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EFFECTS OF VAN HIELE'S PHASES OF LEARNING AND THEORY OF GEOMETRY THINKING ON GEOMETRY LEARNING OF MALAYSIAN YEAR FIVE STUDENTS

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By

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May 2016

Chairman: Professor Aida Suraya Md. Yunus, PhD

Faculty: Institute for Mathematical Research

This study investigates the effects of van Hiele's phases of learning strategy and levels of geometry thinking strategy using Google SketchUp in teaching of geometry, one of the areas in the scope on 'Shapes and Spaces' for Integrated Curriculum for Primary School. The study has three purposes. Firstly, identifying strategy that can help improve students' van Hiele's levels of geometry thinking in the learning of geometry at primary level. Secondly, determining students' spatial visualization ability, conceptual knowledge, procedural knowledge and performance in geometry. Thirdly, identifying the extent of effectiveness of van Hiele's theory in helping students in the learning of geometry. The results of the study support van Hiele's theory that student development in geometry is sequential from one level of thinking to the next without skipping any level. The development depends on the content and method of instruction but not on their age.

The first phase of the study involves development of the learning modules. ADDIE Model was adopted and implemented based on the required steps which are analysis, design, development, implementation and evaluation. The van Hiele's Phases of Learning Module (VH-PL) and van Hiele's Levels of Geometry Thinking using Google SketchUp Module (VH-GSU) consist of four units which include Three Dimensional Shapes, Triangles, Squares and Rectangles, Cubes and Cuboids. Each of the modules incorporates relevant content and instruction which are designed to be executed with van Hiele's development of geometry thinking and constructivist approach. For each module, students executed specific tasks in specific order which were aimed to assist them to progress through the first three levels of van Hiele's geometry thinking.

The study had adopted a randomized pre and post true-experimental design using three different groups of subjects. It was conducted to test the effects of the use of the modules on van Hiele's levels of geometry thinking, spatial visualization ability, conceptual knowledge and procedural knowledge. Data was collected before and after the use of modules. The 96 Year five participants of the study were randomly assigned into three equivalent groups to learn the selected geometry topics. The first group was exposed to the conventional learning strategy, the second group used the van Hiele's Phases Learning strategy and the third group used the van Hiele's Levels of Geometry Thinking using Google SketchUp strategy. Data was collected using Wu's Geometry Test, Spatial Visualization Ability Test and Geometry Achievement Test which includes measurement for conceptual knowledge and procedural knowledge.

The analyses revealed that the use of the van Hiele's Phases of Learning and Levels of Geometry Thinking using Google SketchUp modules assisted majority of the students to progress through their first three van Hiele's levels of geometry thinking with most of the progression occurring in sequential order. This study also underlay a framework to capitalize van Hiele's theory in developing teaching materials using technology or without technology as a practical alternative in assisting learners to progress through the levels of van Hiele's geometry thinking and ultimately reducing their learning difficulties in geometry. The study showed that there were significant differences in students' spatial visualization ability (p=.000 < .05), conceptual knowledge (p=.000 < .05), procedural knowledge (p=.000 < .05) and performance as a result of learning geometry using the modules developed. Finally, the study has proven that teaching based on interaction of van Hiele's theory, constructivism theory and principles of spatial visualization ability, conceptual knowledge and procedural knowledge make learning geometry easier for the students, thus improving their spatial visualization ability, conceptual knowledge, procedural knowledge and van Hiele's levels of geometry thinking.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN FASA PEMBELAJARAN DAN TEORI PEMBELAJARAN VAN HIELE TERHADAP PEMBELAJARAN GEOMETRI MURID MALAYSIA TAHUN LIMA

Oleh

TAN TONG HOCK

Mei 2016

Chairman: Professor Aida Suraya Md. Yunus, PhD

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Kajian ini mengkaji kesan strategi fasa pembelajaran dan tahap pemikiran geometri van Hiele menggunakan Google SketchUp dalam pengajaran geometri, salah satu bidang dalam skop 'Bentuk dan Ruang' bagi Kurikulum Bersepadu Sekolah Rendah. Kajian ini mempunyai tiga tujuan. Pertama, mengenalpasti strategi yang dapat membantu meningkatkan tahap pemikiran geometri van Hiele murid dalam pembelajaran geometri di peringkat sekolah rendah. Kedua, menentukan keupayaan visualisasi ruang, pengetahuan konseptual, pengetahuan prosedural dan prestasi murid dalam geometri. Ketiga, mengenalpasti sejauh mana keberkesanan teori van Hiele dalam membantu murid dalam pembelajaran geometri. Hasil kajian ini menyokong teori van Hiele dimana perkembangan geometri murid adalah berurutan dari satu tahap pemikiran ke tahap seterusnya tanpa melangkaui mana-mana peringkat. Perkembangan ini bergantung kepada kandungan dan kaedah pengajaran tetapi bukan pada tahap umur mereka .

Fasa pertama kajian ini melibatkan pembangunan modul pembelajaran. Model ADDIE diadaptasi dan dilaksanakan berdasarkan langkah yang diperlukan iaitu Analisis, Rekabentuk, Pembangunan, Pelaksanaan dan Penilaian. Modul Fasa Pembelajaran van Hiele (VH-PL) dan Modul Tahap Pemikiran Geometri van Hiele menggunakan Google SketchUp (VH-GSU) terdiri daripada empat unit iaitu Bentuk Tiga Dimensi, Segitiga, Segiempat sama dan Segiempat tepat, Kubus dan Kuboid. Setiap modul menggabungkan kandungan yang relevan dan pengajaran yang direka bentuk untuk dilaksanakan dengan pembangunan pemikiran geometri van Hiele dan pendekatan konstruktivis. Bagi setiap modul, murid melaksanakan tugas tertentu mengikut urutan yang bertujuan untuk membantu mereka melalui tiga peringkat pertama tahap pemikiran geometri van Hiele.

Kajian ini mengguna reka bentuk pra dan pos eksperimen sebenar secara rawak dengan melibatkan tiga kumpulan sampel yang berbeza. Ia dilaksanakan untuk menguji kesan penggunaan modul terhadap tahap pemikiran geometri van Hiele, keupayaan visualisasi ruang, pengetahuan konseptual dan pengetahuan prosedural. Data dikumpul sebelum dan selepas penggunaan modul. Sembilan puluh enam peserta kajian yang terdiri daripada murid Tahun Lima telah di agihkan secara rawak kepada tiga kumpulan yang setara untuk mempelajari topik geometri terpilih. Kumpulan pertama didedahkan kepada strategi pembelajaran konvensional, manakala kumpulan kedua menggunakan strategi Fasa Pembelajaran van Hiele dan kumpulan ketiga menggunakan strategi Tahap Pemikiran Geometri van Hiele menggunakan Google SketchUp. Data telah dikumpul menggunakan Ujian Geometri Wu, Ujian Keupayaan Visualisasi Ruang dan Ujian Pencapaian Geometri yang merangkumi pengukuran bagi pengetahuan konseptual dan pengetahuan prosedural.

