EFFECTS OF 5E GUIDED LEARNING WITH GRAPHING CALCULATOR ON FORM FOUR STUDENTS ACHIEVEMENT AND HIGHER ORDER THINKING SKILLS IN THE TOPIC GRAPHS OF FUNCTIONS II

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by

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LIST OF ABBREVIATIONS

HOTS	Higher Order Thinking Skills
JPN	Jabatan Pelajaran Negeri
MOE	Ministry of Education
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics
USM	Universiti Sains Malaysia

KESAN PEMBELAJARAN TERBIMBING 5E DENGAN KALKULATOR GRAFIK TERHADAP PENCAPAIAN DAN PEMIKIRAN ARAS TINGGI PELAJAR-PELAJAR TINGKATAN EMPAT DALAM TOPIK GRAF FUNGSI II

ABSTRAK

Penyelidikan ini bertujuan untuk mengkaji kesan penggunaan kalkulator grafik terhadap Pencapaian dan Merekabentuk secara Kreatif (kreativiti adalah pada tahap KBAT tertinggi) di kalangan murid dengan kalkulator grafik . Kajian ini berfokus kepada Bab 2: Graf Fungsi II daripada silibus Matematik KBSM. Sampel terdiri daripada 108 orang murid Tingkatan 4 dari tiga buah sekolah dalam lokasi bandar di negeri Pulau Pinang (Kumpulan eksperimen 1, n = 36; Kumpulan eksperimen 2, n = 36; Kumpulan kawalan, n = 36). Pembolehubah bebas adalah pengajaran dan pembelajaran berbantukan kalkulator grafik melalui tiga pendekatan iaitu Pembelajaran 5E Inkuiri Terbimbing (5EGIL). Pembelajaran 5E (5EL) dan Pembelajaran Konvensional (CL). Kumpulan 5EGIL dibimbing oleh kaedah penyoalan guru dengan soalan-soalan beraras tinggi (KBAT) dengan menyediakan tugasan khas dan lembaran kerja yang memenuhi keperluan Kitaran Pembelajaran 5E. Kumpulan 5EL juga mengamalkan Pembelajaran 5E tetapi dibimbing secara minima oleh guru. Bagaimanapun, pelajar-pelajar dalam kumpulan ini diberi tugasan khas dan lembaran kerja yang sama seperti kumpulan 5EGIL. Kumpulan CL pula diberi lembaran kerja dan aktiviti seperti yang dicadangkan dalam buku teks dengan kalkulator grafik. Pembolehubah bersandar adalah Pencapaian bagi Graf Fungsi II dan Merekabentuk secara kreatif dengan kalkulator grafik. Kreativiti adalah pada tahap

kemahiran berfikir aras tinggi (KBAT) yang tertinggi dalam Taksonomi Bloom. Kajian ini menggunakan pendekatan kajian gabungan dengan kedua-dua kaedah kuantitatif dan kualitatif bagi pungutan data. Bagi kaedah kuantitatif, data dari kuasi-experimen dipungut untuk membandingkan kesan ketiga-tiga pendekatan tersebut. Data yang diperolehi daripada ujian pra dan ujian pos, dianalisis menggunakan statistik diskriptif dan statistik inferens. Statistik inferens yang digunakan ialah ANOVA Satu-hala untuk menguji dua hipotesis utama. Pada keseluruhannya, kajian ini menunjukkan bahawa tidak ada perbezaan signifikan dalam skor ujian pos Pencapaian Graf Fungsi II. Bagaimanapun, terdapat perbezaan signifikan dalam skor ujian Merekabentuk secara kreatif dengan kalkulator grafik merentasi ketiga-tiga kumpulan pendekatan. Data kualitatif melalui analisis tematik dengan data temubual yang ditriangulasi dengan data daripada analisis dokumen pelajar dan nota lapangan pengkaji menyokong dapatan data kuantitatif kerana pendekatan 5EGIL adalah lebih baik daripada pendekatan 5EL dan CL kerana berupaya untuk memupuk pemikiran Matematik, inovatif dan kreatif, pemikiran kritikal dan membuat keputusan, menunjukkan kemahiran dan nilai dalam menyelesaikan masalah dan penekanan kepada strategi metakognitif agar pelajar dapat membuat refleksi terhadap kerja sendiri dan seterusnya memperbaiki kelemahan sendiri. Ia adalah bersesuaian dengan penekanan kepada KBAT. Bagaimanapun, penggunaan sebarang teknologi Matematik hanya akan menunjukkan hasil yang berkesan sekiranya penggunaannya diwajibkan dalam proses penilaian seperti yang dicadangkan oleh pelajar untuk menjadikannya sebahagian daripada penilaian berasaskan sekolah.

