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VIDEO TUTORIAL SCREENCAST AND SKETCHUP MAKE (VTS-SUM) FOR LOW ACHIEVERS IN LEARNING 3D GEOMETRY

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Abstract

Students' weaknesses in learning 3-Dimensional (3D) geometry are mostly associated with their low level of geometric thinking. Although a 3D software has been proposed as a manipulative learning tool, they had difficulties using it. Therefore, a suitable learning strategy should be designed to overcome the problems. The purpose of the study was to assess a learning strategy, known as Video Tutorial Screencast SketchUp Make (VTS-SUM), which integrates screencast techniques with a 3D software. VTS-SUM is a know-how video that assists students to visualize steps in drawing the orthogonal projections for 3D objects. A total of 180 students from a secondary school were involved in the study, conducted using a quantitative approach, where, a van Hiele Geometric Thinking (vHGT) test was employed to find out the level of students' geometric thinking. The findings obtained showed that the majority of the students were at the Lowest Level (Level L1). As for usability test, a total of thirty students were selected from among those below this level. They were given some time to watch the video and perform hands-on activities using the software. A seven-point Likert scale questionnaire, comprising four constructs, namely, usefulness, ease of use, ease of learning and satisfaction, was used to measure the students' perceptions of the usability test. The results obtained indicated that the students had positive perceptions towards the usage of VTS-SUM in their learning, thus accentuating its good potentials to enhance learning in mathematics.

Keywords: 3D geometry, Low achievers, Screencast, SketchUp make, VTS-SUM.

1. Introduction

The issue of difficulties in learning geometry is not new in Mathematics education. In Malaysia, students' weaknesses in geometry had been recognized by the Ministry of Education (MOE). A report from Trend in Mathematics and Science Study (TIMSS) showed that only 33% of Malaysian students answered geometry questions correctly, while 53% and 28% of them mastered the cognitive domain of knowledge and cognitive domain of reasoning, respectively [1]. This proved that students' performance in geometry is very alarming. Studies had shown that one of the reasons for this was their low level of geometric thinking [2-4]. Another identified reason was a low level of visual-spatial skills [2, 5]. These two cases were highlighted by the National Council of Teachers of Mathematics (NCTM) as the important factors that influenced students' performance in geometry [6]. As such, an appropriate teaching strategy should be planned to enhance learning in geometry.

Fuys et al. [7] proposed the level of geometric thinking applied in this study, which was based on a geometry thinking model. The model stated that a person will go through five levels of development thinking in learning geometry, namely, level 1 (Visualization), level 2 (Analysis), level 3 (Informal Deduction), level 4 (Formal Deduction), and level 5 (Rigor). Usiskin [2], Wahab et al. [5] and Vojkuvkova and Haviger [8] used the van Hiele Geometric Thinking (vHGT) test widely. In Malaysia, studies had shown that there was a relationship between students who had problems in geometry and their level of geometric thinking [5, 9, 10].

Most of the studies focused on high-achiever students in elementary schools [10], lower secondary schools [9] and upper secondary schools [11]. Not many studies have been done for low achievers in upper secondary schools, although all students in upper secondary schools are compelled to learn 3D geometry for their Malaysian Certificate of Education. Moreover, learning 3D geometry is vital for upper secondary school students to prepare them for university courses, such as engineering and social sciences [12]. Therefore, a suitable learning strategy for 3D geometry should be exposed to all students, especially those with a low level of geometric thinking.

Plan and elevation is a 3D geometry topic in Mathematics for upper secondary school students. An analysis conducted by Malaysian Examinations Syndicate [13] revealed that the majority of the students were unable to answer questions for this topic. They failed to correctly plot dashed lines (hidden sides) for *Y*-elevation and *X*-elevation and were unable to compare objects and orthogonal lines. Hence, 3D virtual manipulatives, such as using 3D software, should be embedded in learning to enhance spatial thinking [14, 15]. The 3D software should be utilized, along with the blended learning concept recommended by MOE to teachers [16]. According to Wahab et al [11] and Panorkou and Pratt [17], the software will help students in their learning engagement and assist them in visualizing 3D objects. However, problems had been identified when using computers in teachings, such as students' different cognitive levels [15] and their attitude towards the use of computers [18, 19]. Therefore, it is a challenge for educators to produce an effective learning strategy that can motivate students to learn geometry.

