

Level of Geometric Thinking Using Van Hiele Test Among Grade 10 Students and their Conceptual Understanding

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Abstract

Geometry is more than just shapes- it is a powerful tool that helps students connect abstract mathematical concepts to the physical world, enhancing their reasoning, creativity, and readiness for future careers. At the secondary level, students are expected to demonstrate a deeper understanding of geometric concepts and relationships. And it is important to assess whether students are developing appropriately in their geometric thinking and conceptual understanding. This study was focused on assessing the geometric thinking based on frameworks such as the van Hiele model and conceptual understanding of geometry among Grade 10 students of private schools within Mindanao State University-Main Campus. A correlational research design was applied. The Van Hiele Geometry Test was first administered to determine the geometric thinking level of the students, while the Conceptual Understanding Test also was administered to determine the performance of the students in geometry

conceptually. Then, the two variables were correlated to identify whether the geometric thinking level and conceptual understanding of the students have a significant relationship. The result of the assessment based on the Van Hiele model of geometric thinking reveals that the majority of the students (75.1%) are at Levels 3 to 5, showing advanced geometric thinking skills. And only a small group (24.7%) remains at the lower levels (1 and 2). The study also revealed that there is a significant relationship between the geometric thinking level and the conceptual understanding of the students. It illustrates that the knowledge of the participants based on geometric thinking coincides with their conceptual understanding. Hence, the researchers recommended that further studies should be implemented to identify the geometric thinking level and conceptual understanding of the students in other ways such as actual solving, through interviews, and other intervention.

Keywords: *Geometry, Geometric Thinking, Conceptual Understanding, Assessment, Van Hiele Geometry Test*

INTRODUCTION

Mathematics is commonly known as one of the most challenging subjects among all subjects but it is also one of the important as it is part of peoples' lives. People use mathematics in everyday life such as buying groceries, measuring ingredients, and even walking on the sidewalks uses mathematics. Learning mathematics is not just all about computing, solving, analyzing, and measuring, it also requires the process of thinking and understanding. Geometry is one of the branches of mathematics that deals with the properties, relationships, and measurement of space such as shapes, angles, distance, and relative position of figures. Geometry is visible in real life such as using navigation and maps to calculate distance and plan efficient paths, constructing bridges and houses, and even making a better shot in playing basketball. By assessing the geometric thinking and conceptual understanding of the students, people can assess, evaluate, and correlate the geometric thinking level and the conceptual understanding of the student's learning and prior knowledge in geometry.

Improving Filipino students' skills in mathematics, linguistics, and science to further exhibit competence in the global job market was stated as a goal of K-12 education, according to DepEd Tagbilaran. Furthermore, the DepEd promised that these strands would not sacrifice higher quality education. K-10 mathematics is a skills-based course. Numbers and number sense, geometry, algebra, patterns, measurement, statistics, and probability are all included in the K-10 curriculum. It includes geometric models and proofs, spatial visualization, reasoning, and the characteristics of two and three-dimensional figures and their interactions. Vector, transformational, and coordinate perspectives that employ both inductive and deductive reasoning are covered in high school geometry classes. As a result, junior-level geometry discussion should not be limited to formal deductive reasoning and basic measurement exercises. Additionally, topology, analytic geometry, and geometric transformations should be studied (K -12 Mathematics Curriculum Guide, 2016).

According to Pierre Van Hiele (1959), a system of relations is a separate construct that has nothing to do with a child's prior experiences. This indicates that the students were simply taught what was required of them. The majority of the time, students are not taught how to use knowledge in real-world situations. According to UAD (2018), students' conceptual grasp of geometry was extremely weak. As a result, students are mostly meant to avoid geometry-related courses due to their extremely low geometric thinking skills and level. Thus, a study that looks into students' geometric thinking proficiency could assist them in gaining consistent knowledge from the geometric thinking proficiency leveling. They could also see the level they had already mastered or were still working on.

In a study conducted by Meng and Idris (2012), they worked on a case study research design using a purposive sampling method. Their study was to explore geometric thinking and the achievement of students in solid geometry and whether it could be improved by conducting phase-based instruction. In their study, they selected eight students from a class who had a mixed ability from one another. During the intervention, they used a manipulative using a Geometer's Sketch Pad (GSP) constructed on Van Hiele's theory. The result presented in their study, from the intervention using their technique could enhance the students' geometric thinking as well as their achievement in terms of solid geometry.

Moreover, based on the outcomes of the research study conducted by Sulistiowati et. al (2018), conducted in Indonesia, they concluded in their research that from the 40 students that were given a Van Hiele geometry test, 30 of them were at level 1 (recognition), 8 of them were at level 2 (analysis), 2 of them were at level 3 (order) and none of them have reached level 4 (deduction) and level 5 (rigor). The result of their study revealed that the students' Van Hiele level and their geometry skills have a significant relationship.

