EFFECTIVENESS OF GRAPHING CALCULATOR'S APPROACH IN LEARNING INTEGRALS TOWARDS MATHEMATICS PRE-SERVICE TEACHERS' ACHIEVEMENT AND MATHEMATICAL REASONING

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UNIVERSITI PENDIDIKAN SULTAN IDRIS

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ABSTRACT

This study aims to investigate the effectiveness of using TI-Nspire CX graphing calculator's approach in learning Integrals and Its Application topic towards pre-service mathematics teachers' achievement and mathematical reasoning. In addition, the study also determine the relationship that exists between the two dependent variables. The sample consist of 44 pre-service mathematics teachers selected using the fish-bowl method to take part in this quasi-experimental non-equivalent pre-post-test design study. A total of 22 pre-service mathematics teachers are participate in each experimental group and control group. The instruments used for the pre and post-test were the Calculus Achievement Test and Calculus Mathematical Reasoning Test to measure the pre-service mathematics teachers' level of achievement and mathematical reasoning skill. The obtained data were analysed quantitatively using the inferential statistics, namely paired sample t-test, one-way MANOVA and Pearson-r correlation analysis. The findings revealed that there was an increase in the achievement's mean score of pre-service mathematics teachers in the Calculus Achievement Test for the control group and experimental group, which the change in the mean score of achievement from 17.09 (SD=9.626) to 46.32 (SD=6.557) with value of p=0.00 for the control group, and from 17.00 (SD=10.933) to 45.95 (SD=10.746), with value of p=0.00 for the experimental group. For the achievement of the Calculus Mathematical Reasoning Test, the experimental group that learned the topic of Integrals and Its Application using the TI-Nspire CX Graphing Calculator Learning Activities was perform better than the control group that underwent learning using the conventional method. The result showed an increase in the mean score of mathematical reasoning for the experimental group from 21.82 (SD=7.938) to 49.64 (SD=6.477) with a value of p=0.00, compared to the value of the increase for the control group which from 21.91 (SD=5.528) to 26.27 (SD=9.067), with a value of p = 0.007. This indicate that there is a positive relationship between the dependent variable of achievement and mathematical reasoning, with the p-value=0.001 and r=0.677. In conclusion, the graphing calculator approach in learning is able to develop the ability of pre-service mathematics teachers in mathematical reasoning skills and improve their achievement. The implication is that the approach involving technology in mathematics learning is very meaningful and relevant nowadays to be applied at the level of higher education institutions.

KEBERKESANAN PENDEKATAN KALKULATOR GRAFIK DALAM PEMBELAJARAN KAMIRAN TERHADAP PENCAPAIAN DAN PENAAKULAN MATEMATIK GURU MATEMATIK PRA-PERKHIDMATAN