2. Literature Review

2.1. Screencast

Based on studies by Zhang et al. [20], a screencast is a technique to capture computer screens (digital video and audio recording) and it give learners the opportunity to control their learning pace. A learner can stop, rewind and replay a screencast video as many times as he or she wishes while progressing at his or her own pace. According to Smith and McDonald [21], a screencast video is also known as a 'know-how' video, due to its capability to record all the steps involved in a process. Therefore, a screencast enables a learner to have his cognitive load lessened in comprehending a process [22]. Special effects, such as screen draw, zoom-n-pan and wide arrow with texts can be embedded in a screencast video to highlight the steps. Sadik [23] referred to these special effects as 'visual effects'.

Screencasting, popular since digital media players reached the market in 2013, is well known among educators [24]. Recent studies by Veronika [25] showed that teaching writing recount text by using screencasting has motivated junior high school students to learn and write the kind of narrative texts. Screencasting was also proven to have positive effects on the performance of National Open University undergraduates in educational technology in Kwara State, Nigeria [26]. Even speaking ability can be improved by using screencast techniques [27]. Besides, technical subjects, such as programming skills [28], chemistry [29] and mathematics [30] also can be taught using screencasting. Screencast devices are simple to configure, portable, and inexpensive [31].

Studies by Zhang et al. [20] and MacLeod et al. [32] showed that a screencast video is an effective tool to assist students in learning new software. Screencast video tutorials had been accepted by MOE for subject Information Communication and Technology (ICT) Year-4 [16]. The videos, in CD, are used as supporting materials for students to learn new software for editing image, audio and video. Therefore, the students must learn three software, namely, mtPaint, audacity and avidemux. Figure 1 shows an example of a flow map from the textbook, which consists of steps to edit an image. Students should refer to the videos from the CD to master the editing skills. Hence, the videos are used as a medium to support blended learning in teaching and learning process.

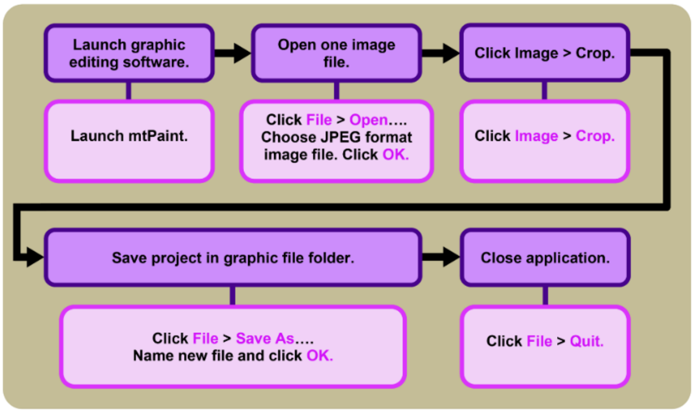

Fig. 1. A flow map in ICT Year-4 textbook.

2.2. SketchUp make

SketchUp Make is a free 3D modelling software that is available online. It is also known as a versatile 3D Computer Aided Design (CAD) software. SketchUp Make has two versions, free and pro. Although the free version was used for this study, it was found to be sufficiently powerful while also being readily available to be a valuable teaching and learning tool to assist students in learning. SketchUp Make is widely used in teaching 2D [14, 15] and 3D Geometry [5, 17, 33] and it also applied in other fields, such as architecture and engineering [34].

SketchUp Make can enhance student's spatial skills in learning geometry. This has been proven in studies by Wahab et al. [11] and Turgut and Urgan [15] who found that using tools in SketchUp could facilitate students in visualizing and creating mental images. Wahab et al. [11] emphasized four tools, namely, orbit, position camera, standard view and section cut in SketchUp Make to enhance visual-spatial skills. These tools were used for rotating, viewing, transforming and cutting the 3D object, respectively. In their study, a group of form-five high achievers were given tasks to be completed using SketchUp Make for topic plans and elevations in Mathematics. The findings obtained proved the selected tools to be capable of improving students' visual-spatial skills.

Meanwhile, Turgut and Urgan [15] did a study on students' spatial visualization ability, where tasks involving 2D mental rotations skills were given to the respondents. A few tools in SketchUp Make, such as top view, pan, select, move, rotate, lines, eraser, rectangle, paint bucket and measurement box were selected. The findings showed that some tools were easy to be used by students, while some others needed instrumental reinforcement. The results obtained also showed that students whose spatial ability performance was better than the other, could finish the given tasks easily.