EFFECTS OF 5E GUIDED LEARNING WITH GRAPHING CALCULATOR ON FORM FOUR STUDENTS ACHIEVEMENT AND HIGHER ORDER THINKING SKILLS IN THE TOPIC GRAPHS OF FUNCTIONS II

ABSTRACT

The aim of this research is to investigate the effect of incorporating graphing calculator on students Achievement and Creative Design with graphing calculator (creativity is the highest level in HOTS). The focus of the study is Chapter 2: Graphs of Functions II from the upper secondary Mathematics syllabus. 108 Form four students from three urban secondary schools in Penang were the respondents. (Experimental group 1, n = 36; Experimental group 2, n = 36 and control group n = 36). The independent variable was the teaching and learning of Graphs of Functions II incorporating graphing calculator with three different approaches. They are 5E Guided Learning (5EGIL), 5E Learning (5EL) and Conventional Learning (CL). The 5EGIL group was guided by teachers use of higher order thinking skills (HOTS) questions and specially prepared tasks and worksheets to comply to the 5E Instructional model. The 5EL incorporated the 5E Instructional model with minimum guidance from teacher. However, the students in this group were given the same tasks and worksheets as the 5EGIL group. The CL were given worksheets and activities as proposed in the text book with graphing calculator. The dependent variables are Achievement for Graphs of Functions II and Creative Designing with graphing calculator. Creativity is at the highest level of higher order thinking skills (HOTS) in Blooms Taxonomy. This study utilised the mixed-method approach with both the quantitative and qualitative method to gather information. As for the quantitative method, quasi-experiment was

conducted to compare the effect of the three approaches. Data obtained through pretest and posttest scores were analysed using descriptive and One-way ANOVA inferential statistics to test the two main hypotheses. Overall, this study shows that that there is no significant difference in the Posttest Achievement score for Graphs of Functions II. The positive findings is related to the ability of the calculator as a visualisation tool, expedited the process of understanding the graphs of functions better. However, there is a significant difference in the more challenging posttest score in the Creative Designing with graphing calculator across the three groups. For the qualitative method, thematic analysis were employed for data from the semi structured interview that were triangulated with document analysis supporting the findings in the quantitative data. 5EGIL approach group was able to create a better opportunity for the students to explore graphs of functions without limit, inculcate mathematical thinking, innovative and creative, critical thinking in making decisions, demonstrated skills and values in solving problem and their practice of metacognitive strategies that requires to reflect on their own work and rectify the shortcomings. However, it has to be mentioned here with caution that the full potential of any Mathematical technology can only be attained if its use is made compulsory into the assessment process as suggested by students to introduce by awarding marks for their school based assessment.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Currently, the Malaysian Education system is giving high priority in developing students' higher order thinking skills (HOTS). According to the Malaysian Ministry of Education, MOE, (2013) HOTS refers to the ability to apply knowledge, skills and values in reasoning, reflecting, solving problems, making decisions, innovative and being creative. Various initiatives had been taken to gear towards achieving this much spoken objective. Furthermore, the Malaysian Education Blue Print 2013-2025 (2012) had also given great importance to ensure the elevation of students thinking skills by realigning our national curriculum to meet international standards.

Students' active participation in the classrooms teaching and learning process plays a vital role in enhancing thinking skills. The subject teacher shoulders the heavy responsibility to provide a classroom environment that enables active student participation. Students should be given opportunity to be engaged in various activities that will require them to explore mathematics especially those related to their daily life and explain their findings to their peers. Which means, there should also be equal amount of attention given to the process of knowledge construction that the students embark on.

Similarly, importance of knowledge construction had also been demonstrated in many educational based studies (Kivunja, 2015; Tanujaya, 2016) across the globe whereby great emphasis are being placed on the development of HOTS by inculcating deeper thinking activities among their students. According to Nessel and Graham

(2007), thinking skill is the most basic skill that should be infused in the classroom as it is key and has the potential to increase achievement among students at all level. In fact, Gall et al. (1990) had also supported that learning how to learn cannot be left to students, it must be taught with the assistance of appropriate tool. As such, the role of the teacher in the classroom is very pertinent to achieve this aspiration and it has been a priority for decades (Abd. Ghafar Mahmud, 2011).

The Malaysian Education Ministry (MOE) with the help of Curriculum Development Division (BPK) in its approach to address this issue, had suggested various programs to improve the thinking ability of students and eventually to elevate them to higher order thinking skills (HOTS). The MOE launched the `Task Force PISA and TIMSS' that will focus on increasing the level of thinking to HOTS in both students and teachers so that they are able to solve non-routine mathematical problems. One of the suggested programs is I-Think, which introduces students to different diagrams that can be incorporated during classroom instruction. It is suggested that the students thinking process should be the key point highlighted which could shed some light on identifying the successful and unsuccessful problem solvers, especially in the area of mathematics. Subsequently, emphasis has been placed in getting students to answer more complex tasks. However, there is a need to investigate further on the thinking process that a student embarks in order to complete the given task especially during a mathematics lesson, instead of just evaluating the total score obtained, which is being used for student ranking.

National Council of Teachers of Mathematics (NCTM) had highlighted that memorizing facts and procedures is a fragile learning strategy. Students should rather understand and know when and how to apply the understanding. For past decades, learning mathematics without understanding has been a common outcome of

mathematics instruction (NCTM, 2000). Students tend to implement algorithms or memorise facts without understanding what they are doing. Lessons are pretty much drills and practice that requires extensive recall of mathematical algorithms.