ABSTRAK

Kajian ini bertujuan mengkaji keberkesanan penggunaan pendekatan kalkulator grafik TI-Nspire CX dalam pembelajaran topik Kamiran dan Aplikasinya terhadap pencapaian dan penaakulan matematik dalam kalangan guru matematik pra-perkhidmatan. Di samping itu kajian juga ingin menentukan hubungan yang wujud di antara kedua-dua pemboleh ubah bersandar tersebut. Sampel terdiri daripada 44 orang guru matematik pra-perkhidmatan yang dipilih menggunakan kaedah *fish-bowl* untuk mengambil bahagian dalam kajian reka bentuk pra-pasca ujian separa eksperimen ini. Seramai 22 orang guru matematik pra-perkhidmatan terlibat dalam setiap kumpulan eksperimen dan kumpulan kawalan. Instrumen yang digunakan untuk ujian pra dan pasca adalah Ujian Pencapaian Kalkulus dan Ujian Penaakulan Matematik Kalkulus bagi mengukur tahap pencapaian dan kemahiran penaakulan matematik mereka. Data yang diperolehi telah dianalisis secara kuantitatif menggunakan statistik inferensi, iaitu ujian t sampel berpasangan, MANOVA sehala dan analisis korelasi Pearson-r. Hasil kajian menunjukkan terdapat peningkatan skor min pencapaian guru matematik pra-perkhidmatan dalam Ujian Pencapaian Kalkulus untuk kumpulan kawalan dan kumpulan eksperimen iaitu perubahan nilai skor min pencapaian dari 17.09 (SD=9.626) kepada 46.32 (SD=6.557) dengan nilai p=0.00 bagi kumpulan kawalan, dan dari 17.00 (SD=10.933) kepada 45.95 (SD=10.746) dengan nilai p=0.00 bagi kumpulan eksperimen. Bagi pencapaian Ujian Penaakulan Matematik Kalkulus, kumpulan eksperimen yang mempelajari topik Kamiran dan Aplikasinya menggunakan Aktitviti Pembelajaran Kalkulator Grafik TI-Nspire CX adalah lebih baik berbanding dengan kumpulan kawalan yang menjalani pembelajaran menggunakan kaedah konvensional. Dapatan menunjukkan peningkatan nilai skor min penaakulan matematik bagi kumpulan eksperimen dari 21.82 (SD=7.938) kepada 49.64 (SD=6.477) dengan nilai p=0.00, berbanding nilai peningkatan bagi kumpulan kawalan iaitu 21.91 (SD=5.528) kepada 26.27 (SD=9.067), dengan nilai p=0.007. Ini menunjukkan terdapat hubungan positif di antara pemboleh ubah bersandar pencapaian dan penaakulan matematik, dengan nilai p=0.001 dan r=0.677. Kesimpulannya, pendekatan kalkulator grafik dalam pembelajaran mampu membangunkan keupayaan guru matematik pra-perkhidmatan dalam kemahiran penaakulan matematik dan meningkatkan pencapaian mereka. Implikasinya adalah pendekatan yang melibatkan teknologi dalam pembelajaran matematik sangat bermakna dan relevan pada masa kini untuk diaplikasikan di peringkat institusi pengajian tinggi.

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CA	Conventional Approach
CAS	Computer Algebra System
CAT	Calculus Achievement Test
CVI	Content Validity Index
CVR	Content Validity Ratio
DV	Dependent Variable
EU	European Union
GCA	Graphing Calculator Approach
ICT	Information and Communications Technology
I-CVI	Item-Level Content Validation Index
I-FVI	Item-Level Face Validation Index
IV	Independent Variable
MS Excel	Microsoft Excel
MOE	Ministry of Education
MRT	Mathematical Reasoning Test
NCTM	National Council of Teachers of Mathematics
NRGS	Niche Research Grant Scheme
S-CVI	Scale-level Content Validation Index
SD	Standard Deviation
SPSS	Statistical Packages for Social Sciences

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The rapid development of technology in education has led to various technology tools invented for the purpose of education, especially in mathematics. This technology is widely used at all levels of education to improve student's achievement. With the use of technology, it can help students to enhance their understanding about the abstract mathematical concepts through visualization or graphical representation where the students can see the relationship between properties and objects (Robova, 2002). In mathematics, the graphing calculator is a technology tool that is frequently used to help students solve mathematics problems involving calculations. Furthermore, it offers a method of calculation and algebraic manipulation that is more effective and accurate compared to traditional methods (Tajudin & Idris, 2014). Nowadays, graphing calculators is one of the most widely adopted technologies in mathematics education as

it has great potential in helping students mastering the important mathematical concepts and also offer specific features which are valuable for the mathematics learning (Khairudin & Ismail, 2017).

According to Tajudin and Idris (2014), the increase in use of technology and changes in demand in the workplace has changed the style of teaching of mathematics in recent years. This requires workers highly skilled and able to apply their mathematics skills to solve complex problems. It can be seen that there is a need to produce students who are capable of self-reliance in the technology community today. Hiebert and Carpenter (1992) stated in their study that students who understand what they have learned in mathematics will remember what they have learnt and be able to transfer their knowledge to new situations. Therefore, the technology should also be in line with the needs of education and technological environment nowadays. According to Tajudin, Tarmizi, Konting and Ali (2009), there are several types of technology which are suitable for the mathematics learning at school, for example; among the very powerful computer software such as Maple, Matlab and Mathematica until to the powerless technology such as calculator. One example of new technology that is currently used in high school mathematics classrooms is TI-Nspire CX CAS handheld calculator (Mickle & Clarke, 2015).