The objective of the study was to reveal the geometric thinking level and the conceptual understanding of the participants based on their learning of geometry. There is a need to study to relate the two to perceive if the mastery of the students in geometric thinking coincides with their learning conceptually. With this, the study would not only benefit the researchers, but it can also benefit the educators which can help them know what to improve and how to assess their students. As for the students, they would know at what level they had surpassed or failed. Also, this will serve as a call or reference that there is a way to guide the students by having the step-by-step on the geometric thinking of students and also their learning of geometry conceptually. Hence, the researchers find it interesting and there is a need to study the geometric thinking of the students and if they learn in their geometry class conceptually.

Review of Related Literature

This section presents the various related literature and studies reviewed for the present research.

Related Literature

Related literature is composed of a discussion of principles and facts to which the present study is associated. The following are relevant review of the literature for geometric thinking and conceptual understanding.

Geometric Thinking

Van Hiele's (1986) approach identifies five hierarchical and sequential levels of geometric cognition. Students at the first level are viewed completely by their appearance. "Because it looks like one" is a common response when questioned to describe why a given quadrilateral is a square. Students may also identify a square with other well-known objects that share a square. At a second level, it can be recognized by a "laundry list" of characteristics, but there are no connections between these features or to other similarly situated. Students view figures that are related to one another based on their qualities at the third level. In addition, the students may begin to understand how a single figure could be called by multiple labels if they have similar features, as a rectangle is a square but a rectangle is not always a square. Deductive reasoning and proofwriting develop significance and worth in the fourth level. With the limited amount of information, students may define and limit things. The capacity of students to switch between geometric and develop beyond a single axiomatic system characterizes the fourth level.

According to Van Hiele, another important aspect of the theory was the levels were distinct and that progressing from one level to the next required a "jump" rather than a steady process. A "crisis of thinking" was required before a student could advance to a new level, according to Lawrie and Pegg (1997). Moreover, because students working at differently, the discontinuity of the levels creates communication issues in the classroom.

There is no guarantee that these five levels correspond to a particular age range. A significant aspect of mathematical reasoning, according to Van Hiele's model, is that a student's age does not always correspond to an increase in their ability of reasoning. A student's advancement through the stages is primarily reliant on their instruction (Jaime & Guitierrez, 1995). Furthermore, it is not possible to skip a level for kids to truly learn. Unfortunately, it has been noted that when pupils are forced to use rote memorization rather than working at the proper higher level, educators may feel guilt of "level reduction" (Clements & Battista, 1992). Learners are trying to reminisce rather than reflect on what their teacher has conveyed to them. Thus, it seemed to be generally at a recollection or knowledge level, when geometry was taught.

Additionally, these levels altered somewhat since their development (Pegg and Davey, 1998). These levels were initially numbered from zero to four as originally proposed by Van Hiele. Researchers have recognized a need even beyond the introductory level, since then. Senk (1989) notes that Van Hiele has no level “below 0” as Van Hiele claims that everyone is at least at Level 0. His subjects were secondary students, which was a challenge. Since then, other researchers have attempted to apply the paradigm to elementary school students as well. Van Hiel and several other researchers have modified a new approach that renumbered the levels one to five to account for these students instead of classifying them as below level 0. Therefore, a student who was previously below level 0 and not at the first level was suddenly given level 0. Both numbering schemes will be provided appropriately for each study, as they have been utilized throughout the Van Hiele model research.

Hence, the model of Van Hiele has shown a reliable framework for characterizing also evaluating learners’ geometric knowledge and development as well as for creating activities that are appropriate for that level (Jones, 2003; Van de Walle et al., 2019). A teacher can determine where students are operating and where they should go next if they know what Van Hiele level the student is (Lim, 2011).

Conceptual Understanding

Conceptual understanding is one of the mathematical learning that some authors believe is essential to successful learning. Kilpatrick, Swafford, & Findell (2001) define it as the ability to relate mathematical concepts and understand their interconnectedness manner into a logical structure of operations, relations, and concepts. The ability of students to internalize concepts and make deductions from them is known as a conceptual understanding. It also relates to the ability to strategically apply them to learn new ideas and solve difficulties. Enabling students to experiment while guiding and motivating them to solve various geometry-related mathematical problems requires familiarity with basic math operations, which the students must then apply to answer the difficulties.

The procurement of conceptual understanding and technical confidence are key components of an effective teaching of mathematics. According to the National Research Council (2001), studying mathematics requires a balanced and integrated development of concepts and techniques. Furthermore, emphasized by the NCTM (1989; 2001) stressed that conceptual understanding, problem-solving, and strategic reasoning serve as the foundation for procedural fluency.

Related Studies

These are various studies about geometric thinking and conceptual understanding that were conducted and are related to the present study.