Currently, the Malaysians are expected to look beyond Vision 2020. In its pursuit of accomplishing this vision, science and technological knowledge is seen as one of the key component in attracting students towards a more interesting and meaningful learning (Dillenbourg & Sanna, 2009). Presently the Malaysian education system is moving rapidly towards student centered learning as it realizes that improving students thinking is a major educational goal in the survival of any nation. Teachers should make use of the opportunities in the classroom to engage students in deep learning and higher order thinking by emphasizing on 21st century skills. The newer generation has to prepare themselves to excel in the areas of science, technology, engineering, and mathematics (STEM). However, the big question mark is how all these efforts could reach more students, immaterial of their ability to score in Mathematics?

The need to comprehend and use mathematics in the workplace and everyday life has never been greater, and will continue to increase (NCTM, 2000). This is also in line with the Teaching Principles proposed by NCTM (2000), "Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well (p.16)".

Teachers are also reminded to incorporate various teaching strategies including method that is more student-centered for the mentioned purposes. This means the teaching method should shy away from traditional method which requires a student to repeat what was taught, just follow algorithm, memorise to remember what is being

taught in classroom and recall it during examination. Instead, an educator should investigate further into the learning process that takes place when a student is given a task to work with. As a matter of fact, the Malaysian Education Blueprint 2013-2025 (2012) that gives great emphasis to this, had gone a step further by introducing the Standard Curriculum for Secondary School (SCSS) or *Kurikulum Standard Sekolah Menengah (KSSM)* and the revised Standard Curriculum for Primary School (SCPS) or *Kurikulum Standard Sekolah Rendah (KSSR),* which was fully implemented in 2017. Importance is given on promoting knowledge and skills such as creative thinking, innovation, problem-solving and leadership involving HOTS (Abdullah et al., 2016; Othman & Mohamad, 2014).

Noraini et al. (2015b) also highlighted the importance of a comprehensive education plan that enables a holistic development for the students. By integrating the Malaysian Education Blueprint 2013-2025 with the proposed 11 shifts in the Government Transformation Plan (GTP) it is anticipated to bring this development. The Malaysian Education Ministry is also expected to adjust accordingly and improvise on the current education system for the betterment of nation building (KPM, 2012).

In the Malaysian context, HOTS is emphasised on four levels of thinking. They are applying, analyzing, evaluating and creating (KSSM, 2016, 2018). The new curriculum requires for students' to demonstrate their mathematical skills associated with creativity, showcasing originality in thinking and ability to connect with their surroundings in a new perspective, thus ensuring the development of creativity and innovation do take place (KSSM, 2016, 2018).

Furthermore, the analysis of the SPM Mathematics results from the Penang Educational department in Table 1.1 show that there is an improvement in the Mathematics subject average grade from 4.93 to 4.60 from the year 2016 to 2017.

Table 1.1

Analysis of the SPM Mathematics results for the Penang State (2015 – 2017)

Year	**Number of students registered**	**Number of students sat**	**Number of students and percentages (%)**		**Absent**	**State subject average grades**	**National subject average grades**
			Passed	Failed			
2017	20845	20534	16795 81.79 %	3739 18.21 %	311	4.60	4.97
2016	19788	19449	15017 77.21 %	4432 22.79 %	339	4.93	5.10
2015	20042	19732	15386 78.0 %	4346 22.03 %	310	4.74	5.15

This analysis shows, even though emphasis has been placed in increasing the difficulty level of the SPM Mathematics paper with the inclusion of higher order thinking skills questions, students, especially the Penang state students are able to show an improved result. The results are above the National level after averaging both the urban and rural results. This may give us an indication that the sample of students involved in this study may be capable of handling more challenging tasks in Mathematics.

1.2 Background of the Study

Higher order thinking skills (HOTS) is the most frequently used acronym in schools with the discussion on problems faced by teachers and students in achieving the thinking society status. As mentioned in many research findings, HOTS is recognized in the international arena as a pressing issue that it has become as our national priority. HOTS is believed to be the backbone of a thinking nation to ensure

the progress of achieving the status of a developed nation. However, the teaching of thinking skills in order to promote students intellectual has been a major challenge to many educators for a long time now and the demand to improve students' learning and thinking skills continues. For the past two over decades there appears to be a paradigm shift away from education and training to learning, from teacher-centered to student-centered education, from rote learning to learning as reflection, and from face-to face to distance and E-Learning. One of the main reasons for this transformation is innovative application of electronic technologies, to improve the conventional teaching approaches. Wongse-ek (2013) and Weintrop (2016) emphasised that knowledge is something we do and not just something that we have. Thus, she pointed out that schools should explore and create future generations that are able to fit into the knowledge-based society. It is supported by empirical evidence by Hiebert and Carpenter (1992) that had already discussed this concern many years ago. It says, students who learn mathematics with understanding will retain what they learn and transfer it in a more meaningful situation.

There are many educators and researchers that have promoted strategies to improve educational instruction based on the constructivist method (Cobb, 1994; Davis, 1990). A notable number of studies that inculcate constructivist learning environment have shown very encouraging cognitive or motivational outcomes in Malaysia too (Kong, 2006; Vickneasvari, 2007; Wong, Kamariah, & Tang, 2003).