Analisis menunjukkan bahawa Modul Fasa Pembelajaran van Hiele dan Modul Tahap Pemikiran Geometri van Hiele menggunakan strategi Google SketchUp ini telah membantu majoriti murid untuk menjangkau tiga peringkat pertama tahap pemikiran geometri van Hiele dan sebahagian besar perkembangan berlaku mengikut urutan. Kajian ini juga mendasari satu kerangka untuk mengunapakai teori van Hiele dalam membangunkan bahan pengajaran menggunakan teknologi atau tanpa teknologi sebagai alternatif yang praktikal dalam membantu murid menjangkau peringkat pemikiran geometri van Hiele yang akan memudahkan masalah pembelajaran mereka dalam geometri. Hasil kajian menunjukkan terdapat perbezaan yang signifikan dalam keupayaan visualisasi ruang murid (p=.000 < .05), pengetahuan konseptual (p=.000 < .05), pengetahuan prosedural (p=.000 < .05) dan prestasi dalam topik geometri menggunakan modul yang dibangunkan. Akhir sekali, kajian ini telah membuktikan bahawa hubungan di antara teori pembelajaran van Hiele, teori konstruktivisme dan prinsip keupayaan visualisasi ruang, pengetahuan konseptual dan pengetahuan prosedural membantu memudahkan pembelajaran geometri bagi murid, justeru meningkatkan keupayaan visualisasi ruang, pengetahuan konseptual, pengetahuan prosedural dan tahap pemikiran geometri van Hiele.

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I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of Tan Tong Hock on his thesis entitled "Effects of van Hiele's Phases of Learning and Theory of Geometry Thinking on Geometry Learning of Year Five Students" in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The committee recommends that the student be awarded the Doctor of Philosophy.

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LIST OF ABBREVIATIONS

ADDIE	Analysis, Design, Development, Implementation and Evaluation
AHS	Adaptive Hypermedia Systems
ANOVA	Analysis of Variance
ANCOVA	Analysis of Covariance
CAP	Comprehensive Assessment Program Geometry Test
CDASSG	Cognitive Development and Achievement in Secondary School Geometry
DGS	Dynamic Geometry System
DMO	Dissection-Motion-Operations
EG	Entering Geometry Test
EPRD	Educational Planning and Research Division
GAT	Geometry Achievement Test
GAT-CK	Geometry Achievement Test: Conceptual Knowledge
GAT-PK	Geometry Achievement Test: Procedural Knowledge
GIAS	Geometry Intelligent Adaptive System
GRA	Grey Relational Analysis
GSP	Geometer's Sketchpad
GSU	Google SketchUp
JPN	Jabatan Pendidikan Negeri
KIG	KDE Interactive Geometry
KBSM	Kurikulum Bersepadu Sekolah Menengah
KBSR	Kurikulum Bersepadu Sekolah Rendah
KSSR	Kurikulum Standard Sekolah Rendah
KPM	Kementerian Pelajaran Malaysia
KR-20	Kuder-Richardson Formula 20

LPM	Lembaga Peperiksaan Malaysia
MOE	Ministry of Education Malaysia
MPCK	Mathematics Pedagogical Content Knowledge
NCTM	National Council of Teacher of Mathematics
NVH-CI	Non-van Hiele - Conventional Instruction
PISA	Programme for International Student Assessment
SPM	Sijil Pelajaran Malaysia
SPSS	Statistical Package for Social Sciences
SVAT	Spatial Visualization Ability Test
TIMSS	Third International Mathematics and Science Study
UTM	Universiti Teknologi Malaysia
UPSR	Ujian Penilaian Sekolah Rendah
VHG	van Hiele Geometry Test
VH-GSU	van Hiele's Levels of Geometry Thinking using Google SketchUp
VH-PL	van Hiele's Phases Learning
WGT	Wu's Geometry Test
WMVHGT	Wu-Ma's van Hiele Geometry Test

CHAPTER 1

INTRODUCTION

1.1 Introduction

Geometry is an important branch of mathematics and it is one of the basic mathematical skills to be mastered (Abdul Halim & Effandi, 2013; Wu, Lee, Lin & Ma, 2015). In Malaysia, geometry has been formally introduced right from early primary education and it is further emphasized in secondary school, where about forty percent of the sixty topics in secondary mathematics curriculum comprise of geometry contents (Ministry of Education Malaysia, 2010). Therefore, a deep conceptual understanding about geometry properties in the primary level is important to the students before they proceed to secondary level.

Schwartz (2014) argued that students recalled their difficulty and unpleasant experience in learning geometry because of inadequate school geometry curriculum. Students would typically resort to rote memorization when they find the subject is difficult or they are unable to understand an area of study. Schwartz acknowledged that elementary and middle school geometry curricula have been designed with too many low-level experiences but students are asked to prove geometry reasoning in high school. This type of unreasonable expectation which expected students to jump to a higher thinking level is quite impossible for the average students. Ideally, the learning process in geometry has to be cumulative. Students should begin learning simple concepts first before proceeding to learn more complex or advanced geometry concepts. However, most school curricula are not designed in this manner. Therefore, learning difficulties encountered in geometry might occur and probably give inadequate experience to students in their early schooling years.

In Malaysia, the teaching and learning of mathematics has been reported to be too teacher-centred and students are not given enough opportunities to develop their own thinking (Abdul Halim & Effandi, 2013; Noraini, 2005; 2007). This situation causes students to be passive information receivers and do not result in conceptual understanding (Abdul Halim & Effandi, 2013; Noraini, 2005). A limitation in infrastructure development and appropriate curriculum (Mohd. Salleh & Zaid, 2013) are also cited as reasons why many students are not able to comprehend their mathematics lessons, especially in the area of geometry because mathematics content is usually taught with the intention of finishing the syllabus and preparing their students for examinations (Noraini, 2007).

Therefore, to provide geometric attainment that is consistent with learning processes in learning theory as well as promoting students' cognitive development while taking care of individual differences, teachers should consider using appropriate technology-related applications to assist students' geometry thinking in terms of spatial visualization ability, conceptual and procedural knowledge in geometry (Abdul Halim, 2013). Learning theory such as van Hiele's levels of geometry thinking and technology related applications has been widely investigated and developed to ease such learning difficulties across all levels of learning (Chang, Sung & Lin, 2007; Chew & Lim, 2013; Hutkemri & Effandi, 2012; Noraini, 2007). For example, in using Geometer's Sketchpad to develop van Hiele's levels of geometry thinking with teaching processes, teachers can give guidance and students are given enough time to explore the concepts by using the software during and after school lessons.

The utilization of technological advancement available nowadays has given both teachers and students an opportunity to have better and more effective ways of learning geometry. Teacher can effectively address the challenge of organizing mathematics instruction so that it attracts and develops the abilities of the greatest possible number of students (Abdul Halim, 2013; NCTM, 2000). Furthermore, through use of technological tools, students can develop geometrical knowledge in terms of visual, concept and procedures in understanding knowledge acquisition in mathematics education (Hutkemri & Effandi, 2012). In addition, Usiskin (1982) has described concepts in geometry such as the study of our physical world by representing them using mathematical system. Hiebert (2013) explained the terms "conceptual knowledge" and "procedural knowledge" as "knowing why" and "knowing how" respectively. Students can thus visualize mathematical concepts as "knowing why" and "knowing how" more easily if they can make use of computers. In a typical classroom, technology would be able to provide easy and clear illustrations, better than what a teacher could make without technology. Thus, students can construct the conceptual and procedural knowledge themselves and build up a strong and concrete base before they proceed to the secondary level (Hutkemri & Effandi, 2012).

In consequence, it is essential for Malaysian mathematics teachers to be prepared in dealing with educational changes, challenges and demands. Besides being experts in mathematics content and pedagogical skills, they should also be equipped with the needs of an ever-changing technological society and always be updated with the innovations and inventions of the latest technology (Leung & Man, 2005). Consistently, it is also stated in the Malaysian Mathematics Curriculum Specifications that the use of technology such as calculators, computers, educational software, websites and relevant learning packages can help to upgrade the pedagogical approach. It can also help to promote students' understanding of mathematical concepts so that they may have in-depth knowledge, and find their study meaningful (Ministry of Education Malaysia, 2010).