The use of graphing calculators can provide an effective strategy in teaching and learning of mathematics (Tajudin et al., 2009). Based on Tajudin and Idris (2014), the use of graphing calculators can facilitate learning mathematics as this learning strategy is efficient and effective. The use of graphing calculators in teaching and

learning enables various kinds of guided explorations to be undertaken (Idris et al., 2014.). According to Mor, Winters, Cerulli and Björk (2006), learning of mathematics is categorised as a science that involves the traditional instructions and abstract formulas, which seem to be easily understood by only a small fraction of students. However, the use of graphing calculators has spawned a new breath in the teaching of mathematics, whereby more learning activities can be generated through the use of graphing calculators. By using a graphing calculator, students can implement learning that can help them to better understand and apply mathematics. Goodrum, Hackling, and Rennie (2001) in their study mentioned that the teaching of mathematics is seen as unattractive to the majority of students, outdated and not relevant to their interests and experiences. This showed that an innovation of teaching methods in mathematics is necessary to develop students' interest in learning mathematics.

Since decades ago, the use of graphing calculators in education has been increasing among students all around the world. In the classroom, this hand-held technology as one of a tool in learning mathematics that turns out to have a good effect on students. With graphing calculator, students can get more ideas in problem solving by their exploration and visualization of the situation, which this advantage cannot be achieved with the use of pencil and paper method, which the student deals with dreary calculation.

According to Stacey and William (2013) and Drijvers et al. (2016), the difference between the approaches of the graphing calculator and the traditional way can be evident mainly in solving mathematics problems. By using graphing calculators,

it helps student to explore with the problems that rich with the arguments, simulation, animation and various types of dynamic problems can be included. Apparently the use of graphing calculators will continue to challenge the traditional ways in solving mathematics problem using paper and pen. This make students with graphing calculator have a better ability to interact with the problems rather than traditional way which might be impossible to include those resources.

A study conducted by Subtil and Domingos (2018) discovered that mathematics learning is the experience of exploratory learning, where students get the experience from the environment of solving different tasks with graphing calculators. This means through the using of graphing calculators, students was given chances to do exploration by various task of learning activities that will improve their understanding in mathematics. This is as per stated by Engeström (2001) which is learning activities that assisted with graphing calculators will developed students' knowledge at the same time.

Based on Tajudin and Idris (2014), students who are exposed to activities that encourage exploration of mathematical concepts will help them to see mathematics as a fun subject. Hence, the use of a graphing calculator is required in order to create more interactive learning and motivate students to participate in learning mathematics. Teachers should use technology in the classroom when the medium is more effective than the traditional way. According to Ortiz and Rico (2001), the use of graphing calculators is due to its interactive characteristics as well as the system's utility in conveying symbolic calculus and its requirements to mathematics teachers and

researchers. Hence, it is important for teachers to guide students in knowing how to use a graphing calculator as it has become a useful learning tool.

Teachers have an important role in minimising the student misconceptions (Dick, 1992), especially on mathematical concepts and formulas. According to European Union [EU] (2011), the mathematics idea is presented in an abstract and theoretical way, without giving ample opportunity for students to engage in problem solving and experimentation. Graphing calculators also help teachers to maximize the learning in the classroom where the teachers do not have to take a long time to show various types of graphs and the students do not have to waste time drawing the graph manually. A more student-centred activity will also be encouraged. Based on Tajudin and Idris (2014), through these kinds of activities, students will be encouraged to do more discussion and group work which needs the use of technology. It is also claimed that an exploratory activity in mathematics may drive an active approach for students' learning rather than a passive approach where the teacher only gives lectures.

According to Firdaus (2016), Malaysian students struggle to understand mathematics, particularly Calculus. Despite the fact that calculus is taught at all levels of education, from basic concepts in secondary school to more advanced applications at the university level, many students still do not grasp the subject and perform poorly in it. De Almeida, Queiruga-Dios and Cáceres (2020) also stated that engineering students frequently encounter problems with the differential and integral calculus, which results in high failure rates which leads to absenteeism and, consequently, dropping out of university studies. Calculus is the mathematical study of continuous

change, in which differential and integral calculus are two fundamental disciplines that are intertwined. Calculus was a foundational concept in the evolution of mathematics and this subject is important for the development of science and engineering fields (Cheshier, 1998; Kent & Noss, 2000). Thus, it is important for students to master both disciplines in calculus. However, learning the subject seems like a nightmare to the students. Calculus is a tough subject for students to grasp because the concept of calculus itself is abstract in nature. When this is combined with the too rigorous and arduous learning of Calculus, students feel burdened and lose interest in this course (Zhang, 2003).