There are also a number of educators (Judson, 2006; Oldknow & Taylor, 2000) who had emphasised on the positive role of technology integration in classroom teaching and learning process. Especially with today's digital natives who are more visually literate than the previous generations (Oblinger & Oblinger, 2005). It is an undeniable fact that technology is essential in teaching and learning mathematics too,

simply because it influences the mathematics that is being taught and enhances student learning. As such, students are expected to be innovative by leveraging technology to ensure active engagement in rigorous mathematics curriculum that focuses on active learning. Just within the last decade, the world has witnessed a multitude of technological advances intended to make our daily life better. Some of the popular technology that had revolutionised our lifes are high-speed Internet, Wikipedia, Google and the smartphones and not forgetting the mathematical software and the hand held technologies. Definitely one cannot deny that these technologies are already being used in the classrooms across the globe. Hence, in this changing world of technology, it is important that we keep up with the technological revolution, particularly in the teaching and learning of Mathematics. Nowadays, as there are many technological tools available, one need to be very careful in selecting the right tool for the relevant topics.

Students in general and middle school students in particular, appear to be well versed on the latest gadgets and games. However, when it comes to using educational tools to learn mathematics, science and technology concepts they seem to face many difficulties in connecting the technology to the learning of concepts. Therefore, there is an urgent need for educators to make the most out of these pedagogical technologies that is readily available for classroom use. Technology is also an avenue that can help teachers to engage their students in activities that will benefit their learning. Most importantly, technology creates ways for students to analyze and understand the world around them.

Beginning from the year 2002 Curriculum Development Centre (CDC) together with Ministry of Education (MOE) conducted several courses at the state level on the use of graphing calculators for secondary school Mathematics and Science teachers.

These courses incorporated all the 3 models (Casio, Texas Instruments and Hewlerd Packard) that were sent to selected secondary schools. To start with, the Ministry of Education provided 108 secondary schools with the CASIO model graphing calculators. Later about 370 schools were furbished with the Texas Instruments (TI) and Hewlerd Packard model of graphing calculators. The TI graphing calculator comes with 5 sets of the CBR (Calculator Based Ranger) and CBL 2 (Calculator Based Laboratory) tools that can be used to collect real life data through experiments and later can be connected straight to any model of TI graphing calculators. However, these tools were used only during the Science experiments. The same goes for the Geometers Sketchpad (GSP) software. The access to its use was given to all the secondary schools in Malaysia (Chew, 2007). The biannual report prepared by the State Education Department (JPN, 2012) shows that both these technologies are under utilised despite being available for both student and teachers use at schools. Effandi et al. (2007) have highlighted that the main reason is teachers' own perception that technology is not able to enhance the teaching and learning of mathematics and complain of insufficient time to prepare Information and Communications Technology (ICT) based lessons.

There are also some studies that question the situation whereby students do not get to know the pedagogical opportunities of this tool (Pierce & Stacey, 2010). They are rather disconnected at the functional opportunities after getting to use it to make the process of solving questions faster and more accurate. Therefore, the educators need to be cautioned this tool should not be used as a computational tool for algebraic methods only. Rather it should be extended to show the connections between numeric, algebraic and graphical representations (Jones, 2005; Tall, 1996) Thus, there is a need to address the trends of education in Malaysia and make it more effective for our future generation. This will eventually lead to better conceptual understanding and improve

students' problem-solving skills (Van Streun, Harskamp, & Suhre, 2000). In fact, the situation may be quite similar among educators in other countries too. Dewey et al. (2009) had reiterated, though graphing technology had shown its track record in the teaching and learning of Algebra in various studies, teachers only use technology as a curriculum supplement rather than to expand the curriculum.

Therefore, the educators have the responsibility to give students the chance to use these technologies in order to keep them engaged in the lesson and to explore further the graphs of functions. With caution that a good planning on the teacher's side is very pertinent. Eventually, students will appreciate mathematics as an easy and fun subject provided, they are given the deserving opportunities to enhance understanding, attitude and inculcate creativity among the learners (Torrance, 1965; Zawawi et al., 2009).

1.3 Rational of the Study

In the past, education is primarily amounting to knowledge gaining. Here, students were made to sit in rows, facing the teacher and the best students were the ones who would retain the most information obtained from a teacher centered classroom. Thus, the only voice is the all-knowing teacher. The person in charge of imparting all their knowledge to their students. However, today's education need has changed, with the fast-paced, ever changing 21st century workplace demands for critical thinkers, confident problem-solvers and technology savvy innovators with a thirst for lifelong learning, students are required to be equipped with skills that will ensure their prosperity in tomorrow's world (Budhai & Taddei, 2015; Young, 2017).

Generally, the teacher-centered method is practiced in most of the mathematics classes (Haggarty & Pepin, 2002) and the same approach is also commonly used in

Malaysia (Tengku Zainal, 2002). This approach zooms students towards memorising mathematical formulas and concepts. There is a very high possibility that students do not understand the mathematical concepts behind it and merely employed the drill and practice method to get better score. They are evaluated with paper and pencil tests.

Therefore, the present study incorporated technology into the teaching and learning process. Oldknow and Taylor (2000) had reiterated that the emergence of technology is able to provide a platform that could engage students to improve their reasoning skills pertaining to mathematical concepts. The utilization of technology in mathematics education also has the potential to make the teaching and learning of the mathematics content more current and intriguing, in contrast to the conventional paper and pencil method that is rather grueling (Mohd Nordin & Zakaria, 2007; Zakaria & Iksan, 2007). There is also a need for the learner, in this case the students to feel curious and would want to investigate further what would eventually direct the student to seek knowledge through teachers structured questioning strategy that requires thinking at higher order cognitive level.

