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Effect of Phase-based Instruction Using Geometer's Sketchpad on Geometric Thinking Regarding Angles

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ABSTRACT

Teaching and learning geometry is not merely about memorising geometrical properties but about grasping the conceptual understanding of geometry as well. Students, however, face challenges in the classroom trying to develop their geometrical thinking. The purpose of this study is to identify whether phase-based instruction using Geometer's Sketchpad helps primary school pupils develop their Van Hiele levels of geometric thinking regarding angles significantly. Eight different pre-sketched activities were designed based on Van Hiele's five phases of learning to guide the students in learning about geometrical angles. Pre and post Van Hiele Achievement Tests were given to both the experimental and control groups before and after the intervention. Inferential statistics such as Mann-Whitney test and Wilcoxon signed-rank test were used in analysing the quantitative data. Results of the pretest indicated no significant difference between both groups of students in their Van Hiele levels of geometric thinking. After the intervention, the findings showed that students in both the experimental and control groups have improved significantly in terms of their Van Hiele levels of geometric thinking. Additionally, results of the Mann-Whitney test revealed that the difference in Van Hiele levels of geometric thinking between students in both groups was significant during posttest. In short, phase-based instruction using Geometer's Sketchpad has helped the students to develop their Van Hiele levels of geometric thinking and provided an insight for the educators to further utilise the software.

Keywords: Van Hiele levels of geometric thinking, phase-based instruction, Geometer's Sketchpad, primary mathematics, geometrical angles

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INTRODUCTION

Battista (2007) stated that "Geometry is a complex interconnected network of concepts, ways of reasoning, and representation systems that is used to conceptualize and analyze physical and imagined special environments" (p. 843). Teachers should stimulate the students' geometric thinking and develop their reasoning skills about geometry that can enable them to carefully analyse spatial problems and situations (Battista, 2002) by preparing meaningful tasks to allow exploration of geometric concepts. Erdogan, Akkaya, and Celebi Akkaya (2009) stress that geometrical thinking is not only limited to mathematics but plays an important role in students' cognitive development in all courses. Therefore, it is important for pupils to develop their own geometrical thinking in the elementary level so that they can progress further at secondary level.

Crowley (1987) emphasise that appropriate instructional guidance is the key to helping students master geometrical thinking based on Van Hiele theory. Abdullah and Zakaria (2013) suggest using various approaches in imparting geometrical knowledge, specifically using Geometer's Sketchpad software based on Van Hiele's phases of learning geometry. Some researchers have conducted studies to develop students' geometrical achievement and geometric thinking using technology tools, specifically the Geometer's Sketchpad. They found that students were motivated to learn geometric concepts through Geometer's Sketchpad, resulting in significant improvement in geometrical achievement as well as Van Hiele levels of geometric thinking (Abdullah & Zakaria, 2013; Chew & Idris, 2012; Chew & Lim, 2013; Dimakos & Zaranis, 2010; Idris, 2009).

Prescott, Mitchelmore, and White (2002) conducted an exploratory research on Year Three pupils to study their difficulties in abstracting angle concepts from physical activities with concrete materials. In short, Prescott et al. (2002) suggested that the concept of angle seems difficult for Year Three pupils. The pupils faced some difficulties in learning angles, which could be classified into four categories: matching, measuring, drawing, and describing. Shoval (2011) also found that the achievement of second and third grade pupils in angles improved after cooperative learning using mindful movement. It seems that the difficulties faced by primary school pupils in learning angles could be overcome through instructional activities that involve frequent interaction.

Research Purpose

This study aims at determining whether phase-based instruction using Geometer's Sketchpad helps primary school pupils develop their Van Hiele levels of geometric thinking regarding angles. The study intends to answer the following research questions:

1. Is there any significant difference in students' Van Hiele levels of geometric thinking between the experimental group and the control group before

the phase-based instruction using Geometer's Sketchpad?

2. Is there any significant difference in students' Van Hiele levels of geometric thinking regarding angles before and after the phase-based instruction using Geometer's Sketchpad?
3. Is there any significant difference in students' Van Hiele levels of geometric thinking regarding angles before and after the instruction using traditional approach?
4. Is there any significant difference in students' Van Hiele levels of geometric thinking between the experimental group and the control group after the phase-based instruction using Geometer's Sketchpad?