A study by Zakaria and Salleh (2015) discovered that integral is more difficult to master rather than differential in Calculus subject. A survey on 191 engineering students found that 78 percent of them stated integral was a difficult subject, with more than 40 percent saying it was the most difficult topic since they had encountered since secondary school. In comparison to the differential that are also covered in Calculus, only 5 percent of them stated integral was a simple topic. Apparently, the results of this study are in line with previous studies conducted by Abdul-Rahman (2005), Mahir (2009) and Salleh and Zakaria (2011), which also discovered there are difficulties among students in understanding the concept of integral calculus. Based on the study, it was found that students who didn't have strong foundation of calculus will continue to achieve low achievement or fail in the advance Calculus courses. Besides, the study also discovered that the respondents are willing and more motivated to follow the process of learning Calculus with the help of technology, in order to improve their understanding and performance in this subject, especially integral topics. This is

because Integrals is a topic that related to everyday life problems. The right teaching approach will give opportunity for students to explore and creating possible problems during the problem-solving learning process, which at the same time stimulates their critical thinking and reasoning skills, as well as enhances their in-depth understanding of the lesson of calculus. Orton (1985) stated that teachers are responsible to ensure the students build their understanding of the fundamental idea of Calculus, otherwise it will lead to misconception of students' future understanding of the subject.

Therefore, it is very important to create an interesting and meaningful Calculus learning environment in order to help students better understand the concept of calculus. The traditional approach which became a practice nowadays needs to be changed to a new approach that uses a graphing calculator that is able to give students a very interesting learning experience, as it will allow students to explore and model mathematical problems and create various representations of mathematical problems. As stated by Texas Instrument (2007), any technology that supports multiple representations will be able to improve students' visualization in the problem-solving process and improve students' understanding as well. Furthermore, the use of graphing calculators also will eliminate the time spent on manual calculations, hence more time for improving the students' understanding of mathematical concepts will be obtained (Waits & Demana, 1998).

Graphing calculators have been found to change the way that students learn. It is believed that the calculator is one of the most important hand-held gadgets that has influenced mathematics education. Study by Tan (2012) has discovered that student

performance while using graphing calculators is significantly increased, where the students become more motivated during the mathematics learning process while using a graphing calculator. In addition, Lazari and Goel (2003) also discovered that this teaching approach is one of the elements that contribute to greater academic accomplishment performance. These two studies also discovered that students who used a graphing calculator scored marginally higher on the final exam than students who did not use it.

Calculus is classified as one of the three main domains of advanced mathematical content, where reasoning skills are very useful in the process of mastering this calculus content. It is also believed that mathematical reasoning is more accurate than mathematical thinking or working mathematically which refers to action. Since students' reasoning skills are part of their conceptual understanding of calculus, it is crucial to determine how these skills can be improved. It is believed that exposure to environments and problems that encourage reasoning activities will assist students in improving their reasoning skills, and in turn will enhance the conceptual understanding of calculus.

Ministry of Education Malaysia (MOE) encourage students to use graphing calculators in their studies. The use of electronic devices is important in the development of the students' mathematical abilities and concepts (Ellington, 2003; Zakaria & Rahman, 2010; Idris et al., 2014). According to Ellington (2003), this technology aids students in improving their problem-solving skills by allowing them to reflect on their learning. Furthermore, prior research have shown that students' problem

solving, mathematical reasoning, and mathematical thinking are influenced by the use of graphing calculators (Idris et al, 2014).

One of the problem solving techniques in mathematics is reasoning skills. It has been recognised that these two elements are related to each other (Mayer & Wittrock, 2012). A study by Hunter (2011) showed that student reasoning skills are impacted positively by using graphing calculators, using graphing calculators to be an effective strategy in mathematics and there is a significant difference between those students who use a graphing calculator and traditional methods using pencil and paper in solving mathematical problems that require reasoning.

