

INTEGRATION OF GEOGEBRA IN TEACHING GEOMETRY TO YEAR 5 PUPILS IN PRIMARY SCHOOL

UDIN, H. S.¹ – ISMAIL, N.^{1*} – ALHASSORA, N. S. A.¹

¹ Faculty of Social Science and Humanities, Universiti Teknologi Malaysia, Johor, Malaysia.

*Corresponding author
e-mail: p-norulhuda[at]utm.my

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Abstract. The TIMSS 2019 results indicated that 55% of Form 2 students in Malaysia struggle with learning geometry concepts. This quasi-experimental research aims to improve students' geometric concepts by developing a geometry learning module. The module integrates GeoGebra and aligns all five van Hiele Learning Phases in the learning activities. The learning activities in this module focus on building and developing basic concepts in geometric measurement such as perimeter, area, and volume. In this research, 50 Year Five students in Tawau District were divided into two groups: the experimental group (n=25) and the control group (n=25). The experimental group used the module while the control group was taught using a traditional teaching style. Pre- and post-tests were used in measuring their geometric thinking levels by referring to the first three van Hiele's Geometric Thinking Levels: visualization, analysis, and informal deduction. The data analysis showed a noticeable increase in geometry thinking levels in the experimental group. This showed that the usage of the geometry learning module integrated with GeoGebra was beneficial in helping pupils improve their learning rather than the traditional teaching style. In conclusion, using technology such as GeoGebra in learning activities can help students learn basic geometry concepts effectively.

Keywords: *van Hiele, geometry, learning module, measurement, GeoGebra*

Introduction

Geometry is one of the topics taught in primary school in Malaysia from Year 1 to Year 6. The mathematics curriculum for Kurikulum Standard Sekolah Rendah (KSSR) Semakan 2017 showed that the basic concept of shapes will be taught in Level 1 (Year 1 to Year 3). Level 2 students (Year 4 to Year 6) will be learning about polygon and measurement concept in geometry. The syllabus is arranged according to the developmental learning method where they will learn the easiest part first before the more complex part after that. The students are expected to understand and comprehend all the basic concepts before leaving their primary school. Unfortunately, the Trends in Mathematics and Science Study (TIMSS) 2019 result showed that 55% Form 2 students' achievement is in low achievement category. There are only 19% from the whole samples who achieved high and very high score. Even though the TIMSS result is taken from Form 2 samples, this showed how low their geometric understanding since they have learned it since Year 1. It is very concerning because they have already learned the basics of geometry in primary school and should be applied in their secondary school (Md Yunus et al., 2019; Tan et al., 2015).

GeoGebra in learning geometry

In this Industrial Revolution 4.0 (IR4.0) and Education 5.0 era, the usage of technology has become a must, especially in teaching and learning process (Miranda et al., 2021; Mian et al., 2020). There are numbers of dynamic geometry software (DGS)

such as Geometer’s Sketchpad, Sketchup and GeoGebra. These DGS should be use to attract student’s focus to learn geometry effectively (Yahya et al., 2022; Pereira et al. 2021; Young et al., 2018). Other than that, the usage of technology in teaching and learning geometry process can make it more student-centered by the hands-on activities (Noh and Abdul Karim, 2021). GeoGebra has been developed by Markus Hoehnwarter in 2001 (Azizah et al., 2021) by merging two mathematics disciplines which are geometry (Dewi et al., 2020) and algebra (Daulay et al., 2021; Tamam and Dasari, 2021). This software has been upgraded numerously by adding and improving more features in it (Widada et al., 2021; Hevko et al., 2020; Lavrentieva et al., 2020). There are many languages to be used in this software so that every teacher and student all over the world can use it without having language barrier problem (Kramarenko et al., 2022). This software also is free to use to learn not only geometry and algebra, but also many more like calculus and statistics (Ziatdinov and Valles Jr, 2022). The applet can be shared globally by using the GeoGebra website. Based on research made by Abdullah et al. (2020), students’ shows more understanding in learning concept and answering questions better after using GeoGebra in their geometry learning. The same result has been achieved by Mazlan (2020) and Roshidan et al. (2020) which shows that students’ understanding has been increased after using GeoGebra in their class. In conclusion, the usage of GeoGebra in learning geometry in school can help the students to gain more knowledge easily. Other than make the learning process more interesting, the students also can do simulation to understand more about what they learn on that day.

