Experts and designated users evaluations on visual tools screencast SketchUp Make (Vi-ToS-SUM)

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Experts and designated users evaluations on visual tools screencast SketchUp Make (ViToS-SUM)

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Experts and designated users evaluations on visual tools screencast SketchUp Make (ViToS-SUM)

The problem and the aim of the study. Students at secondary school are facing problems in learning Mathematics for topic Geometry. The purpose of this study is to examine the validity of a learning strategy for 3-dimensional Geometry, using Visual Tools Screencast SketchUp Make, called ViToS-SUM.

Research methods. ViToS-SUM consists of four components: level of van Hiele geometrical thinking, visual spatial skills, visual tools and video tutorial screencast SketchUp Make. A topic in form 3 mathematics, Plans and Elevations was chosen for this study. The whole process of design and development of ViToS-SUM adopted the five cyclic stages of ADDIE instructional design model. This article addresses the details of the final two stages specifically, implementation and evaluation prior to pilot test. Twelve students from a secondary school and three experts involved in this study. Quantitative approaches were used to collect data as well as to analyse the experts' and students' views on the appropriateness of ViToS-SUM.

Results. The experts agreed that both visual spatial skills (mean = 5.00) and level of van Hiele geometrical thinking (mean = 4.61) should be embedded in ViToS-SUM. Moreover, the experts also agreed that the content of ViToS-SUM is suitable (mean = 4.51) with the mathematics content for topic Plans and Elevations. The pre and post test showed that there were significant differences in mean scores of visual spatial skills before and after learning via ViToS-SUM ($t=12.21$; $p<0.05$). Furthermore, the pre and posttest also revealed that there is a significant difference in students' level of van Hiele geometrical thinking before and after intervention ($Z = -3.18$; $p < 0.05$). Thus, ViToS-SUM had supported most of students in constructing concepts of Geometry. Meanwhile, the findings revealed that all experts agreed that ViToS-SUM served as pedagogical learning strategy for Geometry.

Conclusion. This learning strategy should be integrated in the mathematics curricular for secondary schools to increase students' performance in Geometry. Training is needed for teachers in order to deliver the concepts of Geometry effectively using this mode of teaching. More computer facilities should be equipped to schools in order to encourage teachers and students to utilize technology in teaching and learning.

Keywords: level of van Hiele Geometry thinking, visual spatial skills, screencast video

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Introduction

Students' problems in learning Geometry are pertinent issues to be highlighted by educators [1; 2]. A report from Trend in Mathematics and Science Study (TIMSS) 2015 showed that the Malaysian students' performance in Geometry is very alarming [3]. The students only scored 455 points for Geometry which was below the average score for TIMSS and was classified to be at low level. Similarly, Indonesia and Thailand were also at the same level [3]. The findings indicated that there were pitfalls in teaching Geometry which reflected that teacher failed to inspire students to learn [4]. On the other hand, the topic of 3D Geometry is vital for high school students as it prepares them for university courses in science and technical fields [5]. Besides, this topic also has to do with students' real lives and their future careers [6]. Thus, an effective pedagogical learning strategy for Geometry should be designed and implemented in schools as suggested by Ministry of Education (MOE) in Malaysian Education Blueprint, that educators are encouraged to deliver the best teaching pedagogy for the future leaders [7].

Therefore, the factors that contributed to the problems in learning Geometry should be identified. Students' weakness in Geometry is associated with low level of geometrical thinking [8] and low visual spatial skills [9]. These two cases were highlighted by the National Council of Teachers of Mathematics (NCTM) as the important factors that influenced students' performance in geometry [10]. Level of geometrical thinking is referred to level of van Hiele Geometrical Thinking (LvHGT). It is based on geometry thinking model which was proposed by [11]. This model consists of five levels: level 1 (Visualization), level 2 (Analysis), level 3 (Informal Deduction), level 4 (Formal Deduction) and level 5 (Rigor). Van Hiele believed that students should go through all levels of thinking while learning Geometry. Meanwhile, visual spatial skills (VSS) is ability to rotate, view, transform and cut mentally [9]. In order to learn Geometry, students are required to have high VSS [12]. If they have low VSS, they will have difficulty in visualizing the properties of the 3D object [13]. Students need high VSS to create and manipulate mental images of the solid objects [14].