Significance of the Study

This study contributes to mathematics teachers by providing insights into teaching primary mathematics using technology tools to enhance pupils' Van Hiele level of geometric thinking. The mathematics teacher can try to teach geometry in a sequential way using phase-based instruction to enhance students' Van Hiele levels of geometric thinking as well as guide students' learning through exploration to achieve specific academic goals.

Theoretical Framework

Van Hiele Theory of Geometric Thinking. Van Hiele theory is "an idea that systemizes the experience of mathematical thinking processes" (Lee & Kim, 2012, p. 4088). Van Hiele theory explains the problems which students face and when applied it helps them progress to higher levels of geometrical thinking (Usiskin, 1982). Erdogan et al. (2009) suggest the use of Van Hiele levels in geometrical instruction as it enhances the role of teachers in managing instructional activities.

Van Hiele theory proposes five distinct levels for categorising students' geometric thinking, namely Level 1 (visualisation/recognition), Level 2 (analysis) Level 3 (informal deduction), Level 4 (formal deduction) and Level 5 (rigor). Clements and Battista (1992) suggest an indicator of Level 0 (precognition) for the students who have not mastered Van Hiele Level 1 of geometric thinking. This study involves two of the five levels of geometric thinking, which are covered in Year FourMathematics curriculum:

(a) ***Level 1: Visual/Recognition.*** The students in Level 1 should be able to recognise, name and sort shapes based on the physical appearance of the shapes but cannot identify a figure based on its properties (Crowley, 1987; Erdogan et al., 2009; Van Hiele, 1986).

(b) ***Level 2: Analysis.*** At this level, students should be able to differentiate the geometrical figure based on their characteristics through observations and experiments. In addition, students should use the properties learnt to solve problems. (Crowley, 1987; Erdogan et al., 2009; Lee & Kim, 2012; Van Hiele, 1986).

Van Hiele Phase-Based Instruction. Van Hiele theory also proposes five sequential phases of learning to guide students to develop their geometric thinking. The five phases of learning include:

(a) ***Phase 1: Information / Inquiry.*** Teachers and students engage in conversation and activities such as questioning, observations and vocabulary. From the activities, teachers may know about students' prior knowledge regarding the topic and the direction of further studies as well (Crowley, 1987).

(b) ***Phase 2: Guided / Directed Orientation.*** Students explore the geometrical concepts using the materials carefully sequenced by the teacher (Crowley, 1987; Van Hiele, 1986) with minimal guidance from the teacher (Clements & Battista, 1992).

(c) ***Phase 3: Explicitation.*** Students explain their views about geometrical concepts learnt by combining new knowledge with prior knowledge. The activities in this phase should be done with minimal teacher guidance, specifically only on the use of accurate and appropriate language (Crowley, 1987).

(d) ***Phase 4: Free Orientation.*** Students are challenged with more complex tasks, such as those involving more complicated solution steps and open-ended tasks (Crowley, 1987). "By orienting themselves in the field of investigation, many relations between the objects of study become explicit to the students" (Hoffer, 1983, p. 208).

(e) ***Phase 5: Integration.*** Students summarise what they have learnt and generate their own understanding about geometrical concepts.

Review of Related Literature

Dimakos and Zaranis (2010) conducted a quasi-experimental study on how integrating Geometer's Sketchpad into high school geometry teaching affected students' achievement and proof writing ability. A total of 79 grade seven students participated in this study (40 students were assigned to the experimental and 39 to the control group). A Van Hiele based pretest was given in the first week. Subsequently, students in both groups were taught about triangles and quadrilaterals for six weeks. One or two hours of computer activities using Geometer's Sketchpad per week were carried out for experimental group students. Posttest was given to evaluate students' geometry achievement after the instruction. The t-tests results indicated that students in both groups improved significantly after the instruction. The difference in geometry achievement between the two groups was not significant during the pretest but showed marked difference during the posttest, whereby students in the experimental group scored significantly better than the students in the control group during the posttest.