Geometric Thinking

A study conducted by Meng and Idris (2012) used a purposive sampling technique to develop a case study research design. The idea of their intervention was to conclude whether phase-based training may well improve students’ geometric thinking and proficiency in solid geometry. Eight (8) students from a class with a range of abilities were chosen for their study. They employed a Geometer’s Sketch Pad (GSP) as a manipulator during the intervention. According to their study’s findings, the intervention utilizing their method could improve the geometric thinking and solid geometry proficiency of students.

Moreover, a controlled group and an experimental group were included in the pretest-posttest design employed in the study of Purisima J. Yap (2014). The study aimed to conclude whether or not the spatial activities helped students become more proficient in geometric reasoning. From its findings, level 1 was the only significant post-test result among the third-year students who participated. It shows that each level was obtained at low to high levels in the control group. While in the experimental group, achieved

modest to complete achievement at every level. This indicates that the participants' level of reasoning has increased, rising to level 2 from the control group and level 3 and level 4 from the experimental group. This could imply that the study concluded that these kinds of exercises could raise the students' degree of geometric thinking.

Fitriyani, Widodo, & Hendroanto, (2018) conducted the same related studies. Their study was to identify the improvement of the learners by their geometric thinking level, where Van Hiele's theory is the basis. Accordingly, most students are still at the analytic analytic level. The findings revealed that there were 20% at the pre-analyze level, 13.44% were at the pre-informal deduction level, 6.45% were at the pre-deduction level, only 1.08% were at the pre-rigor level, and there were 4.3% of them that cannot be identified which level are they belong.

In the same year, according to Sulistiowati, Herman, & Jupri (2018), the level of geometric thinking of the learners therefore not only plays a role in geometry when they achieve it. This means that it has a major function in learning. In their study, they administered the Van Hiele Test, and then it was followed by an interview. The findings revealed that those students who have reached level 3, have also mastered the lower level of geometric thinking which was at level 0 to level 2. The researchers suggested that the teachers, specifically those teaching mathematics/geometry, should provide more practice problems to ensure the improvement of the students' geometry skills.

In the study, conducted by Demir, Ilhan, and Sevgi (2023), the Van Hiele Geometry Test and a Circle Achievement Test were directed to the participants of the study and these were correlated to identify their significance. Independent group t-test and ANOVA were performed after the data gathering and it revealed to as the researchers' assumptions were met. It was revealed from the findings that participants' levels in Van Hiele's geometric thinking were lower than they expected. It was found to be a moderate relationship between the Van Hiele test and the Circle Achievement test. Moreover, it revealed a statistically considerable mean difference across the sample schools from the Van Hiele test, while in the Circle Achievement test, there is no statistically considerable mean difference.

In a study conducted by Hadjinor and Buan (2022) where the participants were (20) Grade-10 students from Section 1 of the school year 2021-2022, were divided into two groups; the (10) learners comprised the Culture-Based Lesson Group (CBL Group) and the (10) learners comprised the Culture-Based Lesson with design thinking activity group (CBLDT Group). The participants perform a posttest and pretest to reveal their level. As for the result, the learners in the CBL group reached Level 2, Level 1, and Level 0. In the CBLDT group, one of the learners reaches Level 4, the highest level. The study suggested that activities can be an effective tool for teachers, especially those teaching geometry, in improving their students' geometric thinking abilities.

In the same year, a study was conducted by Angelina P. Lumbré, et. al. (2023) using a non-experimental quantitative correlational approach. The researchers examined the Van Hiele level of thirty (30) mathematics teachers teaching ninth grade and the geometry achievement of 1,489 students. The findings revealed that there was a significant difference with a significant effect size of .64 between the achievements of students whose teachers are functioning at level 5 in the Van Hiele Levels of Geometric Thinking as it highly correlated to student achievement. The study suggested that a more thorough investigation into other mathematical concepts and abilities might be conducted to evaluate their relationship to teachers' Van Hiele levels and students' academic performance.

However, the results of the study conducted by Handan D. & Kudret H. (2022) show that none of the sixteen (16) participants are at Level 0 and 6 of them were seen at Level 1. It was also observed that there were 3 learners at Level 2, 6 learners at Level 3, and 1 learner obtained at Level 4. Hence, it concluded

from the Van Hiele Geometry Test outcome, that the geometric thinking level of the majority of participants, are at the required level.

Conceptual Understanding

The study conducted by Disomangcop, A.F. (2020), entitled “Developing Conceptual Understanding Using Exploratory Approach Solving Rational Numbers” attempted to assess the efficiency of the exploratory approach in teaching rational numbers. The participants of the study are forty-eight (48) Grade-six pupils of Mindanao State University – Integrated Learning School, which was given a researchers-made questionnaire as a research instrument to test the pupils’ conceptual understanding using the exploratory approach in solving rational numbers. The researchers-made questionnaire consisted of two parts with a reliability coefficient of 0.803. A pre-test took place before the intervention and a post-test followed right after the intervention, to examine if there was an improvement. From the result, most students had a qualitative description of good, which measures that the conceptual understanding of the participants improved. It revealed that from the pre-test and post-test of the students, there is a significant difference in their scores. The findings of the study suggest that the function of the exploratory approach positively guided the development of a conceptual understanding of rational numbers.