On the other hand, Kwon [33] claimed that SketchUp Make could assist students in learning Mathematics. Kwon [33] conducted a study among seven- to twelve-grade students, who participated for summer camps. They were given a task to create 3D objects using SketchUp Make. They not only received help from teachers and friends but were also given the opportunity to watch video tutorials provided by SketchUp Make. The findings showed that SketchUp Make had a positive influence on the students' mathematical skills, motivation and technical skills.

Sung et al. [14] and Panorkou and Pratt [17] reported the same argument. The former conducted a study using SketchUp Make among fifth-grade students on topic surface-area for composite solids. The students were divided into an experimental and a control group. The tools in SketchUp Make selected for this study were a rotation, colouring, top view, perspective view, unfolded view, shifting and filling. The results obtained revealed that, the experimental group, which used SketchUp Make exhibited a better performance on achievement tests, compared to those who received traditional instructions. The findings also showed that students with low and moderate abilities from the experimental group exhibited significantly greater improvements of attitudes towards learning Mathematics, compared to those who received traditional instructions.

Panorkou and Pratt [17] done another study, which aim was to explore whether SketchUp Make could facilitate 10-year-old students in learning dimensions. According to them, a dimension might refer to a line as one-dimensional and a filled-in square as two-dimensional. The tools used for the study were line tool, shaded surface tool, orbit tool and push/pull tool. Panorkou and Pratt [17] referred to the tools as 'dimensional tools'. The findings showed that SketchUp Make could facilitate students' experiences about dimensions.

2.3. VTS-SUM

VTS-SUM is a video tutorial that combines screencast software (Camtasia Studio) with SketchUp Make. The video was designed using the ADDIE model. In this study, Camtasia Studio was selected to produce the video as it is the best-known screencasting software [35], one of its strengths being its ability to produce 'visual effects' as shown in Fig. 2.

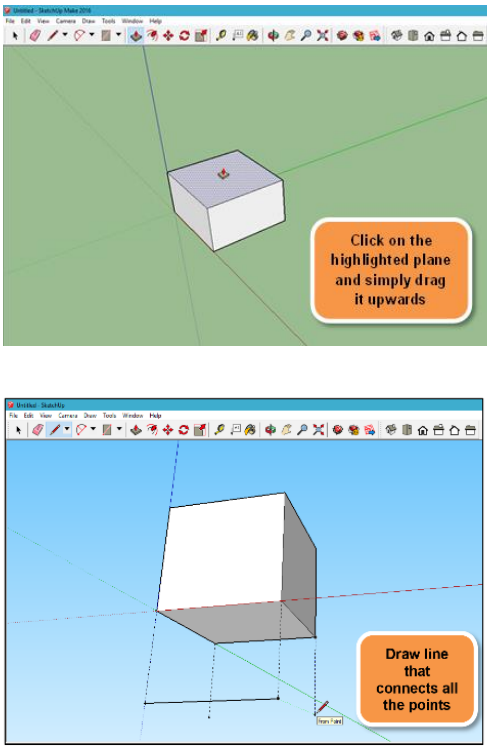

Fig. 2. Example of visual effects in VTS-SUM.

In this study, VTS-SUM was used as a learning strategy for students to learn the concept of orthogonal projection for a cube. This topic is a subtopic for plan and elevation. The first part of the video shows steps to draw a cube in SketchUp Make using tools, such as shape (rectangle), line tool, push/pull tool, measurement box and orbit tool. The second part of the video shows the steps to produce an orthogonal projection for the cube. The tools selected were a tape measure, line tool and shaded surface tool. Through this learning strategy, students were provided with scaffolds to develop knowledge about the orthogonal projection, until they could visualize the orthogonal projection that presents 2D views of a 3D object at a 90-degree angle to each other. The video can be accessed at www.camtasia2u.com.

3. Purpose of study

In this study, a learning strategy using VTS-SUM was proposed. The aim of this study was to examine the effects of using VTS-SUM among low achievers in learning 3D geometry for topic plane and elevation. For this aim, the following research questions were pursued.

- What is the students' level of geometrical thinking?
- Is there any significant gender difference in vGHT scores?
- What is the students' perception of using VTS-SUM in learning 3D geometry?