There are several processes that need to be fulfilled in improving the mathematical reasoning skill, such as building the conjectures, investigating, representing the outcome of the task and justifying all the conclusions in mathematics. Several strategies can be done in order to encourage reasoning in mathematical learning. One of the strategies is using technology that can assist the reasoning process such as using a calculator. In this study, the calculators of T1-Nspire CX were used in the process of completing reasoning in Calculus. This handheld graphing calculator technology aids students in gaining a clearer picture of mathematical issues, as well as amplification and a better understanding of the subject's concepts. Students were aided by the ability of these calculators to create mathematical modelling as well as solve complex operations, reducing students' cognitive load while opening up opportunities for them to experience learning and making multistep problem-solving and other complex operations easier, while also supporting teachers as educators to emphasise

mathematical reasoning rather than just the calculation itself (Roschelle & Singleton, 2008). Students will reportedly be more motivated to learn mathematics as a result of this technology, and their lessons will be stimulated (Rodrigues, 2019).

Furthermore, students can use graphing calculators to assist them in solving computational issues, especially when using graphic and numerical strategies. While exploring mathematics, students can use this tool to practise and gain meaningful context, by enables students to actively collaborate through experiments. This allows students to share their thoughts and cooperate with others on how they solve mathematical problems with their discoveries. Additionally, graphing calculators also aid students in comprehending a wide range of problems, where students can use this tool to accurately complete the mathematical operations while saving a significant amount of time. Algebraic and geometric concepts can be connected by using graphing calculators. This feature is really beneficial when learning. It is undeniable that this mathematical tool can assists students in effortlessly completing the numerical process and gaining a deeper understanding of graphical and symbolic representation (Ng, 2005).

According to National Council of Teachers of Mathematics [NCTM] (2009), reasoning is a critical component of students' mathematical learning and conceptual understanding. The ability to reason out mathematical ideas and concepts is equally important as a means to acquire knowledge of mathematics, which requires reasoning and understanding (Garden et al., 2006). The fact that students are able to reason mathematically permits them to use their acquired knowledge and apply it

appropriately, which ultimately helps the development of their thinking or reasoning process. It is believed that through improving students reasoning skills, they will be able to overcome their difficulties to visualize the circumstances, particularly in problem-solving questions. Therefore, it is very crucial to focus on the development of conceptual understanding, which should be the main purpose of mathematics instruction rather than just algebraic manipulation.

Rapid technological advancements have had a significant impact on the teaching of mathematics at all levels, including the stage of preparation of future teachers (Robova, 2002). Technology, curriculum, teaching, learning, assessment, and equity are listed by the NCTM (2000) as six concepts that should be used to assist and guide teachers in enhancing the content and delivery of mathematics. In the scenario of a mathematics classroom, most pre-service mathematics teachers have basic skills to apply technology as an instructional strategy in delivering the content standards of the subjects. Today's demands for pre-service teachers led them to see an opportunity to start using the graphing calculators by team teaching, and then it will be easier to take the first steps in using the graphing calculator with the students (Mickle & Clarke, 2015).

Consequently, the advancement of graphing calculator technology has led to an increase of the influence of this type of calculator and it also affected mathematics education in Malaysia (Tajudin et al., 2009). The technology developed in the field of graphing calculators should be adopted in mathematics education curriculum so that it is aligned with the current learning needs. Therefore, in line with the growing influence

in the advancement of technology, a curriculum that capable to develop the students' mathematical power need to be produce, where it requires the use of technology in order to focus on the acquisition of mathematical concepts and knowledge rather than just doing the calculations (Tajudin, 2013).

Currently, the integration of technology in teaching and learning of mathematics consistently has been one of the major emphases in Malaysian Integrated Curriculum for Secondary School Mathematics, as recommendation by NCTM (2000) where the vision is learning mathematics with understanding it (Tajudin & Idris, 2014). Recent reforms in Integrated Mathematics Curriculum for Secondary Schools (KBSM), as well as the latest Standard Curriculum for Secondary School (KSSM) in Malaysia, stressed the need to use information technology in the teaching and learning of mathematics. Based on these reforms, mathematics teachers and senior students are encouraged to use scientific calculators and graphs. Secondary school students are also exposed to the use of graphing calculators as a tool that can help them in mathematics calculations in mathematics and additional mathematics. NCTM also supports the use of appropriate technology in the mathematics classroom when it serves as a tool to teach and learn mathematics (Mickle & Clarke, 2015).