In the study conducted by Abdulrahman and Samad (2021), the objective of their descriptive-correlational research was to evaluate the students’ analytic abilities and conceptual understanding of learners in terms of general mathematics under modular teaching. The participants are one hundred forty-two (142) learners that are from two (2) national high schools in Lanao del Sur, Philippines, which tested their analytical thinking and conceptual understanding in terms of general mathematics. The researchers adapted a questionnaire consisting of five multiple-choice items, from a variety of sources that was created using a two-way Table of Specification (TOS) that was aligned with the DepEd-MELC Curriculum. The conceptual understanding of the participants was likewise below average to poor. Conceptual understanding and analytical thinking were found to be correlated, which is not surprising given that they are both cognitive processes that the students must develop to improve their learning.

Students were to gain both theoretical and procedural understanding of fraction and decimal ideas from Appleton’s (2012) study, entitled “Conceptual understanding of fractions and decimals for fourth-grade students”. The study’s findings demonstrated the importance of giving students the time and resources they need to understand the unknown. Therefore, students require experience that will enable them to develop into flexible thinkers who can identify the best possible solution strategy. For this reason, it is important to support instructional practices in mathematics classrooms that help students develop their thinking skills so they can improve their deeper learning of mathematics throughout their academic careers and beyond.

These studies and works of literature regarding geometric thinking and conceptual understanding helped the researchers to find out what to study. They have found these research gaps and it interests them and thought that it is something to study also geometric thinking and conceptual understanding. The researchers find it interesting to study the geometric thinking level and conceptual understanding of the learners in Marawi City. Also, they thought of correlating the variables to find if the two have a significant relationship. So, in this study, the researchers conducted a test questionnaire to evaluate the learners’ geometric thinking level and conceptual understanding of geometry.

Statement of the Problem

The study seeks to evaluate students’ geometric thinking and conceptual understanding in geometry of Grade 10 students of private schools within Mindanao State University – Main Campus.

Specifically, it sought to answer the following questions:

1. What is the students' level of geometric thinking?
2. What is the students' performance on conceptual understanding?
3. Is there a significant relationship between the students' level of geometric thinking and conceptual understanding?

Null Hypothesis

The following assumption of the study was tested at a 0.01 level of significance.

H_o : There is no significant relationship between the Geometric Thinking level and the Conceptual Understanding scores of the participants of the study.

METHODOLOGY

Research Design

This research applied a quantitative approach, specifically correlational research design. It was applied to gather data, from students that were in a specified target schools which provided the possibility to conclude the certain problem. This design was used by conducting a survey in a form of a test questionnaire for both geometric thinking level and conceptual understanding. Then correlate the two variables statistically to determine if these have a significant relationship. It corresponded to the eighty-five (85) Grade-10 students of private schools within Mindanao State University – Main Campus: Miftahus Salam Integrated Academy, Philippine Engineering and Agro-Industrial College, Inc. (PEACI), and Al-Biruni International Academy (Albia).

The researchers used a researchers-made test questionnaire for the conceptual understanding, and an adapted test questionnaire for the geometric thinking level to gather the data needed that convince the research problem. Conducting a test questionnaire for this is relevant in this kind of research. Wherein, the researchers based on the answers of the participants to expand and develop the study. The researchers, in this way, can perceive, evaluate, read, and explain the findings of the assessment which would improve the study. This research was intended to evaluate the level of the learners' geometric thinking level and conceptual understanding of geometry.

Participants of the Study

Researchers used a purposive sampling method to conduct this study. This method was used for Grade 10 students who were chosen because they had learned geometry from their previous year level which is what the study needed to determine. Participants are selected subjects on the aim of this study is to answer the research problems as well as accomplish the objective of this study. The overall number of students who participated in the study was eighty-five (85). The following table displays the names of the private schools within MSU- Main Campus with its total number of Grade-10 learners.

Instruments and Its Validity

In determining geometric thinking level and conceptual understanding of the learners in geometry, some instruments were used, to wit:

Van Hiele Geometry Test. This test questionnaire was adapted from Dr. Usiskin (1982), which he used in his study providing that the test questionnaire would not be reformed nor improved. This test instrument is made of twenty-five (25) multiple-choice questions with provided space for solutions on the right side of the answer sheet if necessary. The test questionnaire was released to evaluate students' Van Hiele levels on geometric thinking. This test questionnaire includes identifying of shapes and figures at

Level 0, properties of figures at Level 1, identifying the relationships of figures at Level 2, proving at Level 3, and understanding and comparing axiomatic systems at Level 4.