1.2 Malaysian Mathematics Curriculum in Geometry

Currently two versions of mathematics curriculum are used in Malaysian primary schools. The *Kurikulum Bersepadu Sekolah Rendah* (KBSR) is being used by the current Year Six students but it will be phased out by 2016. Current students in Year One to Year Five are using the *Kurikulum Standard Sekolah Rendah* (KSSR). Malaysia KBSR mathematics for geometry is categorized under the scope 'Shapes and Spaces'. However, in KSSR, geometry is categorized under the scope 'Measurement and Geometry'. In this study, the researcher used the term 'Shapes and Spaces' with the samples of study instead of geometry because they were more familiar with this term. In this thesis, the topic is referred to as 'geometry'.

Table 1.1: Malaysian KBSR and KSSR Mathematics Contents from Year One to Year Six

Year	Geometry Contents
KSSR Year One	Three-Dimensional Shapes (cube, cuboid, cone, cylinder, square pyramid and sphere), Two-Dimensional Shapes (square, triangle, circle and rectangle)
KSSR Year Two	Three-Dimensional Shapes (Properties and nets of cube, cuboid, cone, cylinder, square pyramid and sphere), Two-Dimensional Shapes (Properties of square, triangle, circle and rectangle)
KSSR Year Three	Three-Dimensional Shapes (prisms, non-prisms), Two-Dimensional Shapes (symmetry line(s) in squares, rectangles and triangles)
KSSR Year Four	Two-Dimensional Shapes (Identify the angles, parallel line, perpendicular line of square, rectangle and triangle; perimeter and area), Three-Dimensional Shapes (cube and cuboid; volume)
KSSR Year Five	Composite Two-Dimensional Shapes (Identify the angles, parallel line, perpendicular line of square, rectangle and triangle; perimeter and area), Composite Three-Dimensional Shapes (cube and cuboid; volume)
KBSR Year Six	Composite Two-Dimensional Shapes (square, rectangle and triangle; perimeter and area), Composite Three-Dimensional Shapes (cube and cuboid; surface area and volume)

In geometry, students learn about the basic features of three-dimensional and two-dimensional shapes and progress to the finding of perimeters and the areas. Later, they are exposed to composite three-dimensional and two-dimensional shapes in Year 5 and have further practice with composite shapes in Year 6 (Ministry of Education Malaysia, 2012a). Table 1.1 shows the geometry content in KBSR and KSSR mathematics from year 1 to year 6.

The coverage on KBSR and KSSR geometry (triangle, square, rectangle, cube, cuboid, pyramid, prism, sphere, cylinder and cone) is compatible with the coverage in geometry in primary and middle school curriculum throughout the world (National Council of Teachers of Mathematics NCTM, 2000). They learn about their properties (edges, angles, corner and surfaces) and the angle view of objects. The topics in geometry are well established in the curriculum and it involves connections to other areas of mathematics; therefore, an understanding of measurement, proportional reasoning, algebra and integers, among others, is necessary to develop the conceptual understanding in geometry. This belief is consistent with research which stated that understanding is built on geometry across the grades, from informal to more formal thinking (NCTM, 2000).

The Integrated Mathematics Curriculum for Secondary Schools (KBSM) is a continuation of KBSR. The entire mathematics contents is categorized into three inter-related areas; Numbers, Shape and Space, and Relationships. This categorization is based on the fact that in any situation it is imperative that a person has knowledge and skills related to counting, be able to recognize shapes and measurements as well as recognize relationships between numbers and shapes. The topics for each area in the syllabus have been arranged according to an accepted hierarchy because the basics have to be taught before abstract concepts can be introduced to students. Table 1.2 shows the Malaysian Mathematics KBSM contents for Form One to Form Five in geometry under the scope 'Shape and Space'. It is a compilation from curriculum specification of KBSM mathematics contents (Ministry of Education Malaysia, 2010). Geometry syllabus for Form 1 is more or less a repeat of what had been learned in primary level.

Table 1.2: Malaysian KBSM Mathematics Contents from Form One to Form Five

Form\Area	Contents on Shape and Space
Form One	Basic measurements; Lines and angles; Polygons; Perimeter and area; Geometrical solids
Form Two	Pythagoras' theorem; Geometrical constructions; Loci in two dimensions; Circles; Transformations; Solid geometry II
Form Three	Lines and angles II; Polygons II; Circles II; Solid geometry III; Scale drawings; Transformations II; Trigonometry
Form Four	Circles III; Trigonometry II; Angles of Elevation and depression; Lines and Planes in three-dimensions
Form Five	Transformations III; Bearing; Earth as a sphere; Plans and elevations

The aim of the KBSM is to develop individuals who are able to think mathematically and who can apply mathematical knowledge effectively and responsibly in solving problems and making decision. This will enable the individual to face challenges in everyday life that arise due to the advancement of science and technology (Ministry of Education Malaysia, 2010).

Similar to other countries, KBSM also emphasises the use of geometry skills to carry out the four basic main mathematical processes, namely problem solving; mathematical communication; making connection; reasoning and the use of technology (NCTM, 2000). Therefore, geometry should not be taught in separate units but should be treated in a natural context which is part of the mathematics curriculum. According to Hong (2005), geometry plays an important role in many mathematical fields, for example, ratios and rates are associated with the concepts of measurement and geometry.

1.3 Malaysian Students' Performance in Geometry

From the performance report of The Third International Mathematics and Science Study (TIMSS), in the area of geometry, the mean scores of the Malaysian students' performance were 497 in the year 1999, 478 (2003), 477 (2007) and 432 (2011). According to Choi, Lee and Park (2015), international comparison studies such as TIMSS have a potential value in providing information about school programs through analysis. These statistics show that in the international arena, performance in geometry of Malaysian Form Two students have declined over the years. When it comes to the analysis of benchmark cut point, Malaysian ranked at the category of "intermediate" which means students can apply basic mathematical knowledge in direct situations. Moreover, they only understand simple algebraic relationships. Students can relate a two-dimensional drawing to a three-dimensional object. They can read, interpret, and construct graphs and tables but are only able to recognize basic notions of likelihood (Mullis, Martin, Gonzalez, Gregory, Garden & O'Connor, 2000; 2004; 2008; 2013).

Malaysia first participated in the Programme for International Student Assessment (PISA) in year 2009. Svein (2015) stated that improving PISA-rankings has become a priority in many countries nowadays. According to the report (PISA, 2012), Malaysia ranked at 57 out of 74 countries with a score of 404 in the year 2009; and later ranked at 52 (out of 65) with a score of 421 in 2012. PISA tested students between the ages of 15 years three months and 16 years two months at the beginning of the assessment period. This is equivalent to Form Two students in Malaysia. With a mean of 500 and standard deviation of 100, Malaysian students' performance is at the bottom third among the countries that participated in the assessment. Shanghai, Singapore, Hong Kong, South Korea and Taiwan are the top five countries in PISA ranking. The PISA mathematics literacy test is different from TIMSS in that it asks students to apply their mathematical knowledge to solve problems set in real-world contexts. To solve the problems, students must acquire a number of mathematical competencies as well as a broad range of mathematical content knowledge. TIMSS measures more traditional classroom content in curriculum attainment such as an understanding of fractions and decimals and the relationship between them. PISA claims to measure application to real-life problems and lifelong learning (PISA, 2012). Through this assessment, Malaysian students' ability to solve real life problems are questionable.

