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USING VAN HIELE-BASED INTERACTIVE VISUAL TOOL TO ALLEVIATE LEVEL OF THINKING IN GEOMETRY AMONG SECONDARY SCHOOL STUDENTS IN PAREPARE

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Abstract

There have been serious concerns about students' learning difficulty in geometry worldwide, including Indonesia. Research findings suggest that such phenomenon is best explained by the established van Hiele model of learning of geometry which associates the learning difficulties with the missing of predictable sequence of levels of development of knowledge and understanding geometry concepts. The model has been widely adopted as framework in the design and development of various technology-related applications designed to help learners to learn geometry effectively. However, the suitability and effectiveness of such applications among most of the post-SMP Indonesian school children is very likely to be dampen due to the lack of suitable infrastructure and inappropriate educational emphasis and practices. In addition, most of the applications were designed to help learners to develop knowledge and understanding across the spectrum of geometric topics rather than to help them to progress through their van Hiele geometry thinking on the level-by-level basis. This research paper discusses the needs to develop alternative learning instructions which address these discrepancies. A conceptual framework of the design and development of such instructions would also be discussed. The ultimate goal of the research is to develop interactive learning instructions (called Interactive Visual Tools or IVT) which assist post-SMP students in the region of Parepare to progress through van Hiele levels of geometry thinking via utilization of limited local resources over a minimal technology-oriented educational environment.

Keywords: van Hiele Model, geometry level of thinking, Interactive Visual Tool.

Introduction

The field of geometry covers a very broad scope and has many applications, such as ability to specify locations and describe spatial relationship (which is used in navigation to shipping or transportation), transformation and symmetry (which is used in a range of projects from packaging to artistic expression and in programming of computer graphics). Battista (1999) and Michelemore (2002) stated that learning geometry was not easy and many of students fail to develop an adequate understanding of geometry concepts, geometry reasoning and geometry problem solving skills.

Research findings suggest that the students' learning difficulties in geometry is best explained by the established van Hiele model of learning of geometry which associates the learning difficulties with the missing of predictable sequence of levels of development of knowledge and understanding geometry concepts (van Hiele,1959). Based on the relatively vast experiences as mathematics educators, the researchers strongly believe that the truth, validity and suitability of this specific learning model in geometry should remain applicable among Indonesian school children.

The technological advancement has benefited both mathematics educators and learners in easing various forms of mathematical difficulties, including geometry. The van Hiele model itself has been widely adopted as framework in the design and development of various technology-related applications designed to help learners to learn geometry effectively. However, the suitability and effectiveness of such applications among most of the post-SMP Indonesian school children is very likely to be dampen due to the lack of suitable infrastructure and inappropriate

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educational emphasis and practices. In addition, most of the applications were designed to help learners to develop knowledge and understanding across the spectrum of geometric topics rather than to help them to progress through their van Hiele geometry thinking on the level-by-level basis.

This paper highlights the nature of students' learning difficulties in geometry, worldwide and in particular, the Indonesian context. Results from preliminary studies will be reported to highlight the problems encountered by the researchers if we were to employ the existing remedial methods (especially the technology applications) which are designed and built for the use of school children in the developed nations. It thus discusses the needs to develop alternative learning instructions which address the problems of learning geometry encountered by Indonesian high school children. A relevant conceptual framework which is based on the van Hiele model would be discussed to provide an underlying theory of the design and development of learning geometry instructions. Specifically, these learning instructions would be designed and developed to assist post-SMP students in the region of Parepare to progress through the van Hiele levels of thinking which ultimately help them to ease their learning difficulties. It must be noted that these learning instructions by will be capitalizing the limited local resources over a minimal technology-oriented educational environment.