The buzz word in the school environment is `HOTS' (Higher Order Thinking Skills). The strenuous environment is further infused with the increase of HOTS types of questions tested in the summative assessment such as Ujian Penilaian Sekolah Rendah (UPSR), Penilaian Tahap Tiga (PT3), Sijil Pelajaran Malaysia (SPM) and Sijil Tinggi Pelajaran Malaysia (STPM). This is made worse with the announcement by MOE, that the percentage of HOTS questions in the SPM exam will be increased to 20% in year 2014, 30% by year 2015 and 50% in year 2016 (Elemen KBAT Dalam Pentaksiran , 2014). The big question that each and every one of us has to pause and think is `How would the average and the weaker students will cope with this situation?'. Several studies (Mahamad, Ibrahim, & Taib, 2010; Sabran, 2013; Zakaria,

2009) show that many students even have difficulty in understanding the basic mathematics questions. Hence, to solve these issues, teacher's tent to drill and practice students with examination type questions. This scenario is pretty much similar in many other countries in the South East Asia too (Sadiman, 2004).

One of the important elements in HOTS is the expansion of students' creativity and critical thinking. This means the solution to a task should not be a fixed answer or at least should give the student an opportunity to try to solve the task in multiple methods. This will automatically create a room for students to reflect on their cognitive strategies that needs them to plan, monitor and evaluate their strategies. Therefore, the lesson can inculcate them to be risk takers and more logical in exploring the mathematical concepts especially in the presence of technology.

The researcher would like to say with caution that technology is a tool that facilitate the learning and the most important factor is the role of the teacher as a facilitator. The big question that need to be addressed here is, `Are the technological tools being used as learning aid to facilitate teaching and learning process or are they used merely as an instructional medium? In fact, the graphing calculator technology that is proposed can be replaced with any other mathematical software that is available such as GSP, GeoGebra, Mathematica, Graph Charts or others.

It is clear that Malaysian Government is going all out to integrate the information technology into the process of teaching and learning. In fact, school administrators, teachers and students were also given exposure and training. Teachers are the group that benefited the most with numerous professional development courses with various information and skills incorporating technology from time to time (Nur'Ain et al., 2011; Teoh & Fong, 2005). The Malaysian Education Ministry had provided infrastructure such as computer labs, laptops, LCD projectors, internet connections to

schools to enhance the process of teaching and learning. One of the latest facilities in Malaysian schools for the benefit of students and teachers is the Virtual Learning Environment more commonly known as `VLE Frog' that is incorporated in the teaching and learning process as well.

A study done by Thomas (2002) had proposed that thinking is socially mediated and the classroom setup is the key factor that can influence students' metacognitive development especially through the constructivist approach. This is the basis used to introduce the 5E Instructional Model which is very much constructivist in nature and had proven its results in science lessons. Now, mathematics education that has potential to be more explorative and student-centered is also suitable to be incorporated with this 5E Instructional Model. However, there are very few studies of the incorporation of the 5E Instructional Model that is documented in the mathematics lessons compared to the science lessons.

Therefore, this study incorporated Bybee's 5E Instructional Model that is widely used in Science Education so that students dominate the classroom activities. Though there are few studies documented in the mathematics lessons compared to the science related field, the 5E Instruction Model deemed suitable for mathematics education looking at its potential to be more explorative and student-centered. Rodger Bybee, the chief developer of the constructivist plan, based the format of the new design on five instructional phases; Engage, Explore, Explain, Elaborate and Evaluate. According to Bybee et al. (2006):

- *Engage* is presented to excite the students in the topic;
- *Explore* directs the students to examine the topic in small groups;
- *Explain* allows the students to describe to others what their team has discovered;
- *Elaborate* encourages the students to further investigate the topic;

- *Evaluate* provides the students a way to assess what they have learned.

Emphasis will be given to knowledge construction of students with constructivist approach and the change in the students' higher order thinking skills will be given priority. Thompson (2011) mentions, it is important to study the HOTS of a student because it affects the acquisition, comprehension, retention and application of their learning. In addition, HOTS have an impact on the student's efficiency of learning, problem solving and critical thinking ability.

In view of this, a survey was done by researcher among 30 experienced mathematics teachers (teaching SPM Mathematics at least for 5 years) attending a course organized by the Penang Education Department in 2016. They were asked to list down focus topics for the students to score in paper 2 SPM (Sijil Pelajaran Malaysia) Mathematics and the corresponding reasons. Almost all of them gave the answer as: -

1. Graphs of Functions
2. Statistics

Moreover, all their reasons sound alike that is easy for students to score marks, and from years of experience in teaching at SPM level, these are is the topic that students can score the highest marks because students can be trained and drilled to do the paper and pencil drawing and then solve the relevant questions. With that, it can be concluded as the questions are very straight forward and quite predictable.

With this aspect in mind, a similar survey was conducted among a group of students taking the SPM examinations during a SPM Mathematics seminar. 30 students were selected and asked the same questions. They were asked to list down the topics that that would ease them to score in paper 2 SPM Mathematics. Almost all of

them (a mix of good and weaker students) gave the same answer as were given by the experienced mathematics teacher. The topics are: -

1. Graphs of Functions
2. Statistics

They added further that these are their favorite questions and they are sure to be able to answer them from their previous experience in school examinations or practices with the SPM type questions. Since both the teachers and students have given the topic `Graphs of Function' as their first choice, researcher decided to investigate further on this topic.