However, most of the lessons conducted in school for Geometry in Malaysia are contradicted with van Hiele geometry thinking model [15]. They claimed that basic knowledge of Geometry was neglected and students were directly exposed to formal deduction (L4). Consequently, most of the students are having problems in reasoning skills that required them to analyse answers and make conclusion [8]. In contrast, the students are supposed to start from L1 and they will go through all levels based on the van Hiele model. Previous studies had shown that learning strategy using van Hiele model among students in Malaysia, had increased their LvGHT [16]. On the other hand, they also found that majority of the Malaysian students were at the lowest level of van Hiele model. Thus, there is a need to implement this model in Geometry curricular. Teaching strategies that used by teachers in class also influence students in learning Geometry [17]. Besides using textbook and marker board, most of the teachers use 3D models and draw 2D drawings of 3D objects in their teaching of 3D Geometry topics, but both methods are considered ineffective because they are not sufficient to represent the 3D objects [18]. Thus, this mode of teaching will encourage students to learn by memorizing the concepts of Geometry [19]. However, the problems can be overcome by using a 3D manipulative software that provides powerful tools to assist students in visualizing the solid objects [20]. Yahya et al. [21] named them as visual tools.

Even though the 3D software supports students in learning, students encountered problem as they could not remember all the steps in using the tools [22]. Moreover, teachers found difficulty in teaching students with different ICT skills [23]. These obstacles can be solved by applying video tutorial with screencast technique as suggested by [24]. The steps in using the tools in 3D software can be recorded as video tutorial by using a special software [20]. Thus, the screencast video helped to reduce user's cognitive load [25]. In this study, SketchUp Make is chosen as a 3D software and video screencast which is called as Video Tutorial SketchUp Make (VTS-SUM), was developed for the activities in the module. Thus, the purpose of this study is to determine the validity of Visual Tools Screencast SketchUp Make (ViToS-SUM) which has been designed and developed before its effectiveness was tested in mathematics classrooms.

Level of van Hiele Geometrical Thinking (LvHGT)

LvHGT comprises of five levels but only four levels of Geometry progression from Level One (Visualization) to Level Four (Formal Deduction) will be embedded in this module. The fifth level (Rigor) is related to high-level thinking, which is complicated and complex. Thus, it is not suitable for high school students [26]. Crowley [26] stated that teachers must provide material at one level to enable students to move to the next level. L1 is the first level where students are able to visualize the geometrical shape of the object given to them such as vertices, edges and faces. L2 is the second level where students will investigate the properties of the solid objects such as length of the edge and size of the angle. The third level is L3 where students can make non-formal judgement about the orthogonal projection for the solid objects. In this order to do that, students should be able to transform 3D object to 2D image for the orthogonal projections. The last level, L4 is the highest level where students should be able to reason formally the orthogonal projections of the solid objects including the hidden lines in the objects which cannot be seen but can be inferred by other attributes.

Visual Spatial Skills (VSS) and Visual Tools

VSS consists of four elements: rotate, view, transform and cut mentally [11]. Yahya et al. [21] proposed a set of tools in SketchUp Make that could perform task for VSS. The tools are orbit, position camera, standard view and section cut. Orbit is used to rotate the solid object in the plane that permits users to explore the properties for the solid object. The second tool, position camera sets the camera mode on parallel projection to allow users to see solid edges more clearly. The standard view is a tool that enable users to transform the 3D objects to 2D images that relate to orthogonal projections of the objects, while section cut is used to cut the surface of the solid object to let the users see the sides inside the objects.