The Van Hiele theory in geometry

In geometry, the van Hiele Theory is the popular theory to be used by many researchers. This theory was introduced by Pierre van Hiele and his wife, Diana van Hiele-Geldof (Md Yunus et al., 2019). In this theory, there are two important elements which are the van Hiele Geometric Thinking Levels and van Hiele Learning Phases. The students’ achivement in geometry measured by using van Hiele’s Geometric Thinking Levels (Yi et al., 2020; Hiele, 1988; Usiskin, 1982). There are five levels in the geometric thinking level as shown in the *Table 1*. Each levels have their own expected age where the geometry learning should take place (FengSer et al., 2022; Yi et al., 2020; Tan, 2016; Škrbec and Čadež, 2015; Burger and Shaughnessy, 1986). All these levels have its own characteristics. First, there are fixed sequence of levels. No one should skip any levels because the students should master the levels first before going to next level of geometric thinking. This is to ensure the students build the knowledge firmly before learning something more complex on another level. Second, each level has its own terminologies and relationships to be learn. Third, separation which means two students with different levels cannot understand each other. Fourth, the attainment for what the students has learned by using van Hiele’s Phases of Learning. *Table 2* shows the five phases to be experienced by the students.

Table 1. The van Hiele Geometric Thinking Levels.

Level	Name	Expected age
1	Visualization	Preschool / Kindergarden
2	Analysis	Primary school
3	Informal Deduction	Primary school
4	Formal Deduction	Secondary school
5	Rigor	Higher learning

Table 2. The van Hiele’s Phases of Learning.

Phase	Name
1	Introduction
2	Guided Orientation
3	Explanation
4	Free Orientation
5	Integration

These five phases are the guide for teacher to teach geometry to the students (FengSer et al., 2022; Naufal et al., 2021; Hiele, 1988). The teacher can plan their learning activities based on the phases. Even though there are five phases, it can be implemented repeatedly without following the order (Meng and Idris, 2023). One phase can be implemented and move to another phase, and back to the previous phase. This is to make sure the scaffolding process to happen and help the students attain the knowledge for long time. *Figure 1* shows an example on how the phases of learning can be done in a teaching and learning activities for geometry. Based on the past research that has been made, it's been found that students' geometric thinking levels is still on the lower level than the actual level that they should achieve (Novitasari et al., 2021; Adelabu et al., 2019). Adelabu et al. (2019) said that there are 42.53% of 9th Grade students are still in Level 0 while 43.68% of them in Level 1. The other research shows that 10.91% of the students are in Level 0 while 30.91% still in Level 1 (Novitasari et al., 2021). This shows that there are a lot of secondary students whom didn't achieve the actual geometric thinking level that they should achieve yet. This statement is supported by Szabó et al (2020) research that shows most of students in Grade 9 to 12 didn't have any positive progress in their geometric learning. Based on one of the characteristics of van Hiele's Geometric Thinking Level, students' attainment in learning geometry can be done by implementing van Hiele's Phase of Learning. In Meng and Idris (2023), the learning session has been done by using all five phases in van Hiele's Phase of Learning. By the end of the learning session, 6 out of 8 students has achieved Level 3 while the other 2 achieved Level 2. This shown that the usage of the phases in teaching students is more effective to increase students' geometric thinking level (FengSer et al., 2022; Naufal et al., 2021; Abdullah and Zakaria, 2013; Usiskin, 1982).