In fact, an analysis of students' performance in the *Ujian Pencapaian Sekolah Rendah* (UPSR) in 2012, 2013 and 2014, for the subject of Mathematics, students have low performance in 'Shapes and Space' especially in the context of perimeter, area and volume. (Ministry of Education Malaysia, 2012b; 2013a; 2014). Report from the Examination Board of the Ministry of Education for the year 2011 and 2012 (Ministry of Education Malaysia, 2013c) showed that the performances for Mathematics in Malaysian Certificate of Education examination (*Sijil Pelajaran Malaysia,* SPM) ranged between 74.68 percent and 68.49 percent. The results above indicated that despite years of educational development and innovations, it would seem that a lot more needs to be done to improve the Mathematics performance among Malaysian secondary school students. New instructional methods or techniques should be attempted to ensure improvement in learning.

Since geometry is a branch of school Mathematics education, the deficiency in understanding geometry concepts at elementary level would affect their subsequent learning in geometry. This has direct consequences as in the secondary level there are more topics which are related to geometry concepts. The low rankings of Malaysian Form Two students in TIMSS and PISA, as well as poor performance in UPSR and SPM Mathematics results indicated that students' level of geometry thinking are still far from satisfactory. Therefore, there is a need to provide a firm foundation of geometry attainments in order to develop their geometry thinking. As far as the conceptual and procedural understanding of geometry is concerned, students must watch, listen, jot down the notes and think about what their teacher said (Özerem, 2012). Thus, primary geometry education is an empowerment to in- depth conceptual and procedural understanding before students are able to proceed to secondary level.

1.4 Learning Theories and Processes Related to Mathematics

When it comes to the learning of geometry in schools, many mathematics educators associate the development of its ideas and concepts with a famous model called van Hiele's model of geometry thinking (Abdul Halim & Effandi, 2013; Burger & Shaughnessy, 1986; Ding & Jones, 2006; Eleanor, 2003; Fuys, Geddes, & Tischler, 1988; Gutiérrez & Jaime, 1991; 1995; 1998; Mason, 1998; Neslihan & Mehmet, 2012; Noraini, 1998; 2007; Saifulnizan, 2007; Škrbec &. Čadež, 2015; Senk, 1989; Usiskin, 1982; Wu, 2004; 2005; Wu & Ma, 2005a; 2005b; 2009; 2015). This model was first proposed approximately 53 years ago by Dina van Hiele-Geldof and Pierre van Hiele at the University of Utrecht in the Netherlands. They identified five differentiated levels of geometry thinking and theorised that the students must progress sequentially from one level of thinking to the next without skipping any level. These levels are categorised into: Level 0 (Recognition or Visualization), Level 1 (Analysis or Descriptive), Level 2 (Informal Deduction or Ordering), Level 3 (Deduction) and Level 4 (Rigor). The progression from one level to the next is dependent on the content and method of instruction (van Hiele, 1986). The content of geometry topics can be systematically structured based on van Hiele's phases of learning geometry. These instruction phases include (i) Information, (ii) Guided Orientation, (iii) Explicitation, (iv) Free Orientation and (v) Integration (van Hiele, 1986). These five phases of learning will provide good guidance for teachers in designing their instruction if they wish to facilitate their students' ascension in knowledge from one level to the next.

When viewed from van Hiele's development of geometry thinking, the learning process of geometry involves all the five levels of thinking. However, when benchmarked with established research work conducted elsewhere, it was found that the first three levels (i.e. Level 0 (L0), Level 1 (L1) and Level 2 (L2)) play much more important roles in producing better conceptual understanding of elementary geometry (Knight, 2006). In

KBSR, the primary mathematics syllabus for geometry covers the basic characteristic of three-dimensional and two-dimensional shapes, finding perimeters and areas and composite three-dimensional and two-dimensional shapes. The expectation for students up to Year Six is to determine the relationships between these properties and between different figures but they are not expected to provide reasons as proof. Therefore, the van Hiele's levels of geometry thinking for Malaysia's primary level are only at informal deduction level (L2). As proposed by Gutierrez et al. (1991), when students are applying the procedures associated with each of the van Hiele's levels, the teacher is able to determine their degree of acquisition of the van Hiele's levels, and most of the students are usually at the first three levels. Burger and Shaughnessy (1986) claimed that van Hiele's levels are useful in describing students' thinking processes when they work on polygons. Adapting the study's procedures to investigate other geometry concepts seems clearly appropriate as many students who had studied geometry formally are assigned level 0 or 1 on tasks, not on higher levels such as level 2 or 3.

Geometry learning involves the ability to visualize as most of the geometrical concepts require visual interpretations (Noraini, 2006). In general, spatial visualization refers to the understanding and applications of geometry concepts using visualization-based representations and processes presented in diagrams, computer graphics programs and physical models (Claudia, 2003). The importance of spatial visualization ability in the process of learning geometry is very obvious at elementary level as it offers a method to see the hidden, enriches the process of scientific discovery and is a rich source of visualization for arithmetical, algebraic, and statistical concepts (Noraini, 2009; Zimmerman & Cunningham, 1991). In most cases, the lack of spatial visualization ability is found to be the main factor contributing to serious learning difficulties in geometry (Kurtulus & Yolcu, 2013; Pittalis, Mousoulides & Christou, 2010; Rahim & Siddo, 2009). It is in this case that the spatial visualization capacities of a dynamic software program are shown to be especially useful. Graph, diagram, pictures and geometrical shapes or models are tools for visualization of the abstract concepts in geometry. By means of these, human reason sets up a relation between physical or external world and the abstract concepts (Konyalioglu, Ipek & Isik, 2003). By using spatial visualization approach, many geometrical concepts can become concrete and clear for students to understand.

The use of technology in teaching and learning mathematics systematically assists in metacognitive process because it is able to produce symbols, formulas, tables, graphs, numbers, equations and manipulative materials to link the various real-world ideas and forms of conceptual and procedural knowledge (Hutkemri, 2012). Conceptual knowledge is seen as the knowledge of the core concepts and principles and their inter-relations in a certain domain. In contrast, procedural knowledge is seen as the knowledge of operators and the conditions under which these can be used to reach certain goals (Byrnes & Wasik, 1991). When the students have well-organized knowledge, this organization helps them to access relevant information easily and to apply it in the answering process. According to Aysegul (2012), the relations among knowledge types are required for success. He further reiterates that the distinction between conceptual and procedural knowledge is similar to the well-known distinction between declarative and procedural knowledge. We see conceptual knowledge as one kind of declarative knowledge among others, e.g. knowledge of examples and memories of specific situations.

Besides the conceptual and procedural knowledge, constructivist learning theory offers a sharp contrast to traditional instruction which is based on the transmission or absorption view of teaching and learning. Typically, the traditional approach would firstly involve a teacher's model through the completion of several examples and then students would attempt to repeat the same procedures demonstrated. From the constructivist perspective, learners are actively involved in the construction of their own knowledge, rather than in passively receiving knowledge (Bruning, Schraw, Norby & Ronning, 2004; Shelly, Cashman, Gunter & Gunter, 2004). In situations where learners are in control of elements in the learning environment, learning results are higher (Mayer & Moreno, 2002). For mathematics education, this constructivist perspective of learning is extremely appealing because having the learner constructs his or her own understanding is very conducive to build strong problem solving skills (Lee, 2006).