Video Tutorial Screencast SketchUp Make (VTS-SUM)

VTS-SUM is a know-how video that guides students how to use SketchUp Make to complete the activity in the module. This video is particularly useful for students as they may control their learning rate [20]. Students may stop the videos and replay them as much as possible at their own pace [4]. Special effects (such as screen draw, screen-zoom (zoom-n-pan) and arrow with text (callout with text) may be included in the video to emphasize the steps involved in a process.

Van Hiele learning phases

The activities in the module are developed based on ADDIE Model. In order to promote van Hiele model to students, phases of instructions are needed as guideline for teachers [8]. This module is structured to be carried out based on the five phases of Van Hiele learning: (1) Phase 1 (Inquiry/Information), (2) Phase 2 (Direction Orientation), (3) Phase 3 (Explanation), (4) Phase 4 (Independent Orientation) and (5) Phase 5 (Integration). Each activity starts with phase 1 that provides information to students a general overview of following steps and directions in their lesson. In phase 2, students will be given clear instructions on how to observe the digital 3D objects via the video tutorials provided. In phase 3, students will present their experiences of the observed structure using their own expressions. In phase 4, students are provided with digital 3D objects to test their understanding of the concepts learned beforehand. Students are free to choose the digital objects given in the exercise. Finally, in phase 5, students will interpret the knowledge acquired through the previous lessons, activities and discussions.

Hence, ViToS-SUM consists of a learning module which is a packet of teaching materials that contains objectives, a sequence of activities and evaluation. It is also defined as a kit of learning in which students are guided by step-by-step instructions and it can be executed individually or in groups [27]. At present, there is a lack of studies concerning the integration of these four components. A learning strategy which is called Visual Tools Screencast SketchUp Make (ViToS-SUM) is designed to address the issue of student's incompetence in doing 3D Geometry, particularly in the sub-topic of Plans and Elevations. This topic is chosen because it has both LvGHT and VSS [2]. ViToS-SUM was developed with the help of an experienced teacher and three lecturers. There were eight activities in this module that incorporated the four core elements: LvHGT, VSS, Visual Tools and VTS-SUM. The module for ViToS-SUM is accordance with form 3 mathematics, chapter 7 regarding Plans and Elevations. It was designed for two learning objectives: Orthogonal projections and Plans and Elevations. The first objective for this topic requires students to draw orthogonal projections and compare and contrast between objects and the corresponding orthogonal projections, while the second objective needs to draw the plan and elevations of an object to scale.

Purpose of the study

The purpose of this study is to examine the validity of a learning strategy for 3-dimensional Geometry, using Visual Tools Screencast SketchUp Make, called ViToS-SUM.

Research methods

Design of the Study

The data of this study were collected through quantitative approaches. The quantitative data collection was divided into two stages, specifically Stage I (expert validity) and Stage II (Pre-test and Post-test).

Study participants

Two groups of subjects were involved in this study, namely experts and students. For stage I, the experts were assigned to evaluate the content validity of ViToS-SUM. For stage II, the selection of students for pre and posttest comprised of twelve form 3 students from a secondary school with purposive sampling method that aligned with [28] the number of respondents involved in the research. They were given Pre-test for VSS and LvHGT before using the intervention and Post-test for VSS and LvGHT after the intervention.

Instrument for data collection

Expert Validation

The validity study of ViToS-SUM was conducted before testing in the actual study. This aims to ensure that the objective of the study can be achieved; that is to improve VSS and students' level of geometrical thinking. Validity refers to how accurate the measuring instrument can measure the problem being studied. Meyer [29] and Russell [30] suggested method that can be used is expert validation. The instruments consist of four sections, A (respondent demography), B (van Hiele levels of Geometry thinking), C (Visual Spatial Skills) and D (Mathematics content) which are measured on a 5-point Likert scale (1: Strongly Disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly Agree). Instrument reliability indicates that the instrument is consistent or stable to be used as an instrument. The standard of reliability coefficient of .70 is usually associated with the instrument's reliability [31] and was adopted as the benchmark for the instrument in this study. The data were analyzed based on Cronbach's Alpha coefficient. The test obtained the reliability at 0.80, which is considered 'very good'.