4. Methodology

4.1. Method

The research design is a survey research. The data were collected using two tools, namely, vHGT test and usability questionnaire. The study was conducted at a secondary school in Melaka.

4.2. The vHGT test

The vHGT test was administered to gauge the students' level of geometric thinking. According to Usiskin [2], if the respondents answered correctly at least 3 of 5 items at any level in vHGT, they were considered to have mastered it. The level of students' geometrical thinking is defined by calculating their scores, based on the weighted score established by Usiskin [2], as shown in Table 1. As an example, for students who obtained the scores at levels 1, 3 and 4, their scores would be counted as 13 (1+4+8).

Usiskin [2] described a total of 32 scores, starting with score 0 to 31, to facilitate the development of students' geometrical thinking in the categories above. Subsequently, the table of van Hiele's level of force (as shown in Table 2) should be referred to, in order to determine the students' level of geometric thinking [9].

Table 1. Weighted van Hiele geometric thinking test scores.

Item no.	Level of vHGT test	Score
1, 2, 3, 4, 5	L1	1
6, 7, 8, 9, 10	L2	2
11, 12, 13, 14, 15	L3	4
16, 17, 18, 19, 20	L4	8
21, 22, 23, 24, 25	L5	16

Table 2. Table of Van Hiele's level of force.

Level of vHGT Test	Score total weight
L1*	0, 2, 4, 8, 16, 18, 20 or 24
L1	1, 5, 9, 17, 21 or 25
L2	3, 11, 19 or 27
L3	6, 7, 22 or 23
L4	13, 14, 15, 29, 30 or 31
Not in any weighted	10, 12, 26 or 28

Level *L1 is categorized for phase under L1

4.3. Usability test

A general definition of usability can be found in the International Standards Organization's "Ergonomics of Human System Interaction Part 11: Guidance on Usability" [36], which defines it as the extent to which, a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". In this study, usability was defined as users' acceptance of VTS-SUM and four attributes, namely, usefulness, satisfaction, ease of use and ease of learning were selected. "Usefulness" is to study if the students will get benefit from the video tutorial and "satisfaction" is to test users' attitudes towards the video. Meanwhile, "ease of learning" is to determine whether the video tutorial is easy to learn and "ease of use" is focusing on whether the video is easy to be used for beginners. Lund [37] prepared the questionnaire for this study in reference to USE (Usefulness, Satisfaction, Ease of Use and Ease of Learning).

4.4. Participant

A total of 180 students, 96 male and 84 female were involved in the study. They represented the whole population of form-five students in the school. Students from the lowest level of geometric thinking were subsequently selected for the usability test. According to Nielsen [38], the minimum sample quantity for a usability test is five.

4.5. Procedure

The students had learnt 3D geometry for topic plane and elevation in class prior to using VTS-SUM. The video tutorial showed the way to draw an orthogonal projection for a cube. Only thirty students, selected based on their level of geometric thinking, were involved in the usability test. The study was conducted in a computer lab, where the students watched the video tutorial and were assigned a task to draw on their own and the orthogonal projection for a cube using SketchUp Make. A usability questionnaire was distributed to each of the students, right after the task was completed.

4.6. Data analysis

A quantitative method was implemented in this study and the data analysis was performed using SPSS 22.0.

5. Results

5.1. The vHGT test

The findings obtained showed that the majority of the students (61.7%) were at level 1 (L1), while approximately a quarter of them (26.7%) were below L1 (*L1) and 11.6% were at L2, as presented in Table 3.

Table 3. Levels of geometric thinking.

Level	Male	Female	Total	%
*L1	22	26	48	26.7
L1	60	51	111	61.7
L2	14	7	21	11.6
L3	0	0	0	0
L4	0	0	0	0
Total	96	84	180	100.0

5.2. The vHGT test

Since the distribution of the vHGT scores of the groups was not normal, these scores were compared with those obtained from the Mann-Whitney U test, which results are shown in Table 4. As seen in Table 4, the average rank of the male group is 95.41 and that of the female group is 84.89.

Table 4. Rank test for VhGT.

