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Application of Geometer's Sketchpad in Malaysian Schools: A Literature Review

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New technologies are continually being introduced to improve the teaching and learning of mathematics. As an example, dynamic geometry software has been developed to enhance mathematical understanding, especially geometry. Geometer's Sketchpad (GSP), one of many dynamic geometry software, was licensed to the Ministry of Education in 2004 for nationwide use. This paper presents a systematic review on studies carried out on the application of GSP in Malaysian schools, mostly for learning geometry and graph functions. In particular, teachers' and students' attitudes towards the integration of GSP in the Malaysian mathematics classroom are examined. The literature suggests that GSP is effective in improving mathematics learning, and that both teachers and students have shown positive attitudes towards its use. Hence, the adoption of this teaching tool in schools is encouraged. Notwithstanding the advantages GSP brings to the mathematics classroom, teachers admit that time constraints, inadequate professional training, and lack of hardware support pose challenges to bringing out the best in the software. As such, school administrators and authorities are urged to provide training and maintenance support to create an environment that is conducive to the learning of mathematics with the aid of GSP.

Keywords: Geometer's Sketchpad; geometry; graph functions; mathematics

I. INTRODUCTION

There is increasing use of technology in the teaching of mathematics. In Malaysia, mathematics is a compulsory subject in both primary and secondary schools. According to the Ministry of Education (2012), students' performance in national examinations had been improving steadily from 2000 to 2011. However, the national average grade or Gred Purata Nasional (GPN) of the SPM examination deteriorated by 0.07 points from 5.08 in 2014 to 5.15 in 2015, where a lower GPN indicates better performance (Abas, 2016). In contrast, students performed better in the PMR examination in 2013, with a GPN of 2.67 from 2.71 in 2012, with mathematics as one of the subjects that showed improved performance (Priya, 2013). Malaysian students' mathematics performance has been subpar in international assessments. In the Program for International Student Assessment (PISA) 2012, Malaysia was positioned 52 out of 65 participating countries, with a mean score of 421 that was below the OECD average (OECD, 2014). In short, students' mathematics performance at both national and international examinations are inconsistent and tend to fluctuate. Therefore, the adoption of new technologies in mathematics education is an opportunity to raise students' mathematics performance to a consistently high level.

Specifically, dynamic geometry software (DGS) is commonly used to strengthen and enhance students' geometrical thinking and mathematical concepts (Chew & Lim, 2013; Dimakos & Zaranis, 2010; Hannafin, Burrus, & Little, 2001; Idris, 2007; Teoh & Fong, 2005). A geometrical figure can be drawn on-screen using DGS and it can be

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dragged around on display without changing its geometrical properties while maintaining the geometrical relation of the construction of the figure. Hence, such a geometrical software is described as dynamic (Skeketee, Jackiw, & Chanan, 2001; Jones, Mackrell, & Stevenson, 2009). Examples of DGS are Cabri, GeoGebra, and Geometer's Sketchpad (GSP). The licence for Geometer's Sketchpad (GSP) Version 4.05 for Key Press Curriculum was purchased in 2004 by the Malaysian Ministry of Education (Leong, 2014). This paper provides an overview of the use of GSP in Malaysian schools, as well as implications of the attitudes of teachers and students towards GSP. The databases like Education Resources Information Center, ScienceDirect and Scopus were used to search the related papers in this paper. There was no time frame set for the selection of articles in this study but only included the past studies that had used GSP in Malaysian schools.

II. GEOMETER'S SKETCHPAD IN TEACHING AND LEARNING

Geometer's Sketchpad (GSP) is a dynamic geometry software that can be used to create, explore, and analyse a broad range of mathematical concepts such as geometry, algebra, calculus, and trigonometry (Skeketee *et al.,* 2001). It was pioneered by Nicholas Jackiw and first released by Key Curriculum Press (KCP) in 1991 (Jackiw, 1991). According to Jackiw (2007), the mechanical core of the dynamic feature allows student to manipulate a constructed geometrical figure by dragging a vertex in every possible way, while maintaining the fundamental mathematical properties of the figure. In this way, the student's attention is diverted from a static geometrical figure to the relation or proportions that hold in the figure through interactions with the technological tool (Jackiw, 2007; Steketee *et al.,* 2001). As such, conjecture towards the geometrical concepts can be made in an inductive manner after exploration via the dynamic features provided by the GSP (Hannafin, 2004; Guven & Karatas, 2009). Nonetheless, it should be noted that GSP is a sort of processor tool which contains no instructional information (Hannafin & Scott, 2001). Therefore, the effectiveness of the GSP in a mathematics classroom is dependent on how it is actually used to facilitate understanding (Hannafin & Scott, 2001). Therefore, the effectiveness of the GSP in a mathematics classroom is dependent on how it is actually used to facilitate understanding (Hannafin & Scott, 2001), or whether it is used simply as a demonstration.