Pre- and Post-Test

The pre and post-tests were conducted to test the students' levels of VSS and LvHGT. Four instruments used to evaluate VSS were based on a standard criterion for spatial ability. These instruments are widely used by researchers who have conducted studies at secondary schools in Malaysia [2; 16]. Similarly, these instruments had been used by other researchers from other countries [18; 32]. Sorby [33] suggested the Purdue Spatial Visualization for Rotation Test (PSVT: R), Purdue Spatial Visualization for View Test (PSVT: V) and Mental Cutting Transformation test (MCT), while Mohd Safarin [34] developed T3D2D test for transformation. Hence, in this study the PSVT: R was employed to measure a student's ability to rotate mentally, the PSVT: V was used to measure a student's ability to describe an object from the viewpoint of mental assigned, the Mental Transformation test for 3D to 2D (T3D2D) was used to measure the ability to manipulate mentally, and the MCT was employed to measure mental cut abilities. Previous studies had shown that researchers used these instruments. In addition, LvGHT test was applied to measure the level of students' geometric thinking which has been used widely by researchers in Malaysia such as [2; 16]. Besides that, researchers from other countries had used this test to determine students' level of geometric thinking [19; 35]. Therefore, the four levels of LvHGT (L1, L2, L3 and L4) were being displayed as main items in designing the module.

Findings

For stage I, the selection of experts to evaluate the content validity of ViToS-SUM was based on their expertise and feasibility. They comprised of two (2) lecturers and a teacher who have over 20 years of experience. In order to evaluate visual spatial skills and levels of van Hiele Geometry thinking, two lecturers in these fields of study were engaged. Appointment letters were sent out to these experts. They were also contacted through telephone and email. Then appointments were made to meet the experts in person to hand out the validation forms as well as to brief them personally about ViToS-SUM. They were given two (2) weeks to complete their validation reports. Meanwhile in stage II, the researcher used quantitative design approach using a one-group pre-test and post-test quasi experiment. The researcher conducted pre-posttest and recorded the students' performance before and after the intervention. The intervention was carried out in 4 weeks. Thus, the researcher would like to find out if there is any significant difference on level of VSS and LvGHT between pre-test and post-test.

Stage I

The findings from the experts were based on three (3) aspects: (1) van Hiele levels of Geometry thinking, (2) mathematics content, (3) visual spatial skills. The description for the findings is shown as below:

Level of van Hiele Geometry thinking

In Table 1, the highest percentage given by experts (mean = 5) related to learning content for levels of thinking and learning phases in a van Hiele Geometry. The average mean is 4.61.

Table 1

Validity of van Hiele levels of Geometry thinking

No	Items	E1*	E2*	Mean	%
1	Learning content of Plans and Elevations at all van Hiele Geometry Thinking levels is appropriate.	5	5	5	100
2	Learning content delivered in a van Hiele learning phase is appropriate.	5	5	5	100
3	Learning content in van Hiele learning phase at Independent Orientation gives students the opportunity to resolve the problem by using their own opinions.	4	5	4.5	90
4	Learning content in van Hiele learning phase at Independent Orientation gives students the opportunity to resolve the problems by using their own methods.	4	5	4.5	90
5	Learning activities of Plans and Elevations built into every stage of van Hiele Geometry Thinking is appropriate.	4	5	4.5	90
6	Activities through the SketchUp Make (using VTS-SUM) at the van Hiele learning phase are appropriate.	5	5	5	100
7	Activities at Explanations of van Hiele learning phase provide opportunities for students to discuss and use their own language when describing what they have learned.	4	5	4.5	90
8	The composition of the activities in the van Hiele learning phase at each stage of van Hiele Geometry Thinking is appropriate.	4	4	4	80
9	Items in activities at Integration of van Hiele learning phase can evaluate students' Geometry thinking.	4	5	4.5	90

E1 = Expert 1, E2* = Expert 2*

In addition, experts also gave high percentage for activities through SketchUp Make in a van Hiele learning phases. It was apparent from this table that the learning content provided opportunity for students to construct ideas and strategies in solving the problems. Moreover, learning activities at each level in a van Hiele was suitable, engaged students in discussion and capable to determine students' Geometry thinking. Thus, this learning strategy enhances students learning in Geometry by embedding levels of van Hiele Geometry Thinking through activities in the module.