Conceptual Understanding Test. This is a researchers-made test questionnaire composed of twenty-five (25) multiple-choice type of question. This test instrument was pilot tested with fifty (50) number items and a reliability Cronbach's alpha of 0.713 from Grade-10 students of RC-AI Khwarizmi International College, SLS, to ensure its validity and reliability. Though they do not have the same curriculum as what the schools of the participants were using, but what the researchers considered was that the students of both the pilot testers and the participants have a learning and knowledge regarding geometry, that the schools have geometry class. This test questionnaire was in lined with high school geometry such as represents points, lines and planes by concrete and pictorial models, classifies the different kinds of angles, using compass in measuring, illustrates polygons, illustrates a circle and the terms to it, solves problems involving sides and angles of a polygon, solves corresponding parts of congruent triangles, and uses properties to find measures of angles, sides and other quantities involving parallelograms.

Data Gathering Procedure

Before the researchers administered the test questionnaires to the target participants, they first prepare everything that they would need. They first asked permission to Dr. Usiskin, owner of Van Hiele Geometry Test, to adapt the test questionnaire. As for the Conceptual Understanding Test, it runs first in validity and reliability to ensure that the researchers' made-test could be operated in gathering the needed information.

After these, researchers asked permission to the school heads of the target schools to conduct the test questionnaires to their Grade-10 students. After the permission was granted, the researchers conducted first the Van Hiele Geometry Test. The following month, Conceptual Understanding Test was conducted.

The adapted and researchers-made test questionnaire was distributed by giving copies of the Van Hiele Geometry Test questionnaires as well as the conceptual understanding questionnaires to be answered in the answer sheet by the target participants by the use of paper and a ball pen. The Van Hiele Geometry Test questionnaires have a sequence which was divided into five parts, every part has a different level of solving and each question has a corresponding question to test the participants' conceptual understanding. The outcome of their responses then compiled, tabulated, and analyzed to completely comprehend the study. The study intended to have been clarified to the participants and have been assured of the confidentiality of any data they provided.

Data Analysis Procedure

Rubrics. This is an adapted rubric that was used as a basis for the level of the learners in Van Hiele Geometry Test. The levels were Level 0 to Level 4 and the descriptors for every level are provided in the rubric as shown in Table 3.3.

Table 3.3
Geometric Thinking Level Rubrics with its Description

Geometric Thinking Levels	Description
Level 0	Recognition: The student can learn names of figures and recognizes a shape as a whole.
Level 1	Analysis: The student can identify properties of figures.
Level 2	Order: The student can logically order figures and relationships, but does not operate within a mathematical system.
Level 3	Deduction: The student understands the significance of deduction and the roles of postulates, theorems, and proof.
Level 4	Rigor: The student understands the necessity for rigor and is able to make abstract deductions.

General descriptions and examples from Hoffer (1979)

The subsets of the Van Hiele Geometry Test were, Level 0 – item 1-5, Level 1 – item 5-10, Level 2 – item 11-15, Level 3 – item 16-20, and Level 4 – item 21-25. According to the recent study conducted by Hadjinor (2022), from what Usiskin developed which was known as “3 correct of 5” method, this means that if a student scored at least 3 out of 5 items correctly in any of the subsets of the Van Hiele Geometry Test, the student was considered to have mastered the level.

This rubric was categorized into 5 levels. First, level 0, the student is said to be in this level if he/she can recognize and name the figures/shapes. In level 1, the student is said to be in this level if he/she would be able to identify what property the shape is. At level 2, a student is said to be in this level if he/she can recognize or determine the relationship between a shape and of another different shapes. At level 3, a student is said to be in this level if he/she recognizes the importance of deduction and the functions of postulates, theorems, and proof. Lastly, at level 4, a student is said to be in this level if he/she understands how significant the accuracy of the basic principles in a proof.

A Scaling Guide. It was used to reveal the participants’ standing in the Conceptual Understanding Test. The scaling was excellent, very good, good, fair/satisfactory, passing, and failed. This scaling guide was adapted from the new DepEd Transmutation Grade Table.

Table 3.4
Conceptual Understanding Test Scaling with its Description

Conceptual Understanding	Description
98 and above	Excellent
93-97	Very Good
87-92	Good
81-86	Fairs/Satisfactory
75-80	Passing
74 and below	Failed

This scaling guide was based on the transmuted grade with its descriptions and was used to rate the students' performance from the Conceptual Understanding Test. Table 3.4, a student failed the test if he/she got 74 and below of grades. A student got a passing score if he/she got 75-80 and fair/satisfactory if they reached 81-86. A student is said to be performed good in the test if he/she got 87-92 and very good if he/she got 93-97. Lastly, a student excels the test if he/she got 98 and above of grade.

Statistical Tools and Instrument

Frequency and Percentage. This was used to illustrate the participant's geometry performance and scores in geometric thinking test as well as in conceptual understanding test.

Mean and Standard deviation. These were applied to reveal and categorize the participants' level of geometric thinking and conceptual understanding based on the gathered data. These were also used on the reliability testing the Conceptual Understanding test.