Poh and Leong (2014) also conducted a quasi-experimental study to investigate the usage of Geometer's Sketchpad in the teaching and learning of angles for Year Three pupils in a rural school in Pahang. A total of 31 students from an intact mixed-ability classroom participated in the study (16 of them were assigned to the experimental group and the remaining 15 to the control). Three sets of pre and posttests were developed based on the content of right angles, acute angles and obtuse angles. The posttests were administered immediately after the instruction on the specific types of angles. Results of the paired samples *t*-tests showed that the Van Hiele levels of geometric thinking among students in both the experimental group and the control group improved significantly after the intervention. Although the result of the independent samples *t*-tests for three posttests indicated that the Van Hiele levels of geometric thinking did not differ significantly, it is interesting to find that the significance value of the difference reduced over longer duration.

In the following year, Poh and Leong (2015) improvised the instructional tasks and carried out another quasi-experimental study involving 30 Year Three students in a rural school in Pahang to examine whether Geometer's Sketchpad could be used to enhance the Van Hiele level of geometric understanding regarding angles among primary school students. A Van Hiele Achievement Test, consisting of 10 multiple choice items was constructed to assess students' Van Hiele levels of geometric understanding regarding angles. The students in the experimental group underwent six sessions of phase-based instruction on geometrical angles using Geometer's Sketchpad whereas the control group students learnt geometrical angles using the traditional approach for six sessions. After the intervention, the students in the control group obtained higher Van Hiele levels of geometric understanding regarding angles, on average, compared to the students in the experimental group during post Van Hiele Achievement Test, but the difference was not significant. The researchers concluded that the students might be unfamiliar with the software and instructional method because of time constraints. Hence, the instructional activities have been modified once again for the current study to allow sufficient time for students to explore the geometrical concepts on their own.

In a related study, Siew and Chong (2014) conducted a single group pre-test and post-test experimental design study to foster pupils' creativity in terms of Torrance's Figural Test of creative thinking through Van Hiele's five phase-based tangram activities. A total of 144 grade three pupils taken from five mixed-ability classrooms participated in their study. Three hours of phase-based intervention was given to the pupils regarding two-dimensional shapes and symmetry.

In another study, Abdul Halim and Effandi (2013) disagreed with the traditional teaching approach, which encourage pupils to memorise facts and algorithms without understanding the underlying concepts. They used quasi-experimental research design and developed activities for form two students based on the topic of transformations, which aimed to identify the effectiveness of Van Hiele phases of geometry learning using the Geometer's Sketchpad on the geometric thinking among form two students. The results implied that instruction using Van Hiele phases of learning geometry through Geometer's Sketchpad is more effective compared to the conventional way of learning for improving students' geometric thinking. Based on their results, the researchers suggested that teachers should introduce new approaches in their geometry teaching such as utilising Geometer's Sketchpad software since its benefits had been affirmed by previous studies.

Similarly, Chew and Lim (2013) also conducted an exploratory case study to enhance primary school pupils' geometric thinking through phase-based instruction using Geometer's Sketchpad based on the Van Hiele theory of geometric thinking about equilateral triangle, square, regular pentagon, and regular hexagon. Their sample involved a class of 26 mixed-ability Year Four pupils from a primary school in Selangor. Their results indicated that 84.6% of the pupils' improved their Van Hiele levels of geometric thinking from either Level 0 to Level 2 or from Level 1 to Level 2. At the same time, 15.4% of the pupils improved their Van Hiele levels of geometric thinking from Level 0 to Level 1. There was a significant difference in the pupils' Van Hiele levels of geometric thinking for all the regular polygons after the phase-based instruction using Geometer's Sketchpad. Chew and Idris (2012) in their case study also explored whether pupils' geometric thinking and achievement in solid geometry regarding cubes and cuboids could be enhanced through phase-based instruction using manipulatives and the Geometer's Sketchpad based on Van Hiele theory. The results of the post-interview suggested that phase-based instruction using manipulatives and Geometer's Sketchpad had enhanced achievement in solid geometry.