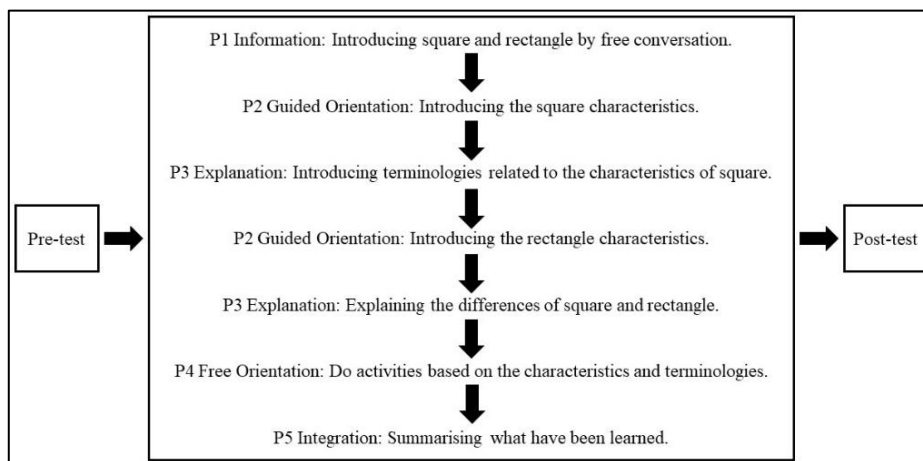


Figure 1. Example of van Hiele's Phase of Learning implementation.

Geometry learning module

Text book has been the official learning aid for so long. Unfortunately, the ability of it to show geometry object only limited to 2-dimension (2D). This situation makes it

difficult for the students to understand better the characteristics of the shapes clearly (Rahimi et al., 2019). Because of that, more teachers and researchers trying to produce some alternative aid to be used, and of that is learning module (Febrianto et al., 2020). In addition, the usage of geometry learning module integrated with GeoGebra can help students boost their understanding in learning basic geometry concepts (Aspari and Hartono, 2021). In this research, a geometry learning module has been developed to help the students to change or improve their geometric thinking. The module developed by integrating all five phases of learning and GeoGebra in the learning activities. The integration can be seen clearly in the lesson plan created for the teacher. The teacher may use the lesson plan step by step or they can improvise it depending on the availability of facilities and time management. *Figure 2* shows the cover of the module.



Figure 2. Front cover of the module.

This module consists of four sections. Section 1 is mainly for introduction to GeoGebra. In this section, the functions, buttons and work area in GeoGebra will be introduced to the user. Section 2 is for perimeter; Section 3 is for area of shape while Section 4 is for volume of shape. In Section 2 until Section 4, it will be started by a simple note on how to measure all three geometric measurement which are perimeter, area and volume. After the simple note, the sections will be continued by teaching the user on how to build a shape and measure it. After a shape is build, the steps will show how to build another shape to be combined with the first shape. The measurements of the combined shape will be showed after it. At the end of each section, there will be a simple exercise by using the GeoGebra applet. After Section 4, some exercises were given to the users to be completed manually and digitally by using GeoGebra. These exercises will help the students to test themselves on how high their understanding level for geometrical measurement. They can do it repeatedly until they can complete it without using any references. The last part is for teacher which is the suggested lesson

plan. This geometry learning module is developed to help the Year 5 students to increase their geometric thinking level. The learning activities has been created and planned by using all five van Hiele's Phases of Learning to make sure the students can form the knowledge and understanding of the concept properly before they move to the next topic. All learning activities in the module also will be used GeoGebra applet to make it more interesting and easier to be learn. The research question to be solved by the end of this research is is there any significant difference between students' geometric thinking level before and after using the geometry learning module?

Materials and Methods

This research is implemented using quantitative research design. Many researchers believes that this kind of research design can test accurately any research objectives numerically by using statistics analysis. To obtain more accurate data, quasi-experimental research design by using Pre-test Post-test Non-Equivalent Control Group Design is used. This design is used because random sampling cannot be done to prevent any disturbance to the school system. The sample used in this research were 50 Year Five students in Tawau District, Sabah. The students divided into two groups equally named experimental group and control group. The experimental group were using the module developed by the researcher while the control group were using traditional teaching style. All samples chosen basen on three criteria; students from Grade A school (school located in the city), have a good facility such as computer lab, and not a Dual Language Programme (DLP). The students' geometric thinking level were measured by the scores of pre-and post-test. Both groups were sat for pre-test and post-test before and after the intervention took place. The effectiveness of the module was determined by comparing both scores from both tests. The scores were calculated by using a marking scheme developed by Usiskin (1982). There are two types of marking schemes. First, student need to answer at least 3 out of 5 questions correctly while the second one is answer at least 4 out 5 questions correctly to be considered mastered the geometric thinking level.