In the latest Malaysian Mathematics Curriculum, starting from the primary school level, it has been stated that reasoning is one of the five important processes in effective mathematics learning (MOE, 2015). This is because reasoning is an important foundation for understanding mathematics more effectively and making the meaning of mathematics more meaningful. Therefore, among the suggested activities mentioned

are engaging mathematical activities that encourage thorough discussion between students, so that the development of logical and critical thinking that is the basis for understanding mathematics in a student can be improved. Thus, this latest Malaysian Mathematics Curriculum supports the use of calculators as a technological skill that needs to be nurtured and developed in a student from the primary to secondary level, along with other skills that have been listed, namely mathematical skills, analysis skills, problem solving skills, research skills and communication skills (MOE, 2015a; MOE, 2015b).

Improvement in the Malaysia national curriculum standard is an approach that can help to solve the issue that mentioned by Tajudin (2013), where not much success about the use of this tool in mathematics classroom practices although the graphing calculators were circulated to some selected schools in 2002 and the license of GSP was given in 2004. This might happen because there is little or no emphasis on the use of technology, especially calculators in the previous national mathematics education curriculum, which at that time was the Integrated Secondary School Curriculum (KBSM), which was used starting in 1998 before the new standard curriculum, the Standard Curriculum for Secondary School (KSSM) which was first used in 2017. The implementation of KSSM takes into account the intentions of the Malaysian Education Development Plan (PPPM) 2013-2025 which recommends that KBSM needs to be reviewed, in line with the changing currents of global education.

1.2 Problem Statement

According to studies conducted in Malaysia, students struggled with mathematics, particularly problem solving, because they lacked understanding and were unable to retrieve concepts, formulae, facts, and procedures, lacked the ability to visualise mathematics problems and concepts, executed logical thinking ineffectively, and had poor strategic knowledge in problem solving (Kadir et al., 2003; Tambychik, 2005; Tay, 2005). It is believed that this problem is due to the lack of mastery in problem-solving skills among the Malaysian students (Zanzali & Lui, n.d.).

Despite the fact that the Malaysian mathematics curriculum emphasises reasoning as a major part in mathematics training, which is consistent with global curriculum content (Jeannotte & Kieran, 2017), its implementation in schools has been unsuccessful. Teachers are still using textbooks as their primary source of information in their classrooms (Nasir et al., 2020; Ramos & Ishizaka, 2021). The process of thinking will not be possible with such a teaching style. This is because students must be exposed to the environment and situations that entail reasoning tasks in order to develop and strengthen their mathematical reasoning skills. This method is the most effective because the issues that students face will inspire them to accomplish a task using their mathematical reasoning skills.

The emphasis in the mathematics curriculum on the process of reasoning is an attempt to help students grasp numerous areas of mathematics that entail reasoning,

such as algebra, geometry, and statistics (NCTM, 2009). It can indirectly assist students in creating the foundation for the concept of calculus, which was previously a challenge for them. It is critical to improving conceptual knowledge in calculus since this understanding can have a significant impact on their ability to solve mathematical problems. A thorough understanding of the topic of Integrals, which is part of calculus, can aid students in comprehending the content of calculus. Integrals are part of Calculus that relates to real-world issues.

Most of the students have difficulty grasping the concepts of calculus until they have scored low achievement (Firdaus, 2016), especially in Integrals topic (Zakaria & Salleh, 2015). As Zhang (2003) argued, students regard calculus as an abstract and boring subject that is difficult to understand, and as a result, many students do not want to learn it despite the fact that it is an important subject in mathematics. This expressively why calculus is seen as a tough topic for students in secondary school and further education. Therefore, there is a need to increase students' mastery of Calculus, particularly in the area of Integrals, which could be accomplished through increasing students' mathematical reasoning skills. Learning activities that emphasize aspects that stimulate reasoning, such as graphing calculator learning activities, can aid in its development.

The use of technology in teaching and learning, such as graphing calculators, is nothing new. Despite the fact that graphing calculators were supplied to selected schools in 2002 and GSP licenses were granted in 2004, there has been little success in the use of this instrument, with the main culprit being a lack of information on how to

utilize it in mathematics education (Tajudin, 2013). Teachers should be prepared and knowledgeable about how to use technology, such as this TI-Nspire CX graphing calculator. Before a new approach is adopted, adequate training and continuing instructional help should be provided. To provide mathematics instruction more successfully, teachers must have a thorough awareness of the capabilities of the technology to be used and how it might aid in student learning (Mickle & Clarke, 2015). Thus, to produce teachers with these skills, it is more effective to train them during their teacher education programme, giving them more exposure to technology tools like graphing calculators. This is because these future teachers must not only be specialists in the mathematical subjects and pedagogical abilities, but they must also be prepared to meet the needs of an ever-changing technological environment, as well as keep up with the most recent technological discoveries and inventions (Tajudin et al., 2009).