Hence, based on previous studies, Geometer's Sketchpad could enhance secondary students' geometric thinking but research using Geometer's Sketchpad as an instructional tool for primary school pupils is insufficient (Chew & Lim, 2013). Moreover, the mathematical content of geometrical angle was first introduced in the current primary mathematics syllabus. So far, no research has been done on teaching geometrical angles to Malaysian primary school pupils, specifically by using phase-based instruction aided by Geometer's Sketchpad. The current study adds to the existing body of research.

METHOD

Research Design

A quasi-experimental study of non-equivalent pretest-posttest design was conducted in one of the primary schools in Pahang, Malaysia. By using non-equivalent pretest-posttest design, the researcher can determine the improvement of pupils in terms of Van Hiele levels of geometric thinking within the intervention period. The research design is shown as follows:

Experimental group	O1	X1	O2
Control Group	O1	X2	O2

O1 represents the pre Van Hiele Achievement Test

O2 represents the post Van Hiele Achievement Test

X1 represents the phase-based instruction of geometrical angles using Geometer's Sketchpad

X2 represents the instruction of geometrical angles using traditional approach.

Population and Sample

The population of this study includes all Year Four pupils in the national type primary Chinese schools in Malaysia. There are 74 national type primary Chinese schools in Pahang. The researcher employed purposive sampling of the Kuantan district to select one of the national type primary Chinese schools in Kuantan area because the school has sufficient personal computers for pupils' use. A total of 74 Year Four pupils (ten years old) participated in the study. The students were chosen from two intact mixed-ability classrooms. The researcher used coin-toss and assigned a class of 38 students as the experimental group and another class of 36 students as the control group.

Instrumentation

The Van Hiele Achievement Test was developed by the researcher to gather information about 74 Year Four pupils' Van Hiele levels of geometric thinking regarding geometrical angles. It consisted of twenty multiple choice items. Sample items for each level of geometric thinking regarding angles are illustrated in the following Figure 1.

Sample items

Van Hiele Level 1 of Geometric Thinking

3. What type of angle is shown on the clock in Diagram 1?

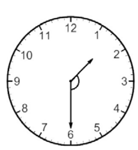

Diagram 1

A Acute angle
B Right angle
C Obtuse angle
D Straight angle
E Reflex angle

Van Hiele Level 2 of Geometric Thinking

18. Based on Diagram 11, which statement is correct?

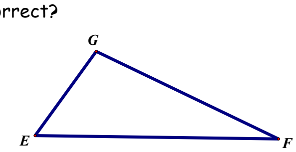

Diagram 11

A $\angle E$ is 30° and it is a right angle.
B $\angle E$ is 80° and it is an acute angle.
C $\angle F$ is 25° and it is an acute angle.
D $\angle G$ is 55° and it is an obtuse angle.
E $\angle G$ is 100° and it is a right angle.

Figure 1. Sample items for each level of geometric thinking regarding angles

The students in both the experimental and control groups were allowed to use Geometer's Sketchpad as another choice in answering the test besides paper and pencil so that they possessed the same condition and environment during the assessment. They were also provided with a protractor and virtual protractor to help them visualise the angles.

Mayberry's (1981) scoring criterion suggest that the students master one Van Hiele level of geometric thinking if they can answer at least three out of five items correctly. In this study, the researchers assumed that the students who answered seven out of 10 items correctly for item 1 to item 10 mastered the visualization level of geometric thinking (Level 1). If the students could answer seven out of 10 items correctly for item 11 to item 20, they were assumed to have mastered the analysis level of geometric thinking (Level 2). The students who were unable to answer seven out of 10 items correctly for item 1 to item 10 were graded as Level 0.

Reliability and Validity of Instrument

The content validity and translation validity of the instrument was confirmed by several experienced senior mathematics lecturers from the local universities in Malaysia. The Cronbach's alpha internal consistency score procedure for the Van Hiele Achievement Test instrument was performed using the Statistical Packages for the Social Sciences (SPSS) version 20.00 and generated Cronbach alpha value of .737. Nunnally (1978) suggested that an instrument with an alpha value above .7 would have sufficient internal consistency.