Spearman's Rho. This was used to measure and reveal whether the geometric thinking level and conceptual understanding of the participants has a relationship and to perceive if the surveyed test has a considerable difference.

Transmutation of Grade. This was adapted from the new DepEd Transmutation Grade Table to identify the participants' score in Conceptual Understanding Test.

$$\text{Formula for Transmuted Grade: } \frac{\text{Raw score}}{\text{Total score}} \times 50 + 50$$

RESULTS AND DISCUSSION

Presentation, Analysis, and Interpretation of Data

This part reveals the findings, statistical analysis, and explanation of the findings based on the test questionnaires' data.

I. Participants' Level of Geometric Thinking

This part presents the respondents' level of geometric thinking.

Table 4.1
Frequency & Percentage Distribution Table for Geometric Thinking Level

Level of Geometric Thinking of the Participants	Frequency	Percentage
Level 0	7	8.2%
Level 1	14	16.5%
Level 2	20	23.5%
Level 3	21	24.7%
Level 4	23	27.1%
Total	85	100%

Table 4.1 revealed the participants' level of geometric thinking. As shown, only 7 or 8.2% of them are in level 0, which means according to Usiskin's test corresponding to Van Hiele's model of geometric thinking that they can recognize the shapes and they learn the names of figures. Followed by level 1 where 14 or 16.5% of the participants, according to Usiskin's test corresponding to Van Hiele's model of geometric thinking, can classify the properties of the figures. 20 or 23.5% of the participants are said to be in level 2, which means that these students are at the level where they can reasonably order figures or shapes and their connections, but they do work containing mathematical systems. 21 or 24.7% are said to be in level 3, which means that they understand the significance of the roles of postulates and deduction, proof, and theorems. Then, a few of the participants, or 27.1% of them are said to be in level 4 of geometric thinking, which means that these learners were successful at composing proofs independently. From these results, this means that most of the participants are in a high level of geometric thinking.

This result may support the findings from the study of Handan D. and Kudret H. (2022). Their study has 16 participants, which are Grade 8 students of a private school in Sivas. Its results to none of the students are in Level 0, which supports the current study where few of the participants are in Level 0. In their study, six students were at Level 1. According to studies, these students' understanding and interpretation of geometry are low. It was observed in the study that there were 3 students at Level 2, 6 students at Level 3, and 1 student at Level 4. The Van Hiele geometric thinking levels of these 10 students which are at level 2 to level 4 are at the required level. This may be used as proof for the current study that most of the participants are at their required level in geometric thinking. Also, since the participants of the study are in their 8th grade, it may support the current study where the participants are already in their 10th grade which is in higher level of grade.

The findings of the study of Hadjinor and Buan (2022) may also support the result of this study. Grade 10 students were also the participants in his study. In comparison, the current study gained a higher level from the geometric thinking level than from the participants of the study of Hadjinor (2022). This may be because the participants from his study were facing challenges during the pandemic, while the participants of this current study may have focused on answering the test as they were not worrying about any circumstance.

II. Performance of the Participants in the Conceptual Understanding

This portion confirms the performance of the participants in the Conceptual Understanding Test.

Table 4.2

Participants' Performance in the Conceptual Understanding Test

Raw Scores	Transmuted Grade	Frequency	Percent	Mean Rating	Qualitative Description
10	70	8	9.4		
11	72	4	4.7		
12	74	4	4.7		
13	76	8	9.4		
14	78	12	14.1		
15	80	13	15.3	14.988/79.976	PASSING
16	82	12	14.1		
17	84	7	8.2		
18	86	7	8.2		
19	88	5	5.9		
20	90	3	3.5		
21	92	1	1.2		
22	94	1	1.2		
Total		85	100.0		

Scaling: 98 and above – Excellent
 93-97 – Very Good
 87-92 – Good
 81-86 – Fairs/ Satisfactory
 75-80 – Passing
 74 and below – Failed

The conceptual understanding test was administered after its validity and reliability. As shown, there were only 16, or 18.8% failed the test. However, there are 33, or 38.8% got a passing score, 26, or 30.5% got a fair/satisfactory score, 9, or 10.6% got a good grade, and only 1, or 1.2% got a very good grade. There was a mean score of 14.988 or 79.976% which is described as passed. Though the result indicated that most of the participants passed the test, a few of them, or 15.3% got a grade of 80 and a grade of 78, and 82 have 14.1% from the participants, which also indicates that none of the participants got an excellent score. Therefore, the test results indicate a generally successful outcome with the majority of participants achieving a passing grade as the result shows.