Ministry of Education Malaysia had provided all schools with Geometer's Sketchpad (GSP). However, the relatively high cost and limited availability of such dynamic geometry software have been a drawback for many students in Malaysia (Mohd. Salleh, Mohamad & Tan, 2012). There are also several self-developed computer prototypes designed to help students in learning geometry, for examples, Cabri, Thales, Cinderella, Dr Geo (Ding & Jones, 2007), and KDE Interactive Geometry (KIG) (Saifulnizan, 2007), but it may not be suitable for primary students because of the unclear or unmatched theoretical framework used in the development. As noted by Chang et al. (2007), most of the learning environment or software was designed according to the researchers' own rationales of learning rather than to the theory of learning geometry. However, there are other open sources such as GeoCAL and LOGO Based Geometry which apply van Hiele's model of geometry thinking. The former is designed mainly for game role whilst the latter is not suitable for the targeted group (elementary level) due to its complexity.

Geometry provides an opportunity for one to improve their spatial visualization ability, an ability which has always been regarded as important in fields such as engineering, architecture and visual arts. It is also applied in many daily life activities ranging from rearranging the furniture and objects in our houses, safe driving to find an address or doing any kind of sport (Kurtulus & Uygan, 2010). Spatial visualization ability in geometry was described as the ability to imagine the rotation of a represented object, to visualize the configuration, to transform a represented object into other shape, and to manipulate an object in the mind. NCTM Report (2000) puts up recommendation to teachers to use these methods to encourage their students to learn up these skills.

Viewed from this perspective, the *Google SketchUp* (GSU) is a free and easy-to-use software developed by Google which incorporates a suite of features and applications for architectural professionals. GSU might be useful to help both mathematics educators and learners to reduce the learning difficulties in geometry which discussed earlier. This can be done by the incorporation of carefully designed content-related instruction that can help to fix the missing part of predictable sequence of levels in the development of knowledge and also to promote the understanding of geometry concepts during the learning. It is envisaged that eventually this will help them to progress through the van Hiele's levels of geometry thinking. GSU which works on the Window environment offers facilities to create unlimited two-dimensional and three-dimensional models, a useful feature that would facilitate the exercise of visualization-oriented activities believed to be able to make many geometrical concepts and properties more concrete and clear for students to understand. Thus, GSU would provide a flexible learning tool at a representational level, linking the concrete to the abstract. Mathematical ideas can then be explored from several different perspectives in an efficient manner, resulting in deeper thinking levels of understanding (Kaput & Thompson, 1994). Through repetitive experience of exploring, problem-solving skill and one's ability to assimilate, ideas can be enhanced. This would certainly be helpful to promote active learning in that students are active learners and teachers act as facilitators in their geometry lessons.

1.5 Statement of the Problem

When recalling their learning experience in geometry, many students not only considered it as unpleasant, but also regarded it as difficult learning experience which discouraged them from further learning of the subject when they moved from elementary level to middle and high school level (Schwartz, 2014). This various facets of learning difficulties in geometry were made evident in numerous research findings. At primary level mathematics, van Steenbrugge, Valcke and Desoete (2009) described an overview of geometry learning difficulties encountered by primary students in Flanders. In United States, it was revealed that geometry posed consistent learning difficulties in all grade levels (Lorenzo, 2001; Schäfer, 2003; Schwartz, 2014; Strutchens, Harris, & Martin, 2001). Other studies conducted in Taiwan and China on the development of geometry proof competency have also provided empirical evidences showing that a large number of students had great difficulties in generating proofs even for simple geometry problems (Ding & Jones, 2006; Wu & Ma, 2005b; Wu et al, 2015).

In Malaysia, several factors have been identified to explain why learning geometry is difficult among students. These factors include geometry language, visualization abilities and ineffective instructions (Noraini, 2005). As reported in TIMSS 2011, internationally, the students in only 10 countries among 42 in total showed relative strength in geometry. From 1999 to 2011, Malaysian students have showed low performance in geometry in TIMSS (Mullis et al., 2000; 2004; 2008; 2013). Similarly, the report in PISA (2012) showed Malaysian students ranked in the bottom third among participating countries. Analysis of *Ujian Pencapaian Sekolah Rendah* (UPSR) showed that insofar as geometry is concerned, students generally have problems in perimeter and area in two dimensional shapes, and volume in three dimensional shapes. (Ministry of Education Malaysia, 2012b; 2013a; 2014). Hence, it seems that learning difficulties in geometry problems are faced by students around the world including in Malaysia.

Geometry in Malaysia is usually taught using traditional approaches such as textbooks, chalkboard and occasionally tools such as compasses and protractors in constructing geometry figures, thus learning becomes forced and seldom brings satisfaction to the students (Noraini, 2009). According to Hutkemri (2012), teachers often use more traditional methods such as explaining the definition of a concept by using procedural knowledge rather than conceptual knowledge when educational system is too exam oriented. Questions in tests usually require producing the procedures. Siew and Abdullah (2012) acknowledged that in primary school education, most of the content in geometry largely focused on knowing terms, definitions and attributes of shapes. Opportunities to manipulate concrete materials are neglected by teachers although much of the learning experiences still depend on the teachers (Noraini, 2006). Most school mathematics curricula are overly concerned with developing procedural knowledge in the form of speed and accuracy in using computational algorithms rather than the development of higher order thought processes (Nor'ain, 2008). In conclusion, teaching and learning in Malaysia are more towards teacher centred approach, and the aims of teaching are focussed on achievement of high scores in examinations rather than on conceptual understanding. This situation discourage active learning practices.

Furthermore, there is no conclusive evidence whether the teachers use van Hiele's model of geometry thinking in the teaching and learning of geometry in Malaysian primary schools. Based on the literature and Mathematics syllabus, van Hiele's model has been mentioned but we do not know the extent that it is being used. However in a small scale study conducted by Chew and Lim (2013) in one of the public primary schools in Selangor, Year Four students performed at level 0 (Visualization) and level 1 (Analysis) in the learning of certain shapes. Other researchers including Abdul Halim & Effandi (2012); Chew (2009); Kuek & Hafizah (2011) found that Malaysia's secondary students performed at the lower levels of van Hiele's model of geometry thinking. These lower levels of van Hiele's geometrical thinking may be due to the teaching approach of the subject at elementary level. Such a cause will have its effect in their geometry learning in their future.

Geometry is a unifying theme for the entire mathematics curriculum because it is rich in visualization. In many procedures it will speed up the algorithm of geometry courses. Several studies have been conducted to assist students in learning geometry in Malaysia such as using van Hiele's model and Geometer's Sketchpad to assist students in learning geometry at secondary level (Chew, 2009; Chew & Lim, 2011; Noraini, 2007; 2009; Abdul Halim, 2013; Abdul Halim & Effandi, 2012; 2013); clarifying van Hiele's model effect in learning (Kuek & Hafizah, 2011); using Geometer's Sketchpad in learning geometry (Johari, Chan, Ramli & Ahmat, 2010); Geometer's Sketchpad assist with visualization in learning geometry (Tat & Fook, 2005); spatial visualization ability in learning geometry (Noraini, 2005); and using KDE interactive geometry (KIG) software to learn geometry (Abdul Halim & Mohini 2008). There are also a few investigations on van Hiele's model using GSP at primary level (Chew & Lim, 2013) as well as study on students' conceptual understanding in geometry (Nasarudin, Effandi & Lilia, 2012). However, in this study, the researcher would attempt to cover more range of the van Hiele's model and compare students' van Hiele's levels of geometry thinking, spatial visualization ability, conceptual knowledge and procedural knowledge in learning geometry by using different methods such as using Google SketchUp software, without the use of software and conventional teaching. The study is aimed at primary level geometry in Malaysia which still lacks investigation. Knowledge in the elementary level is the foundation phase and if it is firmly established, it will ease the transition to further learning in the secondary level.