Background of The Study

Students' Learning Difficulty in Geometry

A report from Trend in International Mathematics and Science Study (TIMSS) in 2007 showed that students in the United States (U.S.), China, Netherland and Singapore scored at or near the bottom in every geometry task. Usiskin (1987) also stated that from all the students enrolled in U.S. high schools, only 63% can correctly identify different types of triangles and 30% can write proofs. Moreover, the National Assessment of Educational/Progress (NAEP) showed that U.S. fourth- and eighth-grade students performed poorly in basic concepts of geometry. The results from the 2007 NAEP revealed that fourth-grade students performed below the basic level on identifying figures based on descriptions and were close to the basic level in their performance on identifying congruent triangles. Eight-grade students had difficulty identifying the result of combining two shapes and performed at the basic level on modelling a geometrical situation given specific conditions (Lee, Grigg & Dion, 2007).

In Indonesia, many students were found to have encountered difficulty in learning geometry. Data from TIMSS 2007 showed that Indonesia's students for eighth-grade ranked 397 and the score was less than the average achievement, i.e. 500. Furthermore, the average Indonesian students' achievement on geometry was the lowest compared than other mathematic contents, i.e. Number 399, Algebra 433, Data and Chance 402, and Geometry 395. In addition, the participation of Indonesia's student in International Mathematical Olympiads still ranked among the lowest, i.e. in year 2008 to 2010 ranked 31, 28, and 36 respectively.

There were limited number of research on students' learning geometry conducted among Indonesian school children, especially at the levels of primary (SD), secondary (SMP) and high (SMA) school. Among them was Madja (1992) who found that the results of student's geometry test in senior high school (SMA) are less satisfactory than other mathematics main components, particularly those related to the understanding of concepts of geometry and those require spatial visualization. Later, Sudarman (2000) found that the achievement of elementary school (SD) students' geometry was low. He also found that many students in junior secondary school (SMP) did not understand the basic concepts of geometry. Moreover, Sunardi (2001) found that many students had difficulty in solving problems related to parallel lines.

The Underlying Theory of Students' Learning Difficulty in Geometry

As mentioned earlier, research findings suggest that the students' learning in difficulties in geometry is best explained by the established van Hiele model of learning of geometry which associates the learning difficulties with the missing of predictable sequence of levels of

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development of knowledge and understanding geometry concepts (van Hiele, 1959). According to van Hiele (1959), there are five levels of thinking in geometry learning, namely,

1. Level 0 (***Recognition***)
2. Level 1 (***Analysis***)
3. Level 2 (***Order***)
4. Level 3 (***Deduction***)
5. Level 4 (***Rigor***)

According to van Hiele, student must first move through a level of "Recognition" in which the student recognizes a shape as a whole and can distinguish a given shape from others that look somewhat the same. Once a student starts recognizing and naming parts and properties of geometry figures, the student could then progress to the next level a level van Hiele called "Analysis". At this level, students still does not require to understand the relationship between properties or to perceive figures. Upon successful completion of mathematical processes, the student can next move into a level called "Order" where he or she perceives relationship between figures, understand the role of definitions, logical implications, and class inclusion. A student at this level should be able to supply reasons for steps in a proof. Once a student is able to link up a sequence of statements to form a proof, the student is at the level of "Deduction." At this level the student also can understand the meaning of proof, the need for proof, and the role of definitions, postulates, and theorems. The highest level of understanding a geometry student is called "Rigor". A student at this level understands how the laws of logic apply to formal deduction and to valid arguments, and the student can manipulate symbols according to the laws of formal logic. A student at this level should understand the role of indirect proof and proof by contra positive. According to Hoffer (1985) and Usisikin (1986), the majority of high school student should reach level 2 (order) whilst level 4 (rigor) is found to be does not exist at the high school.

About the progression from one level to the next, van Hiele was optimistic that cognitive development in geometry can be accelerated by instruction (van Hiele, 1959). Therefore, inherent properties of each level of the theory of van Hiele are sequential and adjacency. Sequantial is students must be taught through the levels in order. To function successfully at a particular level, a learner must have acquired the strategies of the preceding levels and adjacency is at each level of taught what was intrinsic in the preceding level becomes extrinsic in the current level.