According to Ningrum, Usodo, and Subanti (2021), conceptual understanding encompasses the capacity to enhance, communicate, and characterize information in problem-solving, it is also a skill that students should master when learning geometry as a foundation for solving math problems or related difficulties. This supports the findings from the study of Appleton (2012), in which the study concluded and accordingly, student needs experiences that may help them become flexible to identify strategies for solving and becoming a thinker should also be encouraged in instructions inside the classroom, so that students may gain a deeper understanding of mathematics, especially in geometry throughout their school career. The participants of their study were fourth-grade students. This means that the participants in the current study, who are already in tenth grade, have acquired a deeper understanding of geometry based on their performance on the Conceptual Understanding Test.

III. Relationship between Students' Geometric Thinking Level and Conceptual Understanding Test

This part exposes the relationship between students' geometric thinking level and conceptual understanding test.

Table 4.3
Significant Correlation of the Participants' Geometric Thinking Level and Conceptual Understanding

	N	Correlation Coefficient	P-value	Interpretation	Action Taken
Conceptual Understanding	85	0.572	0.000	Significant	Reject Null Hypothesis
Geometric Thinking					

**Correlation is significant, tested at 0.01 level (2-tailed)*

Correlation analysis was performed using Spearman Rho to determine whether the students' geometric thinking level and conceptual understanding are associated with each other. As shown, the p-value 0.000 is less than the level of significance at 0.01, which means that the variables have a significant relationship. This suggests sufficient evidence to show the potential relationship between geometric thinking level and performance in the conceptual understanding of the learners.

Geometric thinking level and performance in conceptual understanding may influence each other as evidenced by the majority's good performance, founded on the scores and levels of the students from the tests. This study was to correlate the geometric thinking level and conceptual understanding of the students in a form of a multiple-choice test by only having their previous knowledge and learning. Jerome Bruner's Discovery Learning theory could serve as a theoretical guide where students illustrate their past understanding and learning and present education to determine facts and connections and new truths to be learned in which participants answered the test thinking and recalling their past learning in geometry. Reflective Learning Theory could also serve as a theoretical guide for this, in which the students reflect on their past learning and knowledge in geometry while answering the tests, and from the result of their tests, they could reflect themselves where they miss on the levels.

The study of Abdulrahman, R. (2022) supports these findings. In their findings, there is a connection between the participants' analytic thinking skills and their conceptual understanding. These were found to be correlated, which is accordingly not surprising given that they are both cognitive processes

that the students must develop to improve their learning. This relates to the current study where both geometric thinking and conceptual understanding are important, in which a student cannot apply his/her understanding of geometry without the idea of spatial sense (geometric thinking).

The connection of geometric thinking and conceptual understanding of the participants in this study were correlated as these two related in a way that geometric thinking was based on the idea of spatial sense. Conceptual understanding is where the participants apply their understanding based on their learning in geometry. The main point was how can students apply his/her understanding of a certain thing when he/she has no intuitive feel towards it or he/she cannot recognize and visualize geometric shapes. The findings of this study illustrate that the knowledge of the participants based on geometric thinking coincides with their conceptual understanding.

IV. Participants' Level of Geometric Thinking

This part presents the respondents' level of geometric thinking.

Table 4.1
Frequency & Percentage Distribution Table for Geometric Thinking Level

Level of Geometric Thinking of the Participants	Frequency	Percentage
Level 0	7	8.2%
Level 1	14	16.5%
Level 2	20	23.5%
Level 3	21	24.7%
Level 4	23	27.1%
Total	85	100%

Table 4.1 revealed the participants' level of geometric thinking. As shown, only 7 or 8.2% of them are in level 0, which means according to Usiskin's test corresponding to Van Hiele's model of geometric thinking that they can recognize the shapes and they learn the names of figures. Followed by level 1 where 14 or 16.5% of the participants, according to Usiskin's test corresponding to Van Hiele's model of geometric thinking, can classify the properties of the figures. 20 or 23.5% of the participants are said to be in level 2, which means that these students are at the level where they can reasonably order figures or shapes and their connections, but they do work containing mathematical systems. 21 or 24.7% are said to be in level 3, which means that they understand the significance of the roles of postulates and deduction, proof, and theorems. Then, a few of the participants, or 27.1% of them are said to be in level 4 of geometric thinking, which means that these learners were successful at composing proofs independently. From these results, this means that most of the participants are in a high level of geometric thinking.

This result may support the findings from the study of Handan D. and Kudret H. (2022). Their study has 16 participants, which are Grade 8 students of a private school in Sivas. Its results to none of the students are in Level 0, which supports the current study where few of the participants are in Level 0. In their study, six students were at Level 1. According to studies, these students' understanding and interpretation of geometry are low. It was observed in the study that there were 3 students at Level 2, 6

students at Level 3, and 1 student at Level 4. The Van Hiele geometric thinking levels of these 10 students which are at level 2 to level 4 are at the required level. This may be used as proof for the current study that most of the participants are at their required level in geometric thinking. Also, since the participants of the study are in their 8th grade, it may support the current study where the participants are already in their 10th grade which is in higher level of grade.