Mean Rank	Sum of ranks
95.41	9159.00
84.89	7131.00

Table 5, meanwhile, shows that the Z value obtained is -1.565 with p (Asymp. Sig. 2-tailed) >0.05 with median score for males and females. This means that there was no significant gender difference in vGHT scores, based on the results of Mann-Whitney U-test (U=3561.00, p>.05). Therefore, it was proved that the male and the female groups were equivalent in terms of van Hiele geometric thinking levels and neither group overran the other, initially.

Table 5. Mann-Whitney U Test for vHGT.

	Score
Mann-Whitney U	3561.000
Z	-1.565
Asymp. Sig. (2-tailed)	118

5.3. Usability test

Based on the findings from vHGT test, a total of 30 students, 18 male and 12 female, from the lowest level of Geometric Thinking (*L1) were selected for the usability test. The findings revealed that the means of all of the constructs were high, the highest of which, being ‘satisfaction’, as shown in Table 6.

Table 6. Usability test.

Construct	Mean	SD
Usefulness	5.96	0.44
Ease of use	5.97	0.47
Ease of learning	6.06	0.71
Satisfaction	6.23	0.48

6. Discussions

Geometrical thinking is a vital element in teaching and learning Mathematics. The results of the case study showed that the majority of the students (61.7%) were at level L1 and approximately a quarter of them (26.7%) were at below L1. Only 11.6 % of them were above level L1. The same results were also reported by Wahab et al. [5], where the majority of the respondents who were high achievers were found to be at level L1. Based on the matrix provided by the National Council of Teachers of Mathematics [6], form-five students were supposed to be at L4. The findings also revealed that there was no significant gender difference in vHGT. On the other hand, results of the usability test showed that all of the constructs, namely, usefulness, ease of use, ease of learning and satisfaction were high and the highest construct found was satisfaction. Thus, the overall findings revealed that the low-achiever students had positive attitudes towards using VTS-SUM to learn about the concept of orthogonal projection. This proved the capability of the screencast technique to assist learners in learning new software [21, 33]. VTS-SUM can reduce learners' cognitive load in visualizing the steps involved in the process [23]. Another factor that contributed to user satisfaction was the 3D software. According to Sung et al. [14], these findings were also in agreement with those in a study by which, it was found that SketchUp Make was proven to be an effective learning tool to motivate low achievers in learning Mathematics. Moreover, as stated by Wahab et al. [11], Turgut and Urgan [15] and Ponorkou and Pratt [17], the tools provided in SketchUp Make play important roles in visualizing 2D and 3D objects.

7. Conclusions

The aim of this study was to examine the effects of using VTS-SUM to low achievers in learning 3D geometry for topic plane and elevation. As highlighted earlier, the low achievers need to be able to master 3D geometry in order to further their studies in certain courses at the university level. Therefore, VTS-SUM is a very useful learning tool in learning 3D geometry.

The know-how video permits students to draw orthogonal projections of the 3D objects on their own. Teachers will only need to guide students to complete the given tasks. In addition, students also will be guided by the steps, which are embedded in the video. Hence, they will be able to create mental images of the 2D and 3D objects. The findings of the study showed that students had positive perceptions about VTS-SUM. Thus, this video tutorial provides scaffolding for low-achiever students to visualize 2D and 3D objects.

Moreover, the video assists students to learn tools and features for a new software. Besides, teachers can use this video as their teaching aid and they will have more time to guide students. As a conclusion, this learning strategy using VTS-SUM should be recognized by policymakers, such as MOE as a solution to overcome problems in teaching and learning geometry in Mathematics.

The respondents in this study were students from a secondary school in Melaka, selected based on their vHGT test scores. They were identified as those below the lowest level of geometric thinking. Meanwhile, VTS-SUM was developed for only one subtopic for plan and elevation. Future studies on moderate- and high-achiever students are recommended, with the learning strategy, VTS-SUM to cover all topics under plan and elevation.

VTS-SUM should also be used to focus on visual-spatial skills, as recommended by NCTM, other than geometric thinking. More tools in SketchUp Make must be explored, to test whether this learning strategy could improve both students' level of geometrical thinking as well as their visual-spatial skills.

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Abbreviations

2D	2-Dimensional
3D	3-Dimensional
CAD	Computer-Aided Design
ICT	Information Communication and Technology
MOE	Ministry of Education
NCTM	National Council of Teachers of Mathematics
TIMSS	Trend in Mathematics and Science Study
vHGT	van Hiele Geometric Thinking
VTS-SUM	Video Tutorial Screencast SketchUp Make

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