Procedures

The research procedure for this study is shown in Table 1. First of all, a Van Hiele Achievement Test was administered to the students in both the experimental group and control group to determine the students' initial Van Hiele level of geometric thinking. Next, an introductory lesson on the Geometer's Sketchpad was given. During the lesson, the researchers demonstrated how to use the basic features in the Geometer's Sketchpad such as rotating, drawing segments and drawing lines. The experimental group students were then paired up based on their initial Van Hiele levels of geometric thinking and left to explore the software on their own for 30 minutes. From the following week, the students in the experimental group underwent eight sessions of phase-based instruction on geometrical angles using Geometer's Sketchpad whereas the students in the control group were taught using the traditional method. At the end of the treatment, post Van Hiele Achievement Test was given to students in both groups to gather information about their post Van Hiele levels of geometric thinking.

Table 1
Research procedures

Groups		Research procedures
Experimental Group	1.	Pre Van Hiele Achievement Test
	2.	Introductory lesson of the Geometer's Sketchpad
	3.	Phase-based instruction using Geometer's Sketchpad
		Lesson 1: Knowing about angles
		Lesson 2: Comparing angles
		Lesson 3: Identify the right angles through visualization
		Lesson 4: Identify the acute angles through visualization
		Lesson 5: Identify the obtuse angles through visualization
		Lesson 6: Identify the properties of the right angles
		Lesson 7: Identify the properties of the acute angles
		Lesson 8: Identify the properties of the obtuse angles
	4.	Post Van Hiele Achievement Test
Control Group	1.	Pre Van Hiele Achievement Test
	2.	Instruction using traditional method
		Lesson 1: Knowing about angles
		Lesson 2: Comparing angles
		Lesson 3: Identify and measure the right angles
		Lesson 4: Identify and measure the acute angles
		Lesson 5: Identify and measure the obtuse angles
		Lesson 6: Identify and measure the right angles in polygons
		Lesson 7: Identify and measure the acute angles in polygons
		Lesson 8: Identify and measure the obtuse angles in polygons
	3.	Post Van Hiele Achievement Test

Data Analysis

Mann-Whitney U test and Wilcoxon signed-rank test were used to analyse the students' pre and post Van Hiele levels of geometric thinking using SPSS software version 20.00 since the data violated the assumptions of normality and homogeneity of variance.

FINDINGS

The frequency and percentage of students in the experimental group and control group who acquired Level 0, Level 1 and Level 2 in the pretest and posttest regarding the topic of geometrical angles are shown in Table 2.

Table 2
Frequency and percentage of students at different levels in the Pre and Post Van Hiele Achievement Test

Van Hiele Achievement Test		Van Hiele levels of geometric thinking					
		Level 0		Level 1		Level 2	
		f	%	f	%	f	%
Pretest	Experimental (n = 38)	27	71.1	10	26.3	1	2.6
	Control (n = 36)	27	75.0	9	25.0	0	0.0
Posttest	Experimental (n = 38)	1	2.6	4	10.5	33	86.8
	Control (n = 36)	9	25.0	2	5.6	25	69.4

Before intervention for the experimental group, the pre Van Hiele Achievement Test was administered to enquire the initial Van Hiele levels of geometric thinking among the students. In the pretest, 27 (71.1%) , 10 (26.3%) and one (2.6%) of the students in the experimental group were found to have acquired Van Hiele Level 0, Level 1 and Level 2 of geometric thinking respectively. On the other hand, 27 (75.0%), 10 (25.0%) and 0 (0.0%) students in the control group had acquired Van Hiele Level 0, Level 1 and Level 2 of geometric thinking respectively. It was found that students in the experimental group performed slightly better than students in the control group in the pretest.

After the phase-based instruction using Geometer's Sketchpad, 33 (86.8%) students in the experimental group acquired Van Hiele Level 2 of geometric thinking but one (2.6%) of the students was still at Level 0. On the other hand, 25 (69.4%) students in the control group had achieved Van Hiele Level 2 of geometric thinking after the instruction of angles using traditional approach. However, nine (25.0%) of them were still at Level 0. In general, the students in the experimental group performed better than the students in the control group in the post Van Hiele Achievement Test.

Question 1: Is there any significant difference in the pupils' Van Hiele levels of geometric thinking regarding angles between the experimental group and the control group before the intervention?