This idea is in alignment with the report in Malaysia Education Blueprint 2013 – 2025 (Ministry of Education Malaysia, 2013b), which proposed to improve Malaysia's school curriculum in order to achieve the top one third of participating countries in TIMSS and PISA especially in Science and Mathematics, other than to enhance the use of technology in our education system.

1.6 Purpose of the Study

This study investigated the effects of van Hiele's phases of learning and levels of geometry thinking strategies using Google SketchUp in teaching geometry under the scope of 'Shapes and Spaces' for KBSR. The study has three purposes. Firstly, identifying strategy that can help improve students' van Hiele's levels of geometry thinking in the learning of geometry at primary level. Secondly, determining students' spatial visualization ability, conceptual knowledge, procedural knowledge and performance in geometry. Thirdly, identifying the extent of effectiveness of van Hiele's theory in helping students in the learning of geometry.

In studying the effects, modules were first developed to be used in the experiment and compare the effect of the two modules with that of conventional teaching strategies on the learning of geometry of Year Five students. Students' learning was determined based on their performance in van Hiele's levels of geometry thinking, spatial visualization ability, conceptual knowledge, and procedural knowledge.

1.7 Objectives of the Study

The objectives of this study were as follows:

1. To develop van Hiele's Phases Learning Module and van Hiele's Levels of Geometry Thinking using Google SketchUp Module for the learning of Year Five geometry.
2. To determine the van Hiele's levels of geometry thinking among the students in Google SketchUp (VH-GSU) strategy group, van Hiele's Phases Learning (VH-PL) strategy group and the conventional instruction (NVH-CI) strategy group.
3. To determine the effect of van Hiele's theory in Google SketchUp (VH-GSU) strategy group, van Hiele's Phases Learning (VH-PL) strategy group and the conventional instruction (NVH-CI) strategy group on students' van Hiele's levels in learning geometry.
4. To determine whether there is any difference in the conceptual knowledge of students before and after the intervention of using different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).
5. To determine whether there is any difference in procedural knowledge of students before and after the intervention of using different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).
6. To determine whether there is any difference in students' spatial visualization ability before and after the intervention of using different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).
7. To determine whether there is consistency in performance in van Hiele's levels of geometry thinking in the pre-test, post-test and retention test between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).
8. To determine whether there is any difference in performance of students in learning different units between those who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).

1.8 Research Questions of the Study

The research questions are as follows:

1. How are the issues related to the achievement of geometrical thinking among year five students addressed in the development of the van Hiele's Phases Learning Module (VH-PL) and van Hiele's Levels of Geometry Thinking using Google SketchUp Module (VH-GSU)?
2. What are the students' van Hiele's levels of geometry thinking before and after intervention using different strategy (VH-GSU, VH-PL and NVH-CI)?
3. What is the effect of the newly developed van Hiele's Levels of Geometry Thinking using Google SketchUp Module (VH-GSU) and van Hiele's Phases Learning Module (VH-PL) in assisting primary school students to progress through the first three levels of van Hiele's geometry thinking in the learning of geometry in KSSR?
4. Is there significant difference in the mean scores of conceptual knowledge before and after the intervention between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)?

5. Is there significant difference in the mean scores of procedural knowledge before and after the intervention between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)?
6. Is there significant difference in the mean scores of spatial visualization ability before and after the intervention between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)?
7. Is there significant difference in the mean scores of students' van Hiele's levels of geometry thinking in the pre-test, post-test and retention test among those who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)?
8. Is there significant difference in the mean scores in the students' geometry performance in each different unit among those who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)?

1.9 Hypothesis of the Study

H_{01} There is no significant difference in the overall mean scores in conceptual knowledge before and after learning geometry using NVH-CI strategy.

H_{02} There is no significant difference in the overall mean scores in conceptual knowledge before and after learning geometry using VH-PL strategy

H_{03} There is no significant difference in the overall mean scores in conceptual knowledge before and after learning geometry using VH-GSU strategy.

H_{04} There is no significant difference in the overall mean scores in conceptual knowledge between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).

H_{05} There is no significant difference in the overall mean scores in procedural knowledge before and after learning geometry using NVH-CI strategy.

H_{06} There is no significant difference in the overall mean scores in procedural knowledge before and after learning geometry using VH-PL strategy.

H_{07} There is no significant difference in the overall mean scores in procedural knowledge before and after learning geometry using VH-GSU strategy.

H_{08} There is no significant difference in the overall mean scores in procedural knowledge between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).

H_{09} There is no significant difference in the overall mean scores in spatial visualization ability before and after learning geometry using NVH-CI strategy.

H_{10} There is no significant difference in the overall mean scores in spatial visualization ability before and after learning geometry using VH-PL strategy.

H_{11} There is no significant difference in the overall mean scores in spatial visualization ability before and after learning geometry using VH-GSU strategy.

H_{12} There is no significant difference in the overall mean scores in spatial visualization ability between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).

H_{13} There is no significant difference in the overall mean scores of van Hiele's levels of geometry thinking in pre-test, post-test and retention test in the learning of geometry for the NVH-CI strategy group.

H_{14} There is no significant difference in the overall mean scores of van Hiele's levels of geometry thinking in pre-test, post-test and retention test in the learning of geometry for the VH-PL strategy group.

H_{15} There is no significant difference in the overall mean scores of van Hiele's levels of geometry thinking in pre-test, post-test and retention test in the learning of geometry for the VH-GSU strategy group

H_{16} There is no significant difference in the overall mean scores of post-test for van Hiele's levels of geometry thinking between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).

H_{17} There is no significant difference in the overall mean scores of retention test for van Hiele's levels of geometry thinking between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI).

H_{18} There is no significant difference in the overall mean scores in the unit *Three Dimensional Shapes* between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)

H_{19} There is no significant difference in the overall mean scores in the unit *Triangles* between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)

H_{20} There is no significant difference in the overall mean scores in the unit *Squares and Rectangles* between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)

H_{21} There is no significant difference in the overall mean scores in the unit *Cubes and Cuboids* between students who undergo different strategies in learning geometry (VH-GSU, VH-PL and NVH-CI)

1.10 Significance of the Study

Radical changes in the world of information technology require educators to deal with enormous challenges faced in education. Based on the National Philosophy of Education, National Curriculum and Vision 2020, the teaching and learning of mathematics need a paradigm shift. This paradigm shift should be aligned with the country's aspiration that knowledge and skills acquired in mathematics will help to propel students forward in their careers. Geometry as a branch in mathematics is important to the students as it has been recognised as a basic skill in mathematics (NCTM, 2000) and also it has important applications to topics in basic mathematics (Sherard, 1981). For example, geometry and shapes are essential for teaching and learning of fractions, decimals and percentage, functions and calculus. In addition, geometry is a foundation for studies in many fields such as science, engineering, architecture, geology and astronomy (van de Walle, 2004). It has important applications to real-life problems (Noraini & Tay, 2004) such as arranging a living room, making frames, or planning a garden. Since it is important to students, a concrete understanding of its basics in elementary level will enable them to proceed to further study at the secondary level. Therefore, it is hoped that this study will encourage awareness among mathematics educators of the potential of using technology in learning geometry especially at the foundation stage. With the appropriate use of technology, it is envisaged that students can learn better. It can be done by planning well-designed lessons, designing instructional activities systematically, selecting strategies appropriately and creating mathematical tasks to take advantage of what technology can do so well and so efficiently.