A. *Use of Geometer's Sketchpad in Malaysian schools*

According to the 2002 Form 1 curriculum specifications, the integration of computer software to explore the concept of polygons was a suggested instructional activity (Ministry of Education Malaysia, 2002). A year later, dynamic geometry software was included in the list of suggested activities to teach the properties of angles (Ministry of Education Malaysia, 2003). Then in 2006, Geometer's Sketchpad was specified as the technological tool for the teaching and learning of straight lines in the Form 4 mathematics curriculum specifications (Ministry of Education Malaysia, 2006). Hence, the changes in suggested activities over the years imply that after the purchase of GSP licence in 2004, the Ministry of Education wanted teachers to utilize GSP in the teaching and learning of mathematics in different mathematics domains. With GSP having been included in the curriculum specifications at both primary and secondary school levels, it is timely to systematically review research studies related to its implementation and application in Malaysian mathematics classrooms.

III. PURPOSE OF THE STUDY

This study aims to review the effectiveness of GSP in geometry and graph functions learning, teachers' and students' perceptions towards the use of GSP in Malaysian mathematics classrooms. The following research questions specifically guided this analysis:

RQ1: What is the effectiveness of GSP in geometry learning as indicated in the reviewed studies?

RQ2. What are the perceptions of teachers and students towards the use of GSP in Malaysia as indicated in the reviewed studies?

IV. METHOD

For this study, we used several selection criteria are used by researchers in the selection of published papers. These include the importance of the journal in the field and the use of databases in which studies are indexed, such as Scopus, ScienceDirect, Web of Science (WOS) and Education Resources Information Center (ERIC).

In every database, the same search terms were used which were "Geometer's Sketchpad" and "Malaysia". A summary of the search results is presented in a flow chart as shown in Figure 1. While conducting the search, the time period was specified from 2004 onwards. In the first search, 29 articles were discovered. These articles were downloaded as full texts to a computer. Each article was then checked to identify whether it was suitable for the purpose of the study. Specifically, we attempted to select articles where the Geometer's Sketchpad was the primary content. Based on the selection criteria, 13 articles were found to be compliant with the purpose of the study.

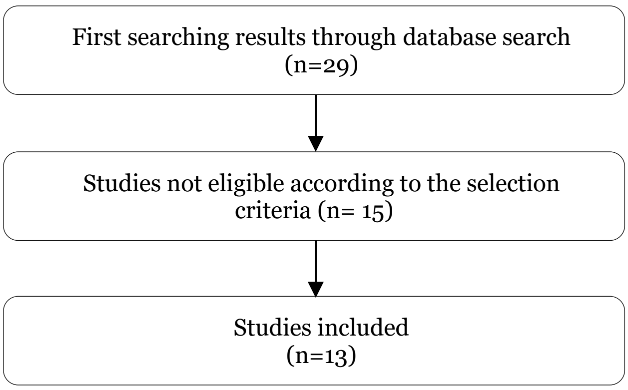

Figure 1. Procedure for the selection of articles.

V. RESULTS AND DISCUSSION

A. *Effectiveness of Geometer's Sketchpad in geometry learning*

Most studies associated GSP with van Hiele's geometry phase-based learning in geometry instructional activities. It should be noted that van Hiele's level of geometric thinking is a model that describes students' geometric thinking levels, from recognizing a geometrical figure to being able to present a formal geometrical proof (Mason, 1998).

Chew and Lim (2013) demonstrated the effectiveness of GSP in designing van Hiele's phase-based instructions for teaching regular polygons to Year 4 students. The case study found that 22 out of 26 students managed to advance their geometric thinking level from level 0 or level 1 to level 2. In the same vein, Leong and Tieng (2018) conducted eight sessions of van Hiele's phase-based instructions using Geometer's Sketchpad for teaching Year 4 pupils' geometrical angles. The study found that pupils in the experimental group showed significant improvement in their van Hiele levels of geometrical thinking (Leong & Tieng, 2018). In addition, Thangamani and Leong (2019) employed a quasi-experimental study on Year 3 pupils and used GSP for teaching and learning activities to help students to understand the topic on symmetry of two-dimensional shapes. The study found that GSP could improve students' achievement in the related topic (Thangamani & Leong, 2019). The positive results imply that a well-designed instructional activity, with the aid of GSP, could enrich students' understanding of geometry.

In contrast, Poh and Leong (2014) did not find such encouraging results when they examined the effects of GSP on Year 3 pupils' van Hiele's geometric thinking levels. The study disclosed there was no significant difference in van Hiele's thinking levels between the treatment and control groups. Poh and Leong (2014) attributed the non-significant effect to the short duration of the study. The researchers were of the view that perhaps students needed more time to master different mathematical concepts.