Various studies have proved the truth of the van Hiele theory of geometry in influencing learning in school, such as Brown (1991), Baynes (1999), Chong (2001), Tay (2003), and Noraini *et al.* (2004). Casbari (2007) also said that the use of the van Hiele model for learning mathematics can improve academic achievement and student motivation and provide an atmosphere in mathematics teaching and learning become more fun. Moreover, Mayberry (1981) had recommended that the secondary school geometry teachers need to be trained to understand the van Hiele Levels and also to develop their students' van Hiele levels.

In Indonesia, there were few researchs focussing on the van Hiele theory. Purnomo (1999) stated that mastery of the concept of geometry in secondary school will make easier for students to follow lessons in high school. Additionally, Zubedah (1999) found that learning geometry through conceptual change racing on the van Hiele theory improved the understanding level of geometry concept. Recently, Kahfi (2009) investigated that teaching geometry based on the van Hiele theory can alleviate the students to learning geometry at higher levels.

Technology Related Aplications in Learning Geometry

In this century, technology has been created to facilitate each job, including classroom teaching and learning process. Various softwares are available on the internet to solve difficulties in teaching and learning mathematics, especially geometry. For example, to facilitate the spatial structuring process and the reasoning required for translating two dimensional representations into three dimensional representations are available in the Geometer's Sketchpad software (GSP). Additionally, Geosupposer, GeoExplorer, Cinderella and Cabri 3D provide students with experiences in analyzing properties and in reasoning inductively (Liang & Sedig, 2009).

Those various applications usually have been prepared on a particular subject in accordance with school curriculum. Even there is a software that be prepared for the whole subject

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of geometry in each level, from elementary to high school. The success of such technology related applications are heavily dependent on the availability of suitable infrastructure, teachers' ability in using the technology available, educational emphasis and practices, educational belief and many other factors.

As mentioned earlier, the van Hiele model itself has been widely adopted as framework in the design and development of various technology-related applications designed to help learners to learn geometry effectively. However, the suitability and effectiveness of such applications among most of the post-SMP Indonesian school children is very likely to be dampen due to the lack of suitable infrastructure and inappropriate educational emphasis and practices. In addition, most of the applications were designed to help learners to develop knowledge and understanding across the spectrum of geometric topics rather than to help them to progress through their van Hiele geometry thinking on the level-by-level basis. These deficiencies are discussed as follows.

A Preliminary Study of the Applications of Technology in the Teaching and Learning among Indonesian Secondary Schools

In general, the use of computer software to facilitate the implementation of geometry learning has not been widely used in Indonesia, especially in local Parepare. There are 14 secondary schools in Parepare including both state and private schools. Based on the survey conducted in July 2010, the results showed that of only 9 schools (60%) which have an internet network and 7 among 9 schools that are using WIFI internet network. Moreover, the comparison between the numbers of students with computer availability at school is approximately 1:50. It means that one computer will be used by 50 students. The complete information about the school, number of teachers, number of students, and information communication technology (ICT) in each school is presented in Table 1.

Table 1. Information about the Use of ICT at Secondary Schools (SMP) in Local Parepare

No.	Name	Status	Established	Total teacher			Total student				Number of computer in lab			Network type		
				Math	Non Math	Total	VII	VIII	IX	Total	Bad	Good	Total	Wireles	Cable	Other
1	SMP Negeri 1	State	1951	6	56	62	288	360	360	1008	11	20	31	v	-	-
2	SMP Negeri 2	State	1960	8	66	74	270	309	301	880	20	10	30	v	-	-
3	SMP Negeri 3	State	1965	6	54	60	256	260	211	727	0	18	18	v	v	-
4	SMP Negeri 4	State	1977	5	45	50	192	161	177	530	2	14	16	v	-	-
5	SMP Negeri 5	State	1978	4	33	37	220	198	167	585	4	16	20	-	v	-
6	SMP Negeri 6	State	1985	5	29	34	128	112	115	355	4	5	9	-	-	-
7	SMP Negeri 7	State	1985	4	20	24	59	54	39	152	0	0	0	-	-	-
8	SMP Negeri 8	State	1992	3	23	26	74	118	86	278	0	0	0	-	-	-
9	SMP Negeri 9	State	1993	7	30	37	224	254	216	694	0	11	11	v	v	-
10	SMP Negeri 10	State	1995	4	38	42	192	167	178	537	6	12	18	-	v	-
11	SMP Negeri 11	State	1994	3	20	23	40	55	50	145	0	5	5	-	-	-
12	SMP Negeri 12	State	1999	3	28	31	96	86	88	270	-	5	3	-	-	-
13	SMP Muhammadiyah	Private	1951	2	19	21	39	45	65	149	1	4	5	v	v	-
14	SMP Frater	Private	1959	2	15	17	47	60	58	165	3	2	5	v	-	-
	TOTAL			62	476	538				6475		122				