The dearth of studies about the usage of computer software in teaching and learning of geometry in primary school in Malaysia has inspired the researcher to carry out this study. It is hoped that the findings of the study will also encourage the use of van Hiele's theory with the assistance of open sources such as Google SketchUp in the teaching and learning of geometry. Malaysian Ministry of Education has supplied Geometer's Sketchpad to secondary schools to be used in the teaching and learning of secondary mathematics. However, there is as yet no software being provided to primary schools which explored the efficacy of this technology. Thus, the empirical information of this study, if favourable, will support the use of GSU in the classroom. It is also hoped that teachers will explore the GSU technology in teaching and learning mathematics, especially in geometry. Further, the empirical information of the study can also benefit the Ministry of Education and school administrators in giving guidance to the planning, management and implementation of the technology.

The use of GSU could also be seen as using technology to improve students' cognitive abilities and students' metacognitive awareness in learning geometry. The integration of learning theories such as van Hiele's theory and constructivist learning theory provide a theoretical and conceptual framework for the understanding of human cognitive accomplishments through the process of constructing cognitive events which encompass the skills of individuals and also include the phenomena that are emerging in social interactions between people and structure in their environments. Therefore, the findings from this study are significant in that they will help to extend the knowledge base of the theories.

The curriculum developers at Curriculum Development Centre, colleges, and universities can use the results of the study to plan mathematics curricula systematically and appropriately using the GSU software. If the experimental group can achieve or record a positive impact from the usage of GSU, courses such as Technology of Mathematics Education can consider the introduction of GSU software in the teaching and learning of geometry. In consequence, the Teacher Training Division of the Ministry of Education can consider using GSU in workshops, seminars and training of pre-service teachers. Furthermore, this study investigates another strategy without technology that may be suitable to those schools which have little or no internet facility. It may help to solve the problem of little or no access to internet in certain schools while still fulfils the goal of increasing the achievement of van Hiele's levels of geometry thinking.

1.11 Limitations of the Study

There are several limitations to this study. Firstly, only geometry topics in the Year Five Mathematics syllabus were incorporated in this study. Therefore, the findings of the study may not necessary applicable to other mathematics areas or other levels of geometry learning.

Secondly, the samples chosen were restricted to Year Five students from schools in Batu Pahat, Johor only. Thus, the findings of the study can only be generalised to students similar to the samples studied.

Furthermore, this study did not intend to prove the theories related to the use of GSU in teaching and learning of geometry. It was only limited to test the applicability and usefulness of those theories in generating more effective instructional methods as compared to the current educational practice. In short, this study will be useful in expanding the knowledge base for the theories.

1.12 Definition of Terms

The definitions of some key terms used in this study are explained conceptually as well as operationally on how they were adjusted in the context of this study.

1.12.1 van Hiele's Levels of Geometry Thinking using Google SketchUp Strategy (VH-GSU)

van Hiele (1986, 1999) in describing levels of geometry thinking posited five sequential and hierarchical discrete levels of geometry thinking. The theory suggests that students pass through numerous levels of geometry thinking merely from recognizing geometry shapes to constructing a formal geometry proof. In this study, the VH-GSU in the teaching and learning of geometry incorporates the use of GSU software, activities such as planning, delivery, and evaluation are effectively disseminated in accordance with van Hiele's theory and based on constructivist learning theory.

Figure 1.1 shows students learn topics in geometry using Google SketchUp software by working on constructive activities to achieve the level of visualization (L0). By analysing features and properties of the shapes, they can achieve the level of analysis (L1) and ultimately they learn to solve concepts problems in order to achieve the level of informal deduction (L2).

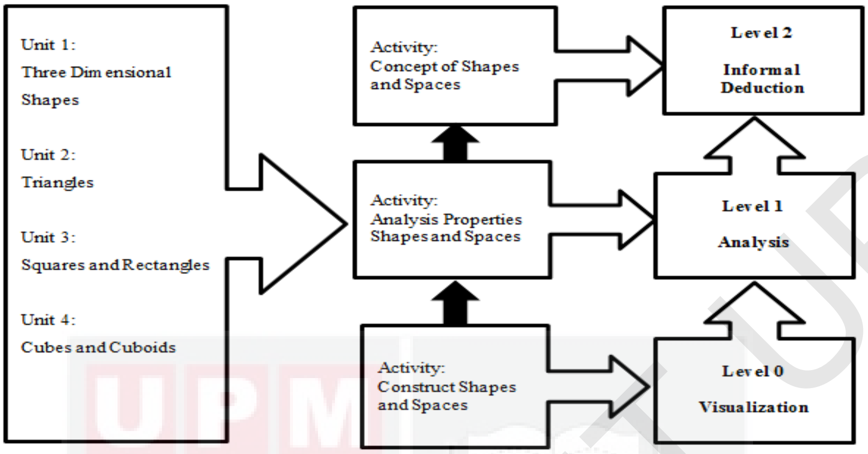

Figure 1.1: Learning Processes of VH-GSU

1.12.2 van Hiele's Phases Learning Strategy without Assistance of Technology (VH-PL)

van Hiele (1986) and Pegg (1995) explained that the van Hiele's phases learning is linked to the van Hiele's levels (Visualization, Analysis, Informal Deduction, Formal Deduction and Rigor). The phases are invariant with respect to any two adjacent van Hiele's levels. This offers teachers a chance to identify clear starting and ending points in their effort to raise students' thought at any given level to the next higher level during instruction in Geometry. Crowley (1987) described the activities for each phase as shown in Table 1.3.

Table 1.3: van Hiele's Phases Learning Strategy

Phase	Activity
Information	Interaction between teachers and students through highlighted discussion.
Guided Orientation	Students make exploration through planned activities.
Explicitation	Students can explain and express their views about the structure of the observed activity.
Free Orientation	Students can complete tasks with more complexity.
Integration	Students make a summary of what has been learned for the purpose of study.

Source: Crowley (1987, p. 5)

Figure 1.2 shows the learning process through van Hiele's phases learning strategy in order to pass through the levels of van Hiele's geometric thinking. Students learn topics in geometry through the phase of Information to achieve the Level of visualization (L0), the phases Guided Orientation and Explicitation to achieve the level of analysis (L1), and finally the phases Free Orientation and Integration in order to achieve the level of informal deduction (L2).