Results of the Mann-Whitney test (as shown in Table 3) for pre Van Hiele Achievement Test indicate that there is no significant difference in Van Hiele levels of geometric thinking between the experimental group (*Median* = 0) and the control group (*Median* = 0), U ($n_1 = 38, n_2 = 36$) = 652.50, $z = -0.44$, $p = 0.66$ at the significance level of 0.05.

Table 3
Result of Mann-Whitney U Test (U) and Effect Size (r) for experimental and control groups in pre Van Hiele Achievement Test

Group	Mean	Median	Mean rank	z	U	p	r
Experimental (n = 38)	0.32	0	38.33	-0.44	652.50	0.66	-0.05
Control (n = 36)	0.25	0	36.63				

The mean rank of the experimental group (38.33) was slightly higher than the control group (36.63) indicating that the students in the experimental group possessed slightly higher Van Hiele levels of geometric thinking at the initial stage than students in the control group. The effect size is -0.05, which shows that both the groups had only a small effect on the students' achievement in pre Van Hiele Achievement Test according to Rosenthal (1991). Using Rosenthal's (1991) interpretation of the effect size, ±0.1 and below, a small effect size, ±0.3 and below indicates a medium effect size while ±0.65 and below reflects a large effect size.

Question 2: Is there any significant difference in the experimental group pupils' Van Hiele levels of geometric thinking regarding angles before and after the phase-based instruction using Geometer's Sketchpad?

Results of Wilcoxon signed-rank test analysis using SPSS (as in Table 4) showed that the students' Van Hiele levels of geometric thinking regarding geometrical angles after phase-based instruction using Geometer's Sketchpad (*Median* = 2) were significantly higher than their Van Hiele levels of geometric thinking before the instruction using Geometer's Sketchpad (*Median* = 0), z = -5.42 with a p-value smaller than 0.01. The difference in Van Hiele level of geometric thinking of the students before and after the intervention period was significant at the 0.05 level of significance as $p<0.05$. The effect size for the phase-based instruction using Geometer's Sketchpad was -0.63 which was large, based on Rosenthal (1991).

Table 4
Result of Wilcoxon Signed-rank Test for difference in Van Hiele levels of geometric thinking for the experimental group

Post VHAT – Pre VHAT	N	Mean Rank	Sum of Ranks	z	Asymp. Sig. (2-tailed	r
Negative Ranks	0[a]	0.00	0.00	-5.42[d]	0.00	-0.63
Positive Ranks	36[b]	18.50	666.00			
Ties	2[c]					
Total	38					

Note: [a] PostVHAT < PreVHAT; [b] PostVHAT > PreVHAT; [c] PostVHAT = PreVHAT; [d] Based on negative ranks

Question 3: Is there any significant difference in the control group pupils' Van Hiele levels of geometric thinking regarding angles before and after the instruction using traditional approach?

Based on the results of Wilcoxon signed-rank test as shown in Table 5, the students in the control group acquired significantly higher Van Hiele levels of geometric thinking in post Van Hiele Achievement Test after the instruction on geometrical angles (*Median* = 2) compared to their Van Hiele levels of geometric thinking before the instruction of geometrical angles (*Median* = 0), $z = -4.65$ with a p-value smaller than 0.01. The result shows that students in the control group had progressed significantly after the traditional instruction on geometrical angles. The difference in the Van Hiele levels of geometric thinking of the students before and after instruction was significant at the level of $\alpha = 0.05$ as $p<0.05$. The effect size for the traditional instruction of geometrical angles was -0.54 which was large based on Rosenthal (1991).

Table 5
Result of the Wilcoxon Signed-rank Test for difference in Van Hiele levels of geometric thinking for control group

Post VHAT – Pre VHAT	N	Mean Rank	Sum of Ranks	z	Asymp. Sig. (2-tailed	r
Negative Ranks	1[a]	6.00	6.00	-4.65[d]	0.00	-0.54
Positive Ranks	27[b]	14.81	400.00			
Ties	8[c]					
Total	36					

Note: [a] PostVHAT < PreVHAT; [b] PostVHAT > PreVHAT; [c] PostVHAT = PreVHAT; [d] Based on negative ranks

Question 4: Is there any significant difference in the pupils' Van Hiele levels of geometric thinking regarding angles between the experimental group and the control group after the intervention?

