of prisms as indicated by the question:

The correct conclusion for an arbitrary prism is

A. *There is always a pair of congruent, opposite sides, which do not have to be parallel.*
B. *The base side must always be a quadrilateral.*
C. *The vertical side must be a parallelogram.*
D. *The vertical side does not always have to be a quadrilateral.*

The question looks at students' abilities related to Geometry Content Knowledge (GCK) or their knowledge related to geometry material, which is by level 1 of van Hiele's theory. Only 18.8% of students chose answer option C, and this answer is appropriate because one of the properties that must be present in a prism is that the vertical side is a parallelogram, while the two base sides are parallel and congruent (Clements et al., 1984; Suryadinata & Linuhung, 2018);. Most of the students' answers lead to option A (62.5%) and the rest to B and C. Based on these answers, there is an indication that there are still misconceptions that occur in students regarding the concept of prisms. Students assume that the congruent, opposite sides or base sides do not have to be parallel, even though the sides in question should be parallel.

Next, question item number 5 is related to the relationship between cubes and prisms and is still in the Geometry Content Knowledge (GCK) section and at level 2 of van Hiele's theory with the question:

Consider the following two statements
Statement 1: Solid shape A is a prism
Statement 2: Solid shape A is a cube
The correct conclusion is
A. Statements 1 and 2 cannot both be true
B. If statement 1 is true, then statement 2 is true
C. If statement 2 is true, then statement 1 is true
D. If statement 1 is false, then statement 2 is true

The correct answer is C because if a solid shape is a cube, it certainly fulfills a prism's properties. However, only 18.8% of students answered C, most (50%) chose option A, and the rest chose B and D. For option A, a solid shape can be a prism and a cube at the same time.

The still quite extreme data is in question item 12, which is related to students' understanding of blocks and prisms and is part of the Knowledge of Geometry and Students (KGS) or knowledge about students' geometry abilities. The question is at level 2 of van Hiele's theory. The questions asked are:

Ms. Ana has a student named Rudi who has achieved Van Hiele's geometric thinking ability level 2 (informal sequencing or deduction). If Rudi observes two objects as a cuboid and a prism, Rudi might give the following conclusions, except

A. *A Cuboid is a unique form of prism, but a prism is not necessarily a cuboid*
B. *Cuboids always have rectangular bases and roofs, while rectangular prisms can have other rectangular bases, such as squares or parallelograms.*
C. *The formula for the volume of a cuboid* $\boldsymbol{V} = \boldsymbol{p} \times \boldsymbol{l} \times \boldsymbol{t}$ *is a unique application of the general formula for the volume of a prism V = Base area × height, where the base area of the cuboid is* $\boldsymbol{p} \times \boldsymbol{l}$
D. *All angles on a cuboid are right angles, while a rectangular prism does not always have right angles.*

The question is how pre-service teachers can determine elementary school students' geometric thinking level by the level of van Hiele's theory. Of the answer choices, option C should not be appropriate for students at level 2 because if students can already conclude the general formula of a prism based on its properties, then they have reached level 3. This makes it possible that students cannot fully apply van Hiele's geometric thinking level to elementary school students.

Furthermore, in other question items, most were still below 50% who answered correctly. Only five questions, which were above 50%, were answered correctly by students. This shows that there are still misconceptions and ignorance of students about how to teach geometry to elementary school students, which are associated with van Hiele's theory. Another misconception related to geometry material (GCK) is related to blocks; students prefer the answer "cuboid must have six congruent square sides" rather than choosing the answer "all sides do not have to be congruent." Misconceptions also occur due to the relationship between cuboids and cubes. Many students (62.5%) still cannot conclude that a solid shape is a cube and can also be called a cuboid.

The difficulties experienced by students are also in the section on differentiating van Hiele's geometric thinking levels for students at level 0 (question number 7) and level 1 (question number 9). Meanwhile, related to Knowledge of Geometry and Teaching (KGT) or knowledge about how to teach geometry, which consists of 3 question items, students are also still below 50%, although not as small as the percentage in other question items, and the smallest percentage is in question item number 15, namely:

> *Joni observed and concluded, "All cubes can be called cuboids, but not all cuboids can be called cubes."*
> *Based on Joni's level of thinking, the most appropriate learning activities for Joni are as follows: EXCEPT ...*
> *A. Arranging formal evidence that shows that a cube is a special cuboid.*
> *B. Identifying objects around that have a shape like a cube or cuboid*
> *C. Identifying the surface area and volume of cubes and cuboids*
> *D. Solving contextual problems related to cubes and cuboids*

Based on the answer choices, of course, the one that is impossible to do is option B because students have reached the conclusion regarding the relationship between cubes and cuboids, meaning that they have understood in detail the properties of the two solid shapes and can connect the related properties, so students should enter learning that hones thinking skills at levels 2, 3 and even 4. However, only 31.3% of students chose B, and the others were spread to options A, C, and D. This can be caused by the research subjects still having difficulty distinguishing between levels of thinking, according to van Hiele's theory. This knowledge is quite essential to use in implementing geometry learning because it can improve students' geometry learning outcomes (Sasmita et al., 2013; Lasmita et al., 2014).

The data collected and analyzed in this study still has limitations because it is only displayed descriptively and based only on student responses when choosing

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answers to each question. However, the data provides an overview that prospective elementary school teachers still have misconceptions and difficulties teaching geometry material, especially in 3-dimensions. From GCK, KGT, and KGS, respondents generally know 50%. This finding is also by the conclusions of Renanda, et al., (2023) that before the learning process was carried out using a constructivist approach, students' geometric thinking abilities were at level 1 to level 3. Student difficulties can be due to internal factors such as student interests, talents, and intelligence as well as external factors such as the use of learning methods from lecturers who have not adjusted to student abilities (Novita et al., 2018).

This finding certainly needs to concern various groups, including lecturers tasked with teaching courses related to elementary school mathematics learning. Lecturers must ensure that students truly understand and master the material primarily associated with geometry and how to teach it. According to Armah & Kissi (2019), most lecturers cannot guide students as prospective teachers to determine the properties of geometric shapes because lecturers do not assign several practical activities to students. In addition, students' geometric thinking level is still weak at a certain level because the previous level was inadequate (Kandaga et al., 2022). However, effective geometry teaching must be aligned with students' geometric thinking levels, which can be accelerated with appropriate teaching activities and materials (van de Walle et al., 2016).

Conclusions and Suggestion

Based on the study results, pre-service elementary school teachers still have misconceptions about the concept of 3-dimensional geometry. These misconceptions are about the properties of prisms and the relationship between prisms, cuboids, and cubes. In addition, most prospective teachers have not been able to understand and distinguish examples of the application of van Hiele's geometric thinking levels at level 0, level 1, or level 2. Another impact is that prospective elementary school teachers still have difficulty determining what kind of geometry learning activities they should provide students.

This study is only limited to the initial and essential identification of pre-service teachers' knowledge related to 3-dimensional geometry learning. Further research can deepen it by adding more and more varied question items so that it can be a tool to measure the level of knowledge of teachers or pre-service teachers about geometry, especially 3-dimensions.

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