In this research, researcher used the first marking scheme to minimize the Type II error. By using this type of marking scheme, it shows that the students actually have the ability to achieve higher levels of thinking, but getting categorized to the lower level by some factors such as bias, inaccuracy and many more (Abdullah and Zakaria, 2019). The pre-and post-test used were improvised from van Hiele Geometry Test (vHGT). Originally, vHGT were build for secondary school students so some items cannot be used for primary school students (Usiskin, 1982). Therefore, researcher improvise it to meet the requirement of the curriculum used in Malaysia's primary school which is KSSR. The question set consists of three sections with three multiple choice questions in each section. The questions in each section are build for Level 1 to Level 3 based on van Hiele's Geometric Thinking Level. Researcher only use Level 1 to Level 3 only because only primary school students were taken to participate in this research. To ensure the usability of this instrument in this research, the validity and reliability test has been conducted first. The instrument has been sent to two experts in mathematics education field to be assessed. The validity assessment shows that the Scale Content Validity Index (S-CVI) for this instrument is 0.93 which means it can be used fir this research. For the reliability test, the Cronbach's Alpha, α is 0.81, which means all the items in the instrument are good to be used. This is based on Musa et al. (2021) whom

said that any α value from 0.80 to 1.00 shows that the consistency of all the items is good and are able to measure the research objectives. For this instrument, there is weighted mark if the students meet the requirement based on the marking scheme for each section as shown in *Table 3*.

Table 3. *Weighted marks for each section.*

Mark obtained	Section
1	A (Question 1 to 5)
2	B (Question 6 to 10)
4	C (Question 11 to 15)

By using the weighted marks above, researcher will use Forced van Hiele Levels to determine the students' final geometric thinking level. The Forced van Hiele Levels were used to give chances to the students to have a geometric thinking level. *Table 4* shows how the weighted marks were used to determine the geometric thinking level. From *Table 4*, we can see that if the students get total weighted marks of 1 and 5 will get Level 1; weighted marks of 3 will get Level 2, while weighted marks 6 and 7 will get Level 3. However, if the students get 0, 2 or 4, they will get Level 0 which is Pre-Visualization. This level is the lowest level of van Hiele Geometric Thinking Level. The uniqueness of the Forced van Hiele Level is if the students did not achieve the first level but achieved the second and third levels, they considered to achieved the third level. This is because one of the conditions of the Forced van Hiele Level is the students need to achieved n and $n-1$ level, but not $n-2$ or $n-3$. For student E, the student has achieved Level 3 (n) and Level 2 ($n-2$), but did not achieved Level 1 ($n-2$). To conduct this research smoothly, some procedures need to be followed. These procedures are meant to protect the confidentiality of the samples and the research ethics. There are a few steps of the procedure that need to be adhere to inform all parties such as university, the ministry, the education office, schools, students and their parents about the aim of this research. *Table 5* shows the procedures of data collection for this study. There are two statistical analysis used namely descriptive statistics and inferential statistics. Descriptive statistics is used to analyze the data briefly and shows it into an easy diagram. The inferential statistics is used to determine whether the results from this research can be used widely to the population or not. In this research, frequency, percentage and median were used for descriptive statistics analysis while Mann-Whitney U test is used for inferential statistics analysis.