The Mann-Whitney test analysis using SPSS (as shown in Table 6) showed that the difference in Van Hiele levels of geometric thinking between the students in the experimental group (*Median* = 2) and the students in the control group (Median = 2) was significant, $U (n_1 = 38, n_2 = 36) = 548.00$, $z = -2.05$, $p = 0.04$ at the significance level of 0.05. The mean rank of the experimental group (41.08) was higher than the mean rank of the control group (33.72), indicating that students in the experimental group possessed higher Van Hiele levels of geometric thinking than students in the control group after the intervention period. The effect size is -0.24, indicating only a small effect on the students' Van Hiele levels of geometric thinking in post Van Hiele Achievement Test according to Rosenthal (1991) as the r-value is below the 0.3 criterion for a medium effect size.

Table 6
Result of Mann-Whitney U Test (U) and Effect Size (r) for the experimental and control groups in post Van Hiele Achievement Test

Group	Mean	Median	Mean rank	z	U	p	r
Experimental (n = 38)	1.84	2	41.08	-2.05	548.00	0.04	-0.24
Control (n = 36)	1.44	2	33.72				

DISCUSSION

Result of the Mann-Whitney *U* Test revealed that the Van Hiele levels of geometric thinking among students in the experimental group and control group did not differ significantly during the pretest. This means that the students in both groups had similar Van Hiele levels of geometric thinking before this study was conducted.

After eight sessions of phase-based instruction using Geometer's Sketchpad, the students in the experimental group improved significantly in terms of their Van Hiele levels of geometric thinking regarding geometrical angles. This result implies that phase-based instruction using Geometer's Sketchpad is useful as an approach for guiding primary school pupils to progress to higher Van Hiele levels of geometric thinking.

On the other hand, students in the control group also improved significantly in their Van Hiele levels of geometric thinking regarding geometrical angles after instruction using the traditional approach. Based on this result, we can see that the students gained higher Van Hiele levels of geometric thinking after traditional teaching of geometrical angles.

By comparing the post Van Hiele levels of geometric thinking among the students in both groups using Mann-Whitney *U* Test, it is clear that students in the experimental group acquired significantly higher Van Hiele levels of geometric thinking compared to students in the control group. Based on this data, it is concluded that the phase-based instruction using Geometer's Sketchpad is more effective than the traditional approach in enhancing students' Van Hiele levels of geometric thinking.

Results of the Mann-Whitney test on pupils' post Van Hiele Achievement Test suggest that pupils who underwent phase-based instruction of geometrical angles using Geometer's Sketchpad performed significantly better than the pupils who underwent instruction using traditional approach at the 5% level of significance. It seems that phase-based instruction of geometrical angles is more effective than the instruction of geometrical angles using traditional approach in improving pupils' Van Hiele levels of geometric thinking.

This finding is consistent with the studies conducted by Chew and Lim (2013), and Chew and Idris (2012) which reported that phase-based instruction using Geometer's Sketchpad is effective in enhancing pupils' Van Hiele levels of geometric thinking. This result also concurs with the study conducted by Dimakos and Zaranis (2010) where the experimental group pupils performed significantly better than the control group pupils in the posttest compared to their pretest after involvement in inductive Geometer's Sketchpad activities.

CONCLUSION

In conclusion, phase-based instruction using Geometer's Sketchpad has helped Year Four students in this study to acquire significantly higher Van Hiele levels of geometric thinking in the topic of geometrical angles. Although it may not be easy for primary school students to utilise the Geometer's Sketchpad well on their own as a tool for learning geometry, well-designed pre-sketched Geometer's Sketchpad activities (Idris, 2009) as well as proper guidance and facilitation from the teacher (Chew & Lim, 2013) may be helpful for students to overcome the difficulties. .

REFERENCES

Abdullah, A. H., & Zakaria, E. (2013). Enhancing students' level of geometric thinking through Van Hiele's phase-based learning. *Indian Journal of Science and Technology, 6*(5), 4432-4446.