The survey also aimed to know the ability of the mathematics teachers at SMP in local Parepare in using ICT in teaching process and the results could be seen in Table 2. The results showed that 10 or 23.8% of 52 mathematics teachers still cannot use computer. Moreover, 44% of them stated that they never used computer in teaching mathematics in the classroom. In addition, only one teacher knew the existence of geometry software on the internet.

The scenarios mentioned above strongly suggest that the remedial of students' learning difficulties in geometry among Indonesian students in the local Parepare could not be eased using the applications of technological advancement designed for the use of school children in the developed nations. The researchers strongly believe that the van Hiele model could be used to

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provide an underlying theory of the design and development of learning geometry instructions (called van Hiele-Based Interactive Visual Tools or IVT). The IVT is to be designed and built to assist students in local Parepare in easing the learning difficulties by means of facilitating the proper progression of van Hiele geometry thinking among the learners as explained in the earlier section. In doing so, the researchers would 'adopt and adapt' the van Hiele model via the utilization of limited local resources over a minimal technology-oriented educational environment in order to develop alternative learning instructions which address the problems of learning geometry encountered by Indonesian high school children. The detail of the conceptual framework is presented in the following section.

Table 2. The Practices of Teaching with Technology among Mathematics Teachers at Local Parepare

NO	QUESTION	RESPONSE (persons and percentage)			
1.	Ability to operate computer	Very good 1 1.9%	Good 23 44.2%	Less 1 6.5%	Poor 9 17.3%
2.	Frequency of using computer in teaching and learning process	Often 8 15.4%	Fair 13 25%	Rarely 8 15.4%	Never 23 44.2%
3.	Frequency of using or browsing internet	Often 3 5.7%	Fair 15 28.8%	Rarely 11 21.2%	Never 22 42.3%
4.	Frequency to get a teaching material from internet	Often 3 5.7%	Fair 12 23.1%	Rarely 16 30.8%	Never 21 40.4%
5.	Do you know about geometry software in internet?	Yes 1 1.9%	No 51 98.1%		
6.	Frequency of using geometry software from internet in teaching the class	Often 0 0%	Fair 0 0%	Rarely 0 0%	Never 52 100%
7.	Do you know about van Hiele theory?	Yes 1 1.9%	No 51 98.1%		
8.	Frequency of pay attention at the level of student thinking in teaching geometry based on van Hiele theory.	Often 0 0%	Fair 0 0%	Rarely 0 0%	Never 52 100%

Conceptual Framework for the Design and Development of van Hiele-Based Interactive Visual Tools

The limited infrastructure and lack of ability of teachers in the mastery of technology are the major barriers in the applications of technology in the teaching and learning of geometry in local Parepare. This condition causes the achievements of the secondary school students in learning mathematics in Parepare were very low from year to year. Consequently, it would be complicate for the students to study mathematics at higher level or in SMA, particularly on the material geometry subject. To overcome this problem, we need to develop a new method to teach geometry to students based on existing conditions.

Hershkowitz (1989) claimed that visualization is a necessary tool in geometry concept formation. Some mathematics educators also recommended more visual activities in the classroom

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to help students understand geometric concepts (Usiskin, 1987; Kor, 1995; Chong, 2001). Theory of multiple intelligent by Howard Garner suggested that some learners are kinaesthetically inclined (in Campbell, Campbell & Dickinson, 1996), it is means that they learn best actively involved with the objects of their learning. For this type of learners, interactive visualization process-oriented activities are considered to be most beneficial.