This is further strengthened with the feedback on the `*Kupasan Mutu Jawapan Pelajar'* that is obtained from the Malaysian Examination Syndicate's website for the year 2004 – 2016. It is mentioned that generally students could answer the questions related to Graphs of Functions well and may show some disability in the skills of joining the points in forming a good curve.

Furthermore, an analysis from the Penang State Education Department (JPNPP) for the year 2016 during the standardised SPM Trial Exam for the Mathematics paper shows quite a similar analysis that students on the whole have done well with the Graphs of Functions question for Paper 2 and only about 25% manage to answer correctly the Question number 30 (Paper 1), that involves the topic Graphs of Functions II.

On a further enquiry among the experienced mathematics educators, it also revealed that teachers tend to concentrate on Paper 2 type of questions only during the revision sessions as preparation for the SPM examinations, primarily for the weaker and average students. However, according to them, the good students do not need much practice on these questions since they are already managing it very well. They

also added that the weaker students are not confident of answering the Paper 1 type of multiple-choice questions for the same topic, thus not much emphasis is given to this type of questions for the weaker group of students. On contrary, the better lot of students are usually able to do well, thanks to the drill and practice method employed in the classroom that ensures their marks.

The difficulty level of questions from the Graphs of Functions II for the SPM examinations for the years 2004 – 2017 was considered. The difficulty level of the questions was finalized after seeking the Mathematics experts' opinion with teaching experience of more than 15 year. The analysis is given in Appendix A.

However, an observation done by the researcher prior to this study on the classroom learning of the topic Graphs of Functions II shows that students are taught in a very clinical manner on the steps involved in answering questions pertaining to this topic. Most of the questions only test the students' knowledge to answer the questions. A closer view by the researcher shows that the good students are able to answer the questions very easily without much problem or further thinking. During the interview they declared that all they have to do is just memorise from what was being taught in the classroom by their subject teacher, as the type of questions are very repetitive and definitely do not involve any higher order thinking. This is also being attested by experienced mathematics teacher teaching the topic Graphs of Functions. As to the mediocre students, they can just manage to answer and there are times they are quite confused on the positioning of the graphs (especially involving quadrants). For the weaker lots, this type of questions is answered with some level of uncertainty. There are times they get it right and most of the time, no explanation can be expressed for the selection of answers. In fact, the text books used in the Malaysian classroom also incorporates similar kind of activities.

They are the type of questions that can be solved easily with very standard routine procedure. That is: -

i) identify the value of *a*

ii) the value of *c*

iii) memorize the positioning of the graphs based on both these values

Here are the characteristics of the question from the chapter Graphs of Functions (year 2004 – 2017): -

- It is always the question no 12 (occasionally question no 13)
- Tests on the sub units

  2.1: Graphs of Function &

  2.2: Solution of an equation by the graphical method

Allocation of marks and the skills that are tested are quite predictable. It is very similar as given in Appendix B.

This scenario is further strengthened with the feedback the researcher obtained from a few experienced mathematics teachers (teaching mathematics for at least 10 years) during the interview, whom teaches the weaker students. Following are their feedbacks :

- *I always concentrate on this topic in classroom discussion, as this is the only question even my weakest student can get marks. Thus, I would advise them to do this question first, without even looking at other questions.*
- *I make sure to include this question in every of my revision class with the students.*
- *I don't have to concentrate on this question, because the students always get full marks and the question is very straight forward for my students from the good classes.*

- *There are times some of my students not able to answer the part (d). It is either they are confused or made a silly mistake in separating the equations so that only new equation is formed and that is the equation that will give the required straight line. So, I do take trouble to sharpen my students on this skill.*

Those teachers teaching the weaker students also admitted that they normally concentrate only on paper 2 type questions during revision classes and focuses only on some easy questions from the paper 1 type questions, whereby, the correct answers are easily obtainable with the use of scientific calculator. This too brings to the researcher's attention that calculators are only used as button pushing tool that has the ability to display the correct answers.

Similar stance was observed by Lim (2006) and Koh (2006). They criticized on the common beliefs that `practice make perfect" where many routine questions are given in an attempt to ensure better achievements in public examinations.

An analysis given by the Malaysian Examination Syndicate on their website gave similar comments that on the whole, almost all the students from the excellent and average group did well. Where else the weaker lots were mentioned as did not draw a clean and smooth graph in this question testing on Graphs of Functions from Paper 2 SPM (MOE, 2014, 2017) and no further elaboration on the performance of students with regards to Graphs of Function. As to the analysis of the overall performance, it was stated that weaker group of students are still very weak in grasping the basic mathematics skills. Many students tend to give answers without any working and they are not able to solve questions involving Higher Order Thinking Skills (HOTS). However, no specific topics were mentioned to show students incapability of answering the questions.