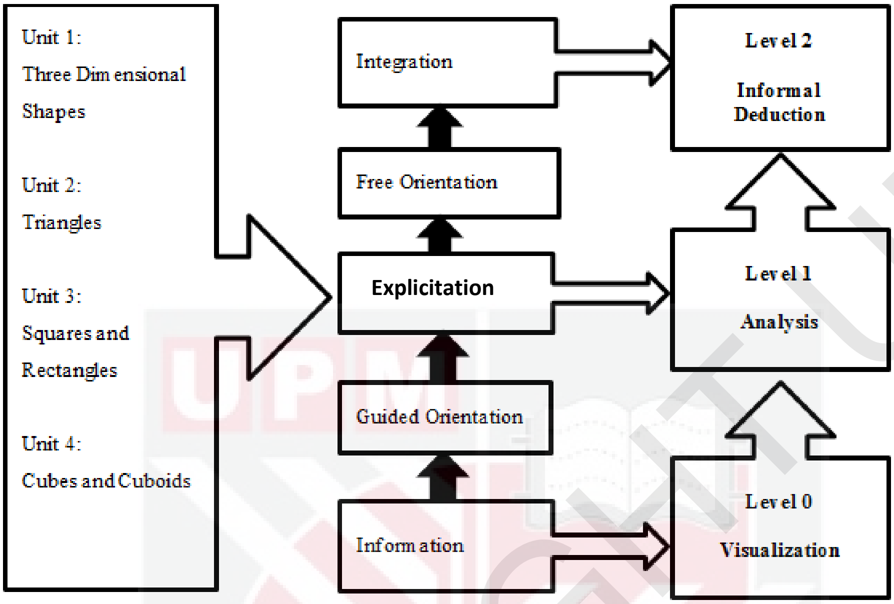

Figure 1.2: Learning Process of VH-PL

1.12.3 Conventional Instruction without van Hiele's Theory Strategy (NVH-CI)

Burden and Byrd (2003) defined conventional instruction as a process of teaching facts and principles verbally and students are expected to take notes. These methods are teacher-centred and do not seem to involve students actively in the teaching and learning process. The instruction is commonly referred to as lecture model. In this study, the conventional instruction strategy (NVH-CI) is the teaching strategy without the use of van Hiele's theory of learning or any software in the mathematics classroom. It is mostly carried out by teachers conveying and explaining a concept and students are given problems to be solved individually. Teachers usually discuss or explain the topic using the white board to draw conclusions about what they are teaching. Students are supposed to receive what is communicated by the teacher and then use the 'received' knowledge to solve problems.

1.12.4 Geometry Learning

Duval (1998) stressed that geometry learning involves three kinds of cognitive processes; which include visualization processes with regards to space representation, construction processes related to constructivism approach which are represented and reasoning in the relationship to discursive processes for extension of knowledge, for proof, and for explanation. In this study, geometry learning refers to the students' ability in spatial visualization ability, conceptual knowledge, procedural knowledge and van Hiele's levels of geometry thinking which are related to the coordination between the cognitive processes as mentioned by Duval (1998).

1.12.4.1 Spatial Visualization Ability

Noraini (2006) described spatial visualization as the ability to perceive the essential relationships among the elements of a given visual situation and creation of a mental image of a given concept of spaces. In this study, spatial visualization ability refers to how well students can mentally visualize views and interpret from different-perspective of two-dimensional pictorial representations (pairing rotated shapes) and three-dimensional structures (find the visible faces of the cubes).

1.12.4.2 Conceptual Knowledge

Hiebert (2013) defined conceptual knowledge as a connected web of knowledge, a network which is linked relationships of the discrete pieces of information. In this study, conceptual knowledge refers to the students' ability to interpret, explain, and apply mathematical concepts in the topic of geometry to a variety of situations and mathematical expressions. Score obtained in the Geometry Achievement Test (GAT) during pre-test and post-test shows the student's ability to make connection between the problem situation, relevant information, appropriate mathematical concepts and logical or reasonable responses.

1.12.4.3 Procedural Knowledge

Hiebert (2013) defined procedural knowledge as the algorithms and rules to complete the mathematical tasks, a mathematical equations or a form of writing included structural knowledge and algorithmic knowledge but not on mathematical content knowledge. In this study, the procedural knowledge shows the ability of students to solve mathematical problems in geometry which requires the application of algorithm-based method. Evidence includes the verifying and justifying of a procedure using concrete models, or the modifying of procedures to deal with factors inherent in the problem for the total score obtained in pre-test and post-test in Geometry Achievement Test (GAT).

1.12.4.4 Geometry Thinking

van Hiele (1986) defined geometry thinking as the levels of reasoning about geometry concept. In this study, the geometric thinking is referred to students' van Hiele's levels of geometry thinking and students' achievement scores in Wu's Geometry Test (WGT) in all the three groups involved in this study: control group (NVH-CI), treatment group 1 (VH-PL) and treatment group 2 (VH-GSU). In this study only the first three levels of geometric thinking were incorporated based on the recommendations of previous research studies as it was found that these first three levels of geometric thinking play much more important roles at primary level (Abdul Halim, 2013; Mohd. Salleh, Mohamad & Tan, 2012; van Hiele, 1986:).

1.12.5 Shapes and Spaces

Piaget, Inhelder and Szeminska (1960) argued that the development of learners' concept on shapes and spaces progresses through various stages of acquisition, representation and characterization of spatial concepts. The geometry content which was focused on in this study is categorized under the scope 'Shapes and Spaces' in KBSR which covers triangle, square, rectangle, cube, cuboid, pyramid, prism, sphere, cylinder and cone. This experimental study focused on all the shapes included under Year Five geometry content.

1.13 Summary

This chapter described the background of the research problem, objectives, research questions and interests. Chapter I also gave an overview of the conceptual framework that would be implemented which involved the development of van Hiele's Levels of Geometry Thinking using Google SketchUp (VH-GSU) Module based on the van Hiele's theory and the van Hiele's Phases Learning (VH-PL) Module. VH-GSU module contains activities based on the van Hiele's theory of learning geometry while VH-PL module contains activities based on the learning phase of the van Hiele's teaching strategy. In addition, the scope of the study and operational definitions were clarified. The following chapter provides a detail literature review regarding the study, which includes discussion on the basic principles of constructivist theory, spatial visualization ability, conceptual and procedural knowledge in learning geometry, van Hiele's model and van Hiele's phases of learning, computer technology as a mediator in the process of teaching and learning of geometry and ADDIE model of instructional design.

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BIODATA OF STUDENT

After obtaining his Teaching Diploma majoring in Chinese Language from *Maktab Perguruan Mohd Khalid,* Johor Bahru, Johor in 1992, Tan Tong Hock was posted to SJK(C) Malayan in Batu Pahat, Johor where he taught Chinese Language, Science and Mathematics. In 1999, he continued his study in UKM and obtained a Bachelor of Science Degree with honours, majoring in Mathematics. After graduation, he was allowed to serve in the same school until 2008. In 2009, he was offered a scholarship: "*Hadiah Latihan Persekutuan*" sponsored by Scholarship Department, Ministry of Education Malaysia to do his Master Degree. He enrolled in UTM and chose to major in Mathematics Education. After obtaining his Master Degree in 2011, he was posted to Tun Hussein Onn Malaysian Teacher Training College in Johor as a mathematics lecturer.

During his service in SJK(C) Malayan, Tan Tong Hock was given many administrative duties on top of his teaching duties. He has served as an assistant principal, an ICT teacher, a discipline teacher, a computer lab coordinator and also worked as a chief invigilator for UPSR exam. He received the Excellent Service Award (*Anugerah Perkhidmatan Cemerlang*) in 2000 and 2007. As a graduate student in UTM, he was given the Best Student Award in Mathematics Education, 2011. When he was serving in Teacher Training College, he received the coveted Quality Award of Tun Hussein Onn Malaysian Teacher Training College Campus in 2012.

To date, Tan Tong Hock has around twenty years of experience teaching Mathematic while serving the Ministry of Education. He was granted a second study leave in 2013 under the Federal Training Award (*Hadiah Latihan Persekutuan)* to continue with his PhD study. He then enrolled in UPM and pursued a Doctor of Philosophy degree in Mathematics Education.

LIST OF PUBLICATIONS

Tan, T.H., Rohani, A. T., Aida Suraya, M.Y., & Ahmad Fauzi, M.A. (2015). Understanding the Primary School Students' van Hiele Levels of Geometry Thinking in Learning Shapes and Spaces: A Q-Methodology. *Eurasia Journal of Mathematics, Science & Technology Education,* 11(4), 793-802.

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