Similar studies have been carried out at secondary school level. A quasi-experimental study involving Form 2 students was carried out for 10 weeks to examine the effectiveness of GSP with regard to their geometric achievement and van Hiele's geometric thinking (Idris, 2007). The experimental group used GSP as an instructional tool while the control group was taught using the conventional teaching approach. The results indicated that the experimental group showed a significant improvement in van Hiele's geometric thinking and geometry achievement. For instance, five students from the experimental group moved from level 1 to level 2 of the van Hiele's geometric thinking while only one student from the control group made the advancement. Besides, 14 students from the control group and only three from the experimental group remained at the level 0 after the post test of the study (Idris, 2007). Another study by Abdullah and Zakaria (2013) also found positive impact on students' geometric thinking levels after the integration of GSP. The study involved 94 Form 2 students who were taught Transformation. Five students each from the experimental and control groups were randomly selected for interview to evaluate their geometry thinking level. Although the students in both the experimental and control groups showed advancement in van Hiele's geometric thinking levels, four out of five from the treatment progressed to Level 3 whilst none from the control group achieved Level 3.

B. *Effectiveness of Geometer's Sketchpad in graph functions*

With regard to graph functions, Teoh and Fong (2005) carried out a quasi-experimental study to compare the effectiveness of using GSP and the graphic calculator in the learning of quadratic functions by Form 4 students. The findings revealed that there was no significant difference in mathematics achievement between students who used GSP and those who used the graphic calculator. This implies that both tools are equally effective in enhancing mathematics learning. Nevertheless, Teoh and Fong (2005) emphasized visualisation as the key to better understanding. They, therefore, urged teachers to continue using GSP or to start using it if they had yet to do so.

In another study, Leong (2013) examined the impact of GSP on 43 Form 6 students who were taught graph functions. In the experimental group, 22 students explored the characteristics of graph functions with the help of computers that were equipped with GSP while 21 in the control group were taught using the traditional teaching approach. The results, in line with that of Teoh and Fong (2005), showed that GSP did improve the students' performance.

In another study, a prototype of the GSP digital module, designed for the teaching and learning of quadratic functions to test its pedagogical usability, was examined by 34 secondary school mathematics teachers (Nordin, Zakaria, Embi, & Yassin, 2008). The teachers found that the GSP digital module met the criteria for pedagogical usability, *viz.* student control, students' activities, objective-oriented, application, value-added, motivation, knowledge value, flexibility, and response. Its features such as plotting graphs and graphing simulations made learning more interactive and interesting as it allowed students to do informal conjecture (Nordin *et al.,* 2008).

Another quasi-experimental study which examined the effectiveness of GSP on the learning of trigonometric functions was carried out in a Malaysian technical school (Ramli, Mustapha, & Ramli, 2015). As expected, GSP improved students' mathematics achievement as the experimental group showed significantly higher mean scores (Ramli *et al.,* 2015).

This paper has, thus far, reviewed the efficacy of GSP in the Malaysian mathematics classroom. Table 1 presents the list of the reviewed studies in this section. Generally, this technological tool has been found to be effective in improving students' geometry and their learning of graph functions in the Malaysian classroom. However, it is important to note that as much as technology can help students understand mathematics better, it does not override students' need to learn and master basic mathematics skills such as addition, subtraction, multiplication, and division (Ministry of Education Malaysia, 2006). Besides, the effectiveness of the technology depends on the way or the extent to which it has been utilized. As emphasized by Teoh and Fong (2005), teachers' enthusiasm in the classroom and their willingness to exploit educational technological tools are the key to effective mathematics learning. It is, therefore, important to examine the attitudes and perceptions of both teachers and students towards using GSP. The following section of the paper will deal with this.

Table 1. List of reviewed studies

Learning content	**Study**	**Study samples**	**Findings**
Geometry	Idris (2007)	Form Two	There were significant improvement of geometric thinking and achievement.
	Chew and Lim (2013)	Year Four	There was advancement of geometric thinking level from 0 or 1 to 2 on the topic of regular polygons.
	Abdullah and Zakaria (2013)	Form Two	Both experimental and control group showed significant improvement, but only experimental group's students showed advancement to level 3.
	Poh and Leong (2014)	Year Three	It was found that no significant

			improvement of geometric thinking levels.
	Leong and Tieng (2018)	Year Four	There was significantly improvement on geometrical thinking.
	Thangamani and Leong (2019)	Year Three	Experimental group's students improved significantly in geometrical thinking
Graph functions	Teoh and Fong (2005)	Form Four	There was no significant difference in mathematics achievement between students who used GSP and those who used graphic calculator.
	Nordin *et al.* (2008)	Secondary school teachers	It was found that GSP digital module met the criteria for pedagogical usability.
	Leong (2013)	Form Six	Form Six students showed improvement in students' performance.
	Ramli *et al.* (2015)	Final year of technical school	There were significant improvement of mathematics achievement and retention of the learning content after two weeks of the study.