Meanwhile, the Ministry of Education has taken note of the trend of the SPM type questions that is very routine and had started some initiative on changing the difficulty of questions from the previous ratio of 5 (easy) : 3 (moderate) : 2 (challenging) to a

new ratio of 3 (easy) : 3 (moderate) : 4 (challenging). However, there is a possibility that it will cause further disadvantage to the weaker students that are already struggling with the easy questions (Chiew & Lim, 2003). A study on a group of students preparing for the SPM examinations using the objective questions from the topic Graphs of Functions, shows an alarming trend too (Jeyaletchumi et al., 2014). The good students could answer all the six objective questions correctly with reasonable explanations on the selection of answers and most of the explanations mentions on the effects of the `*a*' and `*c*' values of the graphs and none of the them touched on the effect of the `*b*' value on a general equation involving graphs, $y = ax^n + bx + c$. Their further explanation during interview states that the questions are very straight forward and they just have to memorise the positioning of the graphs at any of the four quadrants on the Cartesian plane. As for the weaker students, they have no idea on how the positioning of the graph works and their mathematics teacher rarely gives importance to this part of the topic. Therefore, it tallies with the focus of revision that was mentioned by their teacher during the interview session with the researcher. That is, emphasis is given to paper 2 type questions that gives the students an opportunity to score some marks. This means, students are taught to pay more attention to the routine type of questions.

The topic Graphs of Functions had also attracted the attention of other researchers (Mary Ann & Leong, 2018; Leng, 2011; Noraini et al., 2015). Importance was given to the incorporation of graphing technology for deeper learning and to address misconstruction that may appear in a conventional classroom. They also highlighted on the level of strenuousity that students encounter in terms of time and energy to explore graphs such as:

i) $y = x^2$
ii) $y = x^2 + 1$

iii) $y = x^2 - 2$

and other polynomial graphs without the graphing technology tool.

There are many researchers (Hiebert & Carpenter, 1992; Schwarz & Hershkowitz, 1999; Terranova, 2013) who had highlighted that the understanding of mathematical concepts especially graphs and functions need to emphasize on the ability to make connections of its multiple representations. That is its symbolic, numerical and graphical forms. They have suggested that carefully designed curriculum with access to graphing technology is able to address this problem since the function concept is considered by many to be one of the most central concepts in all mathematics but students rarely develop adequate understanding (Hollar, 1999; Slavit, 1994). Furthermore, Leinhardt et al. (1990) had highlighted that the teaching and learning of graphs and function should focus on the use of graphing technology that is able to connect the algebraic, tabular and graphical connections. A study done by Jones (2005) also shows similar results that the use of graphing technology enabled students to approach mathematical problem graphically, numerically and algebraically and eventually to explore further the mathematics that they learn.

1.4 Problem Statement

The latest national mathematics curriculum formulation for secondary school, KSSM is aimed at creating a future society that is able to think mathematically, apply mathematical knowledge effectively in their daily life challenges that are brought about with advancement of science and technology. The curriculum also emphasises on the need to develop the mathematical reasoning of the pupils, which is seen as very closely linked to the progression of intellectuality of the students. The curriculum also states that use of technology especially graphing calculator and computer software in

present day classroom is essential in the enhancement of learning process for mathematics in school. So much so, constructivism is given much importance in many dialogues at national and international arena involving mathematics education. It shows concern on both the students who are successful solvers and also those who are not able to solve the given task, with crucial reminder that one should not be just be taking in information thrown to them by educators. An educator should engage the students in the classroom teaching and give them an opportunity to support their own explanation, application, communication and evaluation.

Despite such importance being placed in aspects of mathematics learning relevant to the HOTS of student and the use of technology in these processes, there are evidence (Leung, 2006; Schacter, 1999; Roschelle et al., 2000) that shows not much have been done in engaging teaching concepts that are incorporating elements of HOTS and technological tools. In fact, in traditional learning set up, students are not given much opportunities to develop decision-making, self-monitoring and attention-checking skills which are necessary for deep conceptual understanding and learning experiences (Perkins, 1993; Shield, 2008; Zaharin, Sharif, & Mariappan, 2018).

There are numerous research studies that has proven that the conventional teaching approach that is dominated by the teacher often not successful in teaching students how they can learn best and the method to process information effectively (Cadle, 2010), with a reminder that the standardized test scores are only able to measure superficial thinking (Kuhn, 2000).

Thus, as mentioned earlier, there are lack of initiatives taken to emphasise on deep conceptual understanding as requested in the current curriculum especially in the topic Graphs of Functions. Most of the studies related to Graphs of Functions, especially in Malaysia had only suggested on how to improve the teaching and learning

of that topic so that students understand the content in the textbook better (Ibrahim & Othman, 2010; Leong, 2013; Mutharasan, 2005; Teoh & Fong, 2005). There is a possibility that the ability of students is not fully developed. In reality, the present-day students are capable of learning more in the presence of technology. Therefore, an educator should allow these students to do more explorations in the process of knowledge construction and should not just limit to paper and pencil. Furthermore, it is evident from Appendix A that the difficulty of items for the Graphs of Functions have not exceeded the domain of understanding until year 2017 and the problems are very straight forward and students can perform well because they have gone through the drill and practice in classroom. This is in contra with MOE's target of increasing the difficulty level of SPM questions drastically to 30% by year 2015 and 50% by year 2016. Could it be the situation that there is a difficulty in increasing the SPM items difficulty levels for Graphs of Functions?