Based on the NCTM's opinion that technology can affect students' reasoning skills, as well as previous studies on the use of graphing calculators and related issues, thus a study on the effectiveness of TI-Nspire CX graphing calculators in developing achievement and mathematical reasoning skills among teachers is needed. Hunter (2011) also noted that the effect of technology on pupils' reasoning skills has yet to be established in any previous study. Furthermore, it is unknown whether using a graphing calculator may affect the students' reasoning abilities when solving calculus issues. Therefore, it is necessary and important to determine the instruction method that contributes the most to developing student reasoning skills. As a result, there is no doubting the importance of conducting this research. Since technology is a necessity

for successful teaching and learning in the twenty-first century, this research should begin with pre-service mathematics teachers.

1.3 Research Objectives

Research has been developed to discover the effectiveness of TI-Nspire CX Graphing Calculator's activities in learning Integrals and Its Application topics towards pre-service Mathematics teachers' achievements and Mathematical reasoning. So, the objectives of this research as stated below:

i. To examine the effectiveness of using TI-Nspire CX graphing calculator's approach in learning Integrals and Its Application topic towards pre-service mathematics teachers' achievements and mathematical reasoning.

ii. To determine the relationship between pre-service mathematics teachers' mathematical reasoning and achievement when using TI-Nspire CX graphing calculator's approach in learning Integrals and Its Application topic.

1.4 Research Questions

In this study, the research questions that guided the requirement of this study to be done are as follows:

i. Is the developed TI-Nspire CX graphing calculator's approach for the Integrals and Its Application topic effective in improving the pre-service mathematics teachers' achievements and mathematical reasoning?

ii. Is there a relationship between pre-service mathematics teachers' achievement and mathematical reasoning when using TI-Nspire CX graphing calculator's approach for the Integrals and Its Application topic?

From these research questions, research hypotheses are developed to focus on the direction of the research.

1.5 Research Hypothesis

In order to answer the first research question of this study, the research null hypotheses are developed as follows:

H_{01} There is no significant difference in the mean scores of pre-achievement test and pre-mathematical reasoning test between the control group and the experiment group.

H_{02} There is no significant difference between the mean scores of pre-test and post-test for the achievement and mathematical reasoning test for the experiment group.

H_{03} There is no significant difference between the mean scores of pre-test and post-test for the achievement and mathematical reasoning test for the control group.

H_{04} There is no significant difference in the mean scores of post-achievement test and post-mathematical reasoning test between the control group and the experiment group.

In order to answer the second research question of this study, the research null hypothesis is developed as follows:

H_{01} There is no relationship between the pre-service mathematics teachers' achievement and the mathematical reasoning when using TI-Nspire CX graphing calculator's approach in learning for the Integrals and Its Application topic.

1.6 Research Significance

This research study gives advantages to students who are facing new demands upon their learning in increasing their knowledge and the need for lifelong learning. Hence, it becomes necessary for students to acquire new as well as existing knowledge. It is imperative for students to be qualified to play the role of active learners for the preparation to meet the social demands. The mathematics achievement of students is a

crucial factor in the mathematics field because it reflects the success in this field of education. Thus, this study could contribute to the Ministry of Education in implementing a better curriculum approach in fostering mathematical reasoning among teachers as educators.

Previous literature shows a significant lack of studies on the effectiveness of graphic calculators such as the TI-Nspire CX graphing calculator in developing mathematical reasoning. Hence this study can be a reference for students who will be doing a similar study related in this field. Last but not least, the outcomes of this research study will be contributed to the biggest University Grant which is 'Niche Research Grant Scheme' which is to develop a Teacher Education Model for preparing quality teachers for the future.