Mathematics Content

For mathematics content, as shown in Table 2, experts' feedback on ViToS-SUM ranged from 80.0% to 100% (average mean = 4.51).

Table 2

Validity of mathematics content

No	Items	E1*	E2*	E3*	Mean	%
1	Introduction of ViToS-SUM is clear.	5	5	5	5	100
2	Introduction to SketchUp Make is clear.	5	5	5	5	100
3	Learning objectives in ViToS-SUM are clearly stated.	5	5	5	5	100
4	The objectives of ViToS-SUM learning is compatible to students' learning levels.	4	5	4	4.33	86.70
5	Content of ViToS-SUM is appropriate to the curriculum developed by Curriculum development Division.	4	5	5	4.67	93.40
6	Content of ViToS-SUM is related to students' prior knowledge.	3	5	5	4.33	86.70
7	Content of ViToS-SUM is appropriate to the diversity of students' abilities.	4	5	5	4.33	86.70
8	Content of ViToS-SUM is appropriate to the age of students.	4	4	4	4.00	80.00
9	Content of ViToS-SUM is appropriate to the level of student learning.	4	5	4	4.33	86.70
10	Learning facts and concepts using ViToS-SUM are appropriate and current.	4	5	5	4.67	93.40
11	The composition of ViToS-SUM content is continuous.	5	5	5	5	100
12	The composition of ViToS-SUM content is not misleading.	4	5	5	4.67	93.40
13	Activities in the ViToS-SUM help to strengthen students' understanding of concepts.	5	5	5	5	100
14	Activities in ViToS-SUM can attract students.	5	5	5	5	100
15	Activities in ViToS-SUM can encourage hands on and mind on learning.	5	5	5	5	100
16	Activities in ViToS-SUM can encourage independent learning.	5	5	5	5	100
17	Activities in ViToS-SUM can promote higher order thinking skills.	5	5	5	5	100
18	ViToS-SUM provides feedback to make sure students learn from mistakes.	5	5	5	5	100
19	ViToS-SUM provides the opportunity to repeat the exercises.	5	5	5	5	100

E1 = Expert 1, E2* = Expert 2, E3* = Expert 3*

These findings revealed that the content of ViToS-SUM was consistent with learning objectives and mathematics content. Furthermore, the findings showed that the module could motivate students to learn, guided them to build the concepts on their own and inspired them learning by 'hands on' and 'mind on'. Moreover, the module could also encourage students to develop higher order thinking skills.

Visual Spatial Skill

For Visual Spatial Skill injected in ViToS-SUM, all items gained 100% (mean = 5.00) as shown in Table 3. The findings indicated that the combination of visual spatial skills, which were unified in the level of thinking and learning phase of van Hiele Geometry was appropriate. The findings also identified that ViToS-SUM was appropriate with the level of students in developing visual spatial skills. In addition, the findings revealed that the application of SketchUp Make reinforced students' visual spatial skills in Geometry.

Table 3

Validity of visual spatial skill

No	Visual spatial skills	Expert 1	Expert 2	Mean	%
1	The combination of visual spatial ability in the learning phase corresponds to van Hiele.	5	5	5	100
2	The combination of visual spatial ability in each van Hiele Geometry thinking level is appropriate.	5	5	5	100
3	The composition of visual spatial ability in the activity in van Hiele Geometry thinking level is appropriate.	5	5	5	100
4	Make use of the application in SketchUp with corresponding visual spatial ability.	5	5	5	100

Stage II

The validation data from this stage are divided into two (2) parts: descriptive statistics and inferential statistics. The description for the findings is shown as below:

Descriptive Statistics

The pre- and post-tests analysis showed that overall visual spatial skills (mental cutting, transformation, rotation and view) of students increased as shown in Table 4. The students' scores for each component of the visual spatial skill tests were based on the number of correct answers, converted into percentages to facilitate data analysis. Much improved results were achieved in the post test for MCT, with the score distribution in the range of 30 to 80, compared to 0 to 30, achieved in the pre-test results. Meanwhile for T3D2DT, the post test score distribution in the range of 70 to 90, compared to 30 to 70, achieved in the pre-test results. For PSVT: R, the post test score distribution in the range of 40 to 93, compared to 20 to 57, achieved in the pre-test results. Finally, for PSVT:V, the post test score distribution in the range of 57 to 90, compared to 30 to 73, achieved in the pre-test results. Moreover, for vHGT, the findings showed that ViToS-SUM had succeeded in elevating students' level of geometrical thinking. As shown in Table 6, four students (33%) were increased from L1 to L2, three students (25%) were increased from L2 to L4 and five students (42%) were increased from L1 to L3. Thus, ViToS-SUM enhances students' geometrical level for topic Plans and Elevations.

Table 4

Pre-Post Test for VSS and vHGT Tests

Types of Tests	MCT			T3D2DT			PSVT:R			PSVT:V			vHGT	
Respondent	% Pre	% Post	X1	% Pre	% Post	X2	% Pre	% Post	X3	% Pre	% Post	X4	Pre	Post
A	20	70	50	50	70	20	40	57	17	53	63	10	L1	L2
B	10	50	40	70	90	20	30	47	17	63	73	10	L2	L4
C	10	50	40	60	80	20	23	40	13	63	73	10	L1	L3
D	20	80	60	70	90	20	40	57	17	73	90	17	L2	L4
E	10	40	30	40	60	20	43	63	20	73	90	17	L1	L2
F	30	50	20	50	70	20	50	70	20	47	67	20	L1	L3
G	10	60	50	50	80	30	57	73	16	40	63	23	L1	L3
H	10	60	50	40	70	30	33	53	20	37	60	23	L1	L3
I	10	50	40	50	80	30	33	57	24	30	57	27	L1	L2

J	0	50	50	50	90	40	20	93	73	43	70	27	L2	L4
K	10	60	50	50	90	40	40	70	30	53	87	34	L1	L3
L	0	30	30	30	80	50	47	77	30	67	57	10	L1	L2

X1 = Post-Test – Pre-Test for MCT, X2* = Post-Test –Pre-Test for T3D2DT,*
X3 = Post-Test –Pre-Test for PSVT: R, X4* = Post-Test –Pre-Test for PSVT: V*

Inferential Statistics

In order to differentiate VSS before and after the intervention, a paired t-test was performed. Allen, Bredero, Van Damme, Ulrich and Simons [28] used the same test with sample size = 12. Prior to that, normality tests were carried out to confirm the normal distribution of the pre-post data for VSS. The findings showed that, there were significant differences in mean scores of VSS, before and after learning via ViToS-SUM ($t=12.21$; $p<0.05$) as shown in Table 5.

Table 5

Paired t-test for VSS

	Paired Differences					t	df	Sig (2-tailed)
	Mean	SD	Std Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Post-Pre	28.31	8.03	2.31	23.21	33.42	12.21	11	0.00

Meanwhile, the researcher used Wilxocon Signed Rank test to examine LvGHT since the geometrical learning as stated by [11] is hierarchical. Table 6 showed that all students were in the Positive Rank value +6.50.

Table 6

Rank Test for LvGHT

		N	Mean Rank	Sum of Ranks
Post - Pre	Negative Ranks	0a	.00	.00
	Positive Ranks	12^b	6.50	78.00
	Ties	0^c		
	Total	12		

Table 7 shows value Z at -3.18 with value p (asmp. Sig. 2-tailed) < 0.05. This proves that there is a significant difference in students' LvGHT before and after intervention.