As mentioned earlier, the researchers have decided to 'adopt and adapt' the van Hiele model as to provide an underlying theory of the design and development of IVT. The IVT would be capitalizing the interactive visualization process-oriented activities focusing on level-by-level basis to assist the learners to progress through the van Hiele geometry thinking under a minimal technology-oriented educational environment. The research focuses only on the progression of the first three levels of van Hiele geometry thinking, namely, Level 0 (L_0), Level 1 (L_1) and Level 2 (L_2). The emphasis of the interactive visualization process-oriented activities would be on the recognition, identification and classification of geometrics objects together with the recognition of other images as well as their geometric properties. These interactive visualization process-oriented activities are designed to engage the students in drawing and finding the properties of each shape by their self in order to make the students could recognize the relationship between shapes. This proposed conceptual framework of the design and development of the IVT is depicted in Figure 1.

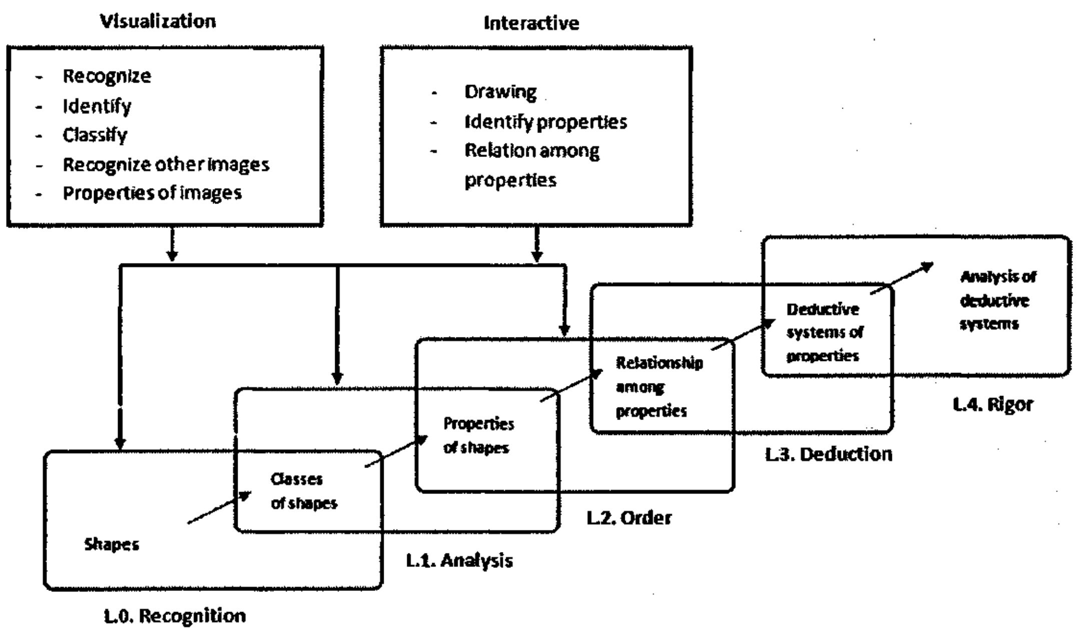

Figure 1. The Conceptual Framework of the Design and Development of van Hiele-Based Interactive Visual Tools

Conclusion

In Indonesia, many students generally have difficulty in learning geometry. This paper has discussed about the needs to develop alternative learning instructions which address the geometry learning, particularly in local Parepare. A conceptual framework of the design and development of such instructions have also been discussed. The ultimate goal of the research is to develop interactive learning instructions (called Interactive Visual Tools or IVT) which assist post-SMP students in the region of Parepare to progress through van Hiele levels of geometry thinking via utilization of limited local resources over a minimal technology-oriented educational environment. Finally, the proposed method is expected to improve the geometry level of thinking students at Parepare.

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