Table 4. *Determining the geometric thinking level.*

Student	Number of correct item [Weighted mark]				Forced Van Hiele level
	Section A	Section B	Section C	Total	
A	4 [1]	3 [2]	2 [0]	3	2
B	4 [1]	3 [2]	3 [4]	7	3
C	2 [0]	1 [0]	1 [0]	0	0
D	4 [1]	2 [0]	3 [4]	5	1
E	2 [0]	5 [2]	4 [4]	6	3
F	3 [1]	2 [0]	2 [0]	1	1
G	1 [0]	2 [0]	4 [4]	4	0
H	1 [0]	4 [2]	2 [0]	2	0

Table 5. *Procedure of data collection.*

No	Procedure
1	Getting letter of approval from university
2	Getting letter of approval from Bahagian Perancangan dan Penyelidikan Dasar Pendidikan, KPM
3	Getting letter of approval from Sabah Education Department
4	Getting consent from the schools

5	Selecting samples and consent from their parents
6	Conducting the research
7	Collecting data
8	Analyzing data

Results and Discussion

Pre-and post-test result

By using the Forced van Hiele Level, students' geometric thinking level has been determined from their answer in pre- and post-test. *Table 6* shows the geometric thinking level obtained by both experimental and control group. *Figure 3* shows the pre- and post-test for experimental group while *Figure 4* shows the pre- and post-test for control group. From *Figure 3* and *Figure 4*, we can see that more students have positive changes in their geometric thinking level in experimental group. There are 18 students shows improvement while the other 7 shows no changes in experimental group while in control group, 12 students show improvement and 13 students shows no change. We also can see the differences on the number of students achieved Level 3 where there are 7 students in experimental group and 3 students in control group for the post-test. To study about the effectiveness of the geometry learning module, the geometric thinking level obtained by both group from post-test were analyzed inferentially by using Mann-Whitney U test. This test was used to compare the differences between two groups when the data is not normally distributed. *Table 7* shows the analysis of the geometric thinking level from post-test for both groups.

Table 6. *Geometric thinking level for experimental and control group.*

Experimental group			Control group		
Student	Pre-test	Post-test	Student	Pre-test	Post-test
E01	2	3	C01	1	1
E02	1	1	C02	1	1
E03	1	2	C03	0	1
E04	1	2	C04	1	1
E05	2	3	C05	0	1
E06	1	2	C06	0	1
E07	2	3	C07	1	1
E08	1	2	C08	1	2
E09	1	1	C09	2	3
E10	1	2	C10	2	3
E11	2	3	C11	1	2
E12	1	1	C12	1	2
E13	1	2	C13	2	2
E14	2	3	C14	1	1
E15	2	3	C15	1	1
E16	1	1	C16	1	2
E17	1	1	C17	1	1
E18	1	2	C18	1	1
E19	1	2	C19	1	2
E20	1	1	C20	1	2
E21	1	2	C21	1	1
E22	1	1	C22	2	3
E23	1	2	C23	1	1
E24	1	2	C24	1	1
E25	2	3	C25	1	1

Table 7. *Inferential analysis of geometric thinking level for experimental and control group.*

Analysis	Value
Mann-Whitney U	204.500
Z	-2.259
Asymp. Sig (2-tailed)	.024

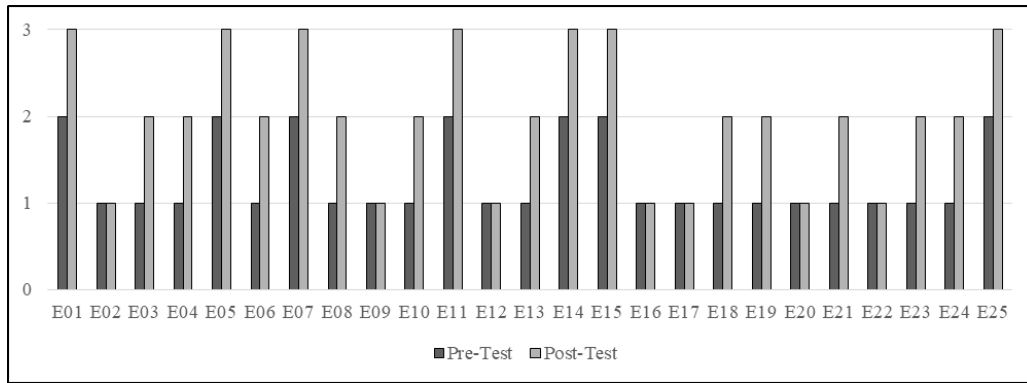


Figure 3. Experimental group geometric thinking level for pre-and post-test.