Table 7

Wilcoxon signed rank LvGHT

	Post-Pre
Z	-3.18
Asymp. Sig. (2-tailed)	0.00

Discussion

The discussion in this section is divided into two stages: Stage I (expert validity) and Stage II (Pre-test and Post-test).

Stage I

Overall findings of ViToS-SUM that applied vHGT, van Hiele learning phases, VSS, Visual Tools and VTS-SUM showed the experts agreed that this mode of learning improved students' level of of VSS and their level of geometrical thinking. The betterment of van Hiele's levels of thinking appeared are thought to be likely resulted by the activities in the modules that linked screencast videos with the 3D software. Besides that, the tasks are challenged enough to engage students with effective reasoning [8] and provide hands-on exploration to them [20]. The outcome of this finding was consistent with other studies in Geometry that used other learning strategies. Similar results were reported by a study conducted by Abu and Abidin [36] who developed learning modules that embedded van Hiele's Level of Geometry Thinking and learning phase but using other software namely Geometer's Sketchpad. The results revealed that the majority of Year 9 students showed an increase in geometrical thinking that from L1 to L2, but no one in that group reached L3. Meanwhile, Tan [37] had used a software called Google SketchUp, to Year 6 pupils. The findings indicated that this software could help pupils in enhancing their level of geometrical thinking, at least by one level. Apart from LvGHT, the experts admitted that the content of ViToS-SUM was compatible with learning objectives and mathematics content for topic Plans and Elevations. They also conceded that learning via ViToS-SUM had improved the ability to rotate, view, transform and cut mentally among the secondary school students.

Stage II

Pre and post-test showed that all students had increased their level of VSS. Referred to the findings obtained above, each intervention of each learning objective conducted in learning via ViToS-SUM was proven to be effective in increasing the ability to rotate, view, transform and cut mentally. Hence, it can be concluded that, the intervention using SketchUp Make and VTS-SUM via ViToS-SUM will have a higher significant impact in increasing the score of PSVT: R, PSVT:V, T3D2DT and MCT among the secondary school students. The outcome of this finding was consistent with [2] that used SketchUp Make as a learning strategy but only to high achiever students in a secondary school. Moreover, pre and post-test also indicate that all students had increased their LvHGT. This outcome is supported by [21], who did a study using SketchUp Make to teach students in a lower secondary school in Malaysia. Furthermore, ViToS-SUM has helped majority of the students (42%) to progress to the first three level of vHGT as shown in Table 6. The results also showed that after using ViToS-SUM, no students remained in L1 (Visualization). In contrast, prior to intervention, majority of them were at L1. The outcome of this finding was consistent with other studies that discovered the majority of students in Malaysia were at L1 [2; 16]. Armah and Kissi [8] claimed that the first two levels (L1 and L2) reflects that the students only have conceptual understanding of Geometry but poor in reasoning. Hence, they suggested geometrically rich tasks should be given to students, so that the students can progress to L3 and L4. Similarly, Wahab et al. [2] argued that L1 demonstrated knowledge about Geometry which was equivalent with what the children had learnt in kindergarten. Thus, this proves that conventional learning does not support LvGHT progression.

Conclusion

ViToS-SUM was created as a learning approach for 3D Plans and Elevations and to be carried out in teaching and learning Mathematics in secondary school. The results of this study showed that ViToS-SUM was well constructed in the context of assimilating four components: visual spatial skills, van Hiele levels of Geometry thinking, visual tools and VTS-SUM. This explanation was verified as expert and student evaluations agreed that ViToS-SUM was appropriate to be used in classrooms. Moreover, this mode of learning has a great potential to promote the understanding of the concepts of Plans and Elevations and develop students' interest in learning Geometry. Besides that, the pre- and post-test results also indicated that ViToS-SUM successfully achieved its objective to elevate students' visual spatial skills and van Hiele levels of Geometry thinking. Thie mode of teaching should be embedded in the current curricular and teachers should be given proper training to implement this teaching method in classroom. Based on these results, it can be concluded that ViToS-SUM can be implemented in teaching and learning process in Geometry and the usage can be further investigated for other related purposes.

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