Battista, M. T. (2002). Learning geometry in a dynamic computer environment. *Teaching Children Mathematics, 8*(6), 333-339.

Battista, M. T. (2007). The development of geometric and spatial thinking. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 843–908). Charlotte, NC: National Council of Teachers of Mathematics.

Chew, C. M., & Idris, N. (2012). Enhancing students' geometric thinking and achievement in solid geometry. *Journal of Mathematics Education, 5*(1), 15-33.

Chew, C. M., & Lim, C. S. (2013). Enhancing primary pupils' geometric thinking through phase-based instruction using the Geometer's Sketchpad. *Asia Pacific Journal of Educators and Education, 28*, 33-51.

Clements, D. H., & Battista, M. T. (1992). Geometry and spatial reasoning. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 420-464). New York, NY: Macmillan.

Crowley, M. L. (1987). The Van Hiele model of the development of geometric thought. In M. M. Lindquist & A. P. Shulte (Eds.), *Learning and teaching geometry, K-12, 1987 Yearbook of the National Council of Teachers of Mathematics* (pp. 1-16). Reston, VA: National Council of Teachers of Mathematics.

Dimakos, G., & Zaranis, N. (2010). The influence of the Geometer's Sketchpad on the geometry achievement of Greek school students. *The Teaching of Mathematics, 13*(2), 113-124.

Erdogan, T., Akkaya, R., & Celebi Akkaya, S. (2009). The effect of the Van Hiele model based instruction on the creative thinking levels of 6th grade primary school students. *Educational Sciences: Theory and Practice, 9*(1), 181-194.

Hoffer, A. (1983). Van Hiele-based research. In R. Lesh & M. Landau (Eds.), *Acquisition of mathematics concepts and processes* (pp. 205-227). New York, NY: Academic Press.

Idris, N. (2009). The impact of using Geometers' Sketchpad on Malaysian students' achievement and Van Hiele geometric thinking. *Journal of Mathematics Education, 2*(2), 94-107.

Lee, J., & Kim, M. (2012). Development of web-based courseware for Van Hiele's visualization level. *International Journal of Modern Engineering Research, 2*(6), 4086-4090.

Mayberry, J. W. (1981). *An investigation of the Van Hiele levels of geometric thought in undergraduate preservice teachers.* (Unpublished doctoral dissertation). University of Georgia, America. Available from ProQuest Dissertations & Theses database. (UMI No. 8123078).

Nunnally, J. C. (1978). *Psychometric theory* (2nd Ed.). New York, NY: McGraw-Hill.

Poh, G. T., & Leong, K. E. (2014). Improving students' Van Hiele level of geometric thinking using Geometer's Sketchpad. *The Malaysian Online Journal of Educational Technology, 2*(3), 20-31.

Poh, G. T., & Leong, K. E. (2015). Enhancing Van Hiele's level of geometric understanding using Geometer's Sketchpad. In C. Vistro Yu (Ed.), *In Pursuit of Quality Mathematics Education for All: Proceedings of the 7th ICMI-East Asia Regional Conference on Mathematics Education* (pp. 501-507). Quezon City, The Philippines: Philippine Council of Mathematics Teacher Educators (MATHTED).

Prescott, A., Mitchelmore, M., & White, P. (2002). Student difficulties in abstracting angle concepts from physical activities with concrete materials. In *Proceedings of the Annual Conference of the Mathematics Education Research Group of Australia Incorporated.* (ED 472950).

Rosenthal, R. (1991). *Meta-analytic procedures for social research* (2nd Ed., Vol. 6). Newbury Park, CA: Sage.

Shoval, E. (2011). Using mindful movement in cooperative learning while learning about angles. *Instructional Science, 39*(4), 453-466. doi: 10.1007/s11251-010-9137-2

Siew, N. M., & Chong, C. L. (2014). Fostering students' creativity through Van Hiele's 5 phase-based tangram activities. *Journal of Education and Learning, 3*(2), 66-80.

Usiskin, Z. (1982). *Van Hiele levels and achievement in secondary school geometry*. CDASSG Project.

Van Hiele, P. M. (1986). *Structure and insight: A theory of mathematics education.* Orlando, FL: Academic Press.