C. *Teachers' and students' perceptions towards Geometer's Sketchpad*

With regard to teachers' use of GSP, a lesson study was mooted to encourage the integration of GSP in the mathematics lesson (Chew & Lim, 2011; Liew & Lim, 2009). A lesson study refers to a form of teacher professional development where a small group of teachers work together, following a fixed time schedule to plan, practice, appraise, and amend collaboratively lesson plans (Chew & Lim, 2011). It was found that most teachers showed positive attitudes throughout the skill training and collaboration process, and this resulted in GSP's efficacy in enhancing students' performance in geometry learning. However, in the interview session, teachers voiced out the challenges they experienced in the process. For instance, they faced time constraint, and as such they had difficulty designing comprehensive instructional activities using GSP (Chew & Lim, 2011; Liew & Lim, 2009). Despite the obvious benefits of the lesson study which enabled teachers to collaborate and exchange their GSP instructional materials, teachers also found it problematic assigning a time slot for their discussions. In view of these challenges, Abdullah, Surif, Ibrahim, Ali and Hamzah (2014) designed a GSP module known as MyGSP. The module, tailored for the Malaysian secondary level mathematics curriculum, includes a video demonstration on GSP usage for teachers and how to hone higher order thinking skills and teaching strategies. The designers of the module were hopeful that mathematics teachers would find it useful (Abdullah *et al.,* 2014).

According to Chew and Lim (2011), apart from time constraint, teachers were also reluctant to use GSP when facilities in the school were not well maintained and supported. For instance, when there were frequent malfunctioning of computers, breakdown of LCD projectors, or insufficient number of computers for students to use, teachers were often discouraged. Therefore, a successful mathematics classroom requires collaboration from teachers, school administrators, and Ministry of Education to support and ensure good hardware maintenance, software updates, and optimal workload.

With regard to students' attitudes towards the use of GSP, it was found that students perceived it as a useful tool (Idris, 2007; Liew & Lim, 2009; Leong, 2013). A study by Leong (2013) on Form 6 students showed improved attitudes towards the learning of graph functions when GSP was integrated in the lesson. The students also participated actively in group discussions (Liew & Lim, 2009). However, one must not discount the fact that the students' positive attitudes towards the GSP in learning might be due to the novelty effects of technology (Hanaffin *et al.,* 2001). Therefore, the role and potential of technology (in this case, GSP) must be examined thoroughly to maximize its effectiveness in teaching and learning (Mohd Ayub *et al.,* 2008).

Overall, the literature suggests that GSP is effective for the teaching and learning of mathematics in Malaysian schools. For instance, GSP is time-efficient when sketching geometrical figures or graph functions with accurate scales. It allows students to visualize and conjecture mathematical concepts that include geometry and graph functions. Meanwhile, teachers would have more time to explain related mathematical concepts than when they used conventional textbook-directed mathematics instructions. The GSP with its dynamic features, therefore, has a positive effect on students' mathematics performance, in particular geometry and graph functions.

While studies have indicated the usefulness of GSP, it is important to bear in mind the challenges faced by teachers when using technology in the classroom. As discussed earlier, teachers' and students' attitudes towards the use of GSP have generally been positive. Nevertheless, it is essential to ensure that teachers do not despair over poor hardware maintenance. It is also important to help teachers overcome the time constraint factor in the preparation of GSP instructional materials as well as equip them with the necessary technical skills to take full advantage of GSP. Therefore, it is proposed that all mathematics teachers be provided with comprehensive training on using and integrating GSP in their mathematics lesson instead of merely training representatives of selected schools. In addition, pre-service mathematics teachers should also be similarly trained to equip them with the essential skills to use GSP effectively. With regard to the challenge of preparing GSP materials with advice from peers. Taken together, it requires teachers' in-depth pedagogical insights to make the most of GSP. Hence professional developement of mathematics teachers is a key factor in improving students' mathematics performance while technology acts as an effective teaching aid.

VI. CONCLUSION

To conclude, GSP might have many useful features such as dynamic features in demonstrating mathematical concepts, but the efficacy of the tool in enhancing students' mathematics performance depends very much so on teachers' willingness and competence to fully exploit GSP. This leads to factors such as teachers' attitudes, perceptions, and values towards integration of technology in their teaching. Further research might explore the effectiveness of teachers' training on the use of GSP in Malaysian schools. To be exact, teachers' internal values and ease with using educational technology are as important as their competence in using technology.

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