Therefore, there is a need to address this gap that does not conform to the aspirations of the current secondary school education system that focuses on HOTS. Probably, an improvised teaching and learning approach and assessment is required to showcase the presence of HOTS among the students in Graphs of Functions particularly the elements of creativity and innovation (KSSM, 2016).

Hence, there is a need to further investigate the topic Graphs of Functions looking at its importance that needs a deep conceptual understanding from the students' side. This study is conducted among the heterogeneous science stream students (mixed ability group) who have very high likely chances of furthering studies to the Pre-U level (Form 6, Matriculation, Foundations) either locally or internationally. Most of the time, they will enroll in courses related to science or any other social science related subject such as economics that needs a good grasp on the

changes that takes place on the graph aspects especially in the subjects related to Microeconomics that would need the students to analyse different types of graphs.

Researchers (Singh et al., 2015) suggests that students should be exposed to more challenging activities that needs thinking at a higher level of cognition. Taking this into consideration, higher order thinking is not only about making the questions more complicated, but rather should be the one that can transform any child into a person that appreciate mathematics and its application in real life. This scenario can be changed with the intervention of more visualization tool that can benefit students especially the heterogenous groups of students. They are the high, average and low ability students. The intervention activities involving 5E Instructional model with the use of graphing calculator may play the role of a stepping stone to inculcate HOTS in the classroom.

Utilisation of modern instruments to extend one's intellectual capabilities, is rather limited. Students are known to declare that they never heard of the name GSP (Geometers Sketchpad), GeoGebra, Mathematica, Autograph or even Graphing Calculator because they only use Scientific Calculator which is a mandatory use for their examinations. However, many studies (Ayub et al., 2008; Effandi, Md. Yusoff, & Norazah, 2007; Jeyaletchumi et al., 2014; Lim & Kee, 2004) had declared that students are very keen and interested to learn mathematics with technology if technology were incorporated in their lessons.

Besides that, whenever students are taught something new, they always echo with a big question `Will this be tested in the exam' or in the case of a technology, students always ask `Are we allowed to use this during the exams?' (Jeyaletchumi, 2013; Rosihan et al., 2003).

Therefore, it is about time a study is carried out to investigate if the students are engaged in an environment incorporating technology, and its impact on students mathematical thinking with the believe that students are capable of handling many activities that requires them to think `Out of Box' provided they are given the right exposure and opportunity. There are also other studies (Azizan & Hashim, 2008; Bakar et al., 2009; Mary Ann & Leong, 2018; Noraini et al., 2015a) that supports the positive impact of graphing calculators and other Dynamic Software as an alternative approach to teaching and learning of mathematics.

There are a few studies done in the local and international arena regarding HOTS and the use of technology especially graphing calculators. For instance, Nur'ain (2013) had used the Metacognitive Awareness Survey (MCAS) pertaining to the topic Straight Line. The MCAS was adapted from the "State Metacognitive Inventory" by O'Neil and Abedi (1996). Prior to this, Noor Shah Saad et al. (2004) had also incorporated the O'Neil inventory into their studies. Similar studies were also conducted by Noraini et al. (2015b). These studies are rather quantitative centric with less focus on the process of HOTS that takes place amongst students during the mathematics learning. Thus, there is a need to investigate further the students HOTS aspects with a mixture of quantitative and in depth qualitative methods.

Although the use of 5E Instructional model had been mentioned as one of the suggested approaches in a constructivist learning environment (CDC, 2001), there is lack of study related to this approach in Mathematics especially in the context of Malaysian classroom incorporating graphing technology. Investigations into technology-related learning creates more opportunity for the application of instructional theories. The present-day advancements in technology has a great potential to study the impact of constructivist approaches in learning (Font, Bolite, &

Acevedo, 2010; Lee & McDougall, 2010; Mahmud et al., 2020; Mergel, 1998; Tajuddin et al., 2009).

All these previous studies only incorporated the three steps lesson of introduction, development and closure. As the current requirement of concentration on producing active learners, it is important and pertinent to embark on a learning cycle that gives importance on explorations and challenge students to progress further.What this means is, there's a need to include more challenging tasks as mentioned by Kastberg and Leatheam (2005). These activities should be able to explore the maximum capacity of the calculator that can showcase the students HOTS and with caution to move away from the common myth that calculator will do the calculation and students only need to key in the values. The calculator should be perceived as a tool that helps to elevate the students' mathematical thinking, with a gentle reminder that learning does not happen in isolation, rather it needs the important role of teacher as the driver who ensures knowledge construction takes place. Hence, the crucial role of a teacher who moves the lesson to a greater height with higher order thinking questions are not to be denied (Aziza, 2018; Jacques et al., 2019; Mason, 2000; Menezes et al., 2014). A study conducted by Hussin (2006) triggered concern for the inclusion of higher order thinking questions because she discovered that the English for Science and Technology (EST) teachers used 87% low level questions and only 13% high level questions. This attributed to a mismatch of the MOE's aspiration to build critical and creative learners.

With these points of interest, this study was conducted to look into the students' HOTS, whereby, their ability to construct knowledge that gives importance to the mathematical process associated with explorations through engagement, planning, monitoring and evaluating their work in completing high demanding tasks and finally