The findings of the study of Hadjinor and Buan (2022) may also support the result of this study. Grade 10 students were also the participants in his study. In comparison, the current study gained a higher level from the geometric thinking level than from the participants of the study of Hadjinor (2022). This may be because the participants from his study were facing challenges during the pandemic, while the participants of this current study may have focused on answering the test as they were not worrying about any circumstance.

V. Performance of the Participants in the Conceptual Understanding

This portion confirms the performance of the participants in the Conceptual Understanding Test.

Table 4.2

Participants' Performance in the Conceptual Understanding Test

Raw Scores	Transmuted Grade	Frequency	Percent	Mean Rating	Qualitative Description
10	70	8	9.4		
11	72	4	4.7		
12	74	4	4.7		
13	76	8	9.4		
14	78	12	14.1		
15	80	13	15.3	14.988/79.976	PASSING
16	82	12	14.1		
17	84	7	8.2		
18	86	7	8.2		
19	88	5	5.9		
20	90	3	3.5		
21	92	1	1.2		
22	94	1	1.2		
Total		85	100.0		

Scaling: 98 and above – Excellent
93-97 – Very Good
87-92 – Good

81-86 – Fairs/ Satisfactory
75-80 – Passing
74 and below – Failed

The conceptual understanding test was administered after its validity and reliability. As shown, there were only 16, or 18.8% failed the test. However, there are 33, or 38.8% got a passing score, 26, or 30.5% got a fair/satisfactory score, 9, or 10.6% got a good grade, and only 1, or 1.2% got a very good grade. There was a mean score of 14.988 or 79.976% which is described as passed. Though the result indicated that most of the participants passed the test, a few of them, or 15.3% got a grade of 80 and a grade of 78, and 82 have 14.1% from the participants, which also indicates that none of the participants got an excellent score. Therefore, the test results indicate a generally successful outcome with the majority of participants achieving a passing grade as the result shows.

According to Ningrum, Usodo, and Subanti (2021), conceptual understanding encompasses the capacity to enhance, communicate, and characterize information in problem-solving, it is also a skill that students should master when learning geometry as a foundation for solving math problems or related difficulties. This supports the findings from the study of Appleton (2012), in which the study concluded and accordingly, student needs experiences that may help them become flexible to identify strategies for solving and becoming a thinker should also be encouraged in instructions inside the classroom, so that students may gain a deeper understanding of mathematics, especially in geometry throughout their school career. The participants of their study were fourth-grade students. This means that the participants in the current study, who are already in tenth grade, have acquired a deeper understanding of geometry based on their performance on the Conceptual Understanding Test.

VI. Relationship between Students' Geometric Thinking Level and Conceptual Understanding Test

This part exposes the relationship between students' geometric thinking level and conceptual understanding test.

Table 4.3
Significant Correlation of the Participants' Geometric Thinking Level and Conceptual Understanding

	N	Correlation Coefficient	P-value	Interpretation	Action Taken
Conceptual Understanding	85	0.572	0.000	Significant	Reject Null Hypothesis
Geometric Thinking					

**Correlation is significant, tested at 0.01 level (2-tailed)*

Correlation analysis was performed using Spearman Rho to determine whether the students' geometric thinking level and conceptual understanding are associated with each other. As shown, the p-value 0.000 is less than the level of significance at 0.01, which means that the variables have a significant relationship. This suggests sufficient evidence to show the potential relationship between geometric thinking level and performance in the conceptual understanding of the learners.

Geometric thinking level and performance in conceptual understanding may influence each other as evidenced by the majority's good performance, founded on the scores and levels of the students from the tests. This study was to correlate the geometric thinking level and conceptual understanding of the students in a form of a multiple-choice test by only having their previous knowledge and learning. Jerome Bruner's Discovery Learning theory could serve as a theoretical guide where students illustrate their past understanding and learning and present education to determine facts and connections and new truths to be learned in which participants answered the test thinking and recalling their past learning in geometry. Reflective Learning Theory could also serve as a theoretical guide for this, in which the students reflect on their past learning and knowledge in geometry while answering the tests, and from the result of their tests, they could reflect themselves where they miss on the levels.

The study of Abdulrahman, R. (2022) supports these findings. In their findings, there is a connection between the participants' analytic thinking skills and their conceptual understanding. These were found to be correlated, which is accordingly not surprising given that they are both cognitive processes that the students must develop to improve their learning. This relates to the current study where both geometric thinking and conceptual understanding are important, in which a student cannot apply his/her understanding of geometry without the idea of spatial sense (geometric thinking).

The connection of geometric thinking and conceptual understanding of the participants in this study were correlated as these two related in a way that geometric thinking was based on the idea of spatial sense. Conceptual understanding is where the participants apply their understanding based on their learning in geometry. The main point was how can students apply his/her understanding of a certain thing when he/she has no intuitive feel towards it or he/she cannot recognize and visualize geometric shapes. The findings of this study illustrate that the knowledge of the participants based on geometric thinking coincides with their conceptual understanding.

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