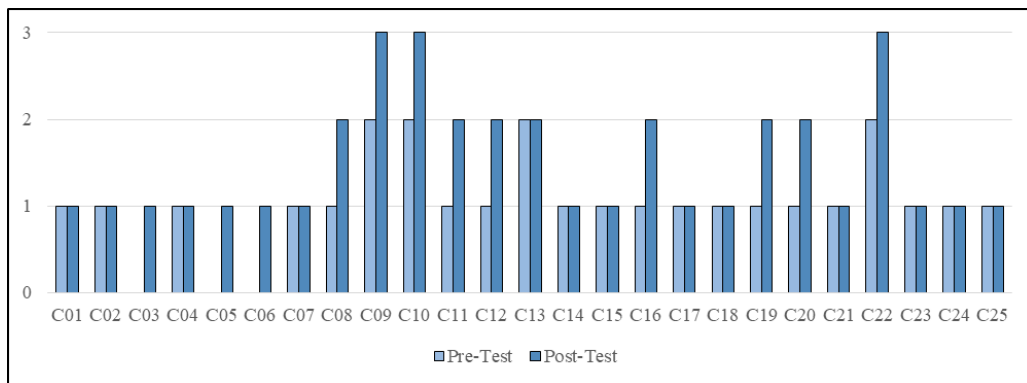


Figure 4. Control group geometric thinking level for pre-and post-test.

Based on the result, we can see that the value of Z is -2.259 with $p=0.024$. Because the p-value is less than 0.05, that means there are significant differences between both groups. This also shows that the learning process using the geometry learning module integrated with GeoGebra and five van Hiele's Phases of Learning is more effective in increasing students' geometric thinking level. The usage of traditional teaching style is not hundred percent wrong. It can still be implemented in the class but should be minimized or just to be used when teaching something basic as a supplementary to the students. The effectiveness of a learning module can be measured by students' increment in performance. In this study, the effectiveness of the learning module is measured by students' positive change in their geometric thinking level. A positive change means that the geometry learning module is effective to be used by them. By looking at Table 6, Figure 3 and Figure 4, we can see the differences between experimental group and control group in terms of their change in geometric thinking level. For experimental group as shown in Figure 3, there are a lot of the samples who shows poitive change from pre-test to post-test. There are no samples showing drastic change like from Level 1 to Level 3 because one of the characteristics of van Hiele's Geometric Thinking Level is one cannot surpass to any level without being in each level first. It means, a student must reach Level 2 after Level 1 before moving to Level 3. There are 7 samples who did not show any changes based on two factors; the low performance in mathematics and absence problem.

Figure 4 shows the geometric thinking level for control group. The students in this group however, shows a somehow monotonous achievement. Many of the samples are stuck in Level 1. Only 7 of them achieve Level 2 and three of them achieve Level 3 in post-test. This result shows that the usage of traditional teaching method, without any

integration with technology and alternative aid in learning process cannot help the students more to improve their geometric thinking level. The usage of text book and teaching aids such as blocks and flashcards is still relevant, but need to be upgraded more with technology so that the students can do simulation and learn more with that. The inferential statistics analysis shows p value from Mann-Whitney U test is 0.024, which is less than 0.05. This shows that there is a significant difference between both groups, experimental and control, for their geometric thinking level after the intervention has been implement. The usage of geometry learning module which integrated with GeoGebra and van Hiele's Phases of Learning is proven effective to improve students' geometric thinking level rather than traditional teaching method. This might be affected by the features of technology which suit the students nowadays more, whom known as Alpha generation.

Conclusion

By obtaining this kind of result, researcher believes that the usage of technology such as DGS in teaching geometry should be implemented widely in primary school. This is to help the primary school students have strong basic geometry knowledge as a preparation before they learn something more complex in secondary school. Other than that, a strong basic knowledge in geometry can help the students to learn geometry more smoothly and having good achievement in the other level of their education. This research should be expanded by adding more geometry topics for primary school such as lines and angles, also the polygons.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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