This research is believed to be important to university students and lecturers. The first significant to the students themselves. This research is a hope to give a better view of the student to graphing calculators. The result and discoveries in this research is hopefully to help students and encourage them to use graphing calculators to assist them while learning mathematics since there is a requirement in a particular fraction of mathematics, especially calculus. It is encouraging that this research opens the different view of students in learning calculus using graphing calculators.

This research is also significant to lecturers that used to teach calculus and mathematics. The result from the experiment that was conducted in this research can be a reference to the lecturers in helping them to decide in using technology and

computers, especially graphing calculators. At the same time, lecturers are able to study the benefits and flaws of using graphing calculators in their teaching. This research might help lecturers develop their method of teaching with their own preferences. The developed lesson plan for the experiment group and control group can be a reference to them in order to execute learning activities that can encourage mathematical reasoning. Therefore, development of this research hopefully to be a starting point to help students with their difficulties in calculus.

This study is also significant to universities or any educational institutions that offer calculus as their prerequisite subject in their educational programme. This study is believed to assist students in their mathematics learning. To be precise, universities or any other educational institutions might reconsider using graphing calculators in their calculus subject regarding the result of the study. The significance of this research might help universities to deploy a new tactic in learning as well in order to achieve excellence in mathematics based on this research result. Consequently, this study is important in broadening the knowledge in the university setting itself.

The curriculum department and developers in the university or any educational institution also might gain benefits from this study. This is a significant part where curriculum developers in university might re-evaluate the usage of graphing calculators in calculus or otherwise. Hence, the result of this experimental study might give expression on the practice of involvement graphing calculators in mathematics. At the same time, the existing curriculum in learning calculus might be revisited to enhance the effectiveness of using graphing calculators positively. There might be possibilities

in enhancing curriculum structure in calculus with the involvement of graphing calculators in order to enhance student achievement in calculus. This research is also believed to be a first step on another revolutionary research.

There are several researches on the usage of graphing calculators in calculus. This research is one of the focusing research especially involving the specific types of graphing calculator to examine their function to the specific calculus fraction. This research has come to a significance when the specific requirement and techniques are involved. It is hoped that this research in specific might help other researchers to continue and broaden their study in the usage of specific graphing calculators. This research might open the idea of conducting a new innovative research and at the same time it might help researchers broaden their knowledge and help to develop new knowledge. Therefore, the next paragraph commences on the limitation of this study.

1.7 Limitation of the Study

The study is limited to only Mathematics pre-service teachers in one of the public universities in Malaysia. This university was choosen because it has speciality in education field and it offers the most education programme compared to others. The sample consists of pre-service students who are taking Beginning Calculus courses in 1st semester. The sample may not represent a bigger population because it is taken from only one state in Malaysia excluding others. In other words, generalization across geographical as well as demographic areas may not be confirmed. Another limitation

is that this study is based on the data gained from a quasi-experimental method which involves only two groups of students. This study has been conducted through quasi-experimental only, although there might be other methodologies that can be used in this study, such as survey or through exploration. From this limitation, the outcome of this study is only representing the number of the students involved. Furthermore, this study will use technical gadgets, thus there are also limitations in this case.

In this study, graphing calculators were used instead of other calculators that also can be used in experimental study. This study limits the usage of any other version of graphing calculator which already exists on the market. The technical limitation of this study is restrained on the model of TI-Nspire CX only. The study did not involve any other previous brand or future brand of graphing calculator. This is because the study of this specific brand of graphing calculator might help to broaden the knowledge in using graphing calculators. At the same time this limitation makes this study more focus on technical function and their result of using graphing calculators. The study also has other limitations especially in theory that drive and designated the direction of this study.

There are only two theories involved in this study. The limitation of this study is only the constructivism theory and distributed cognitive theory. These theories are believed to have connections to skills in mathematics and usage of the graphing calculators. The theories of constructivism focus on knowledge and learning. This theory explains knowing and the process of getting to know something. This theory emerged from basic work of science, biology, psychology and philosophy (Fosnot,

2013). This theory is believed to be connected with the learning of mathematics using graphing calculators. Next, the distributed cognition theory was used in this study.

The distributed cognition theory explained how humans interact with tools. This theory developed to understand the cognitive process of a human on conducting tools for a purpose. The interaction between human and mechanical tools related to distribution of cognitive functions are the main ideas of this theory (Hollan, Hutchins, & Kirsh, 2000). The limitation of this study is limited to two theories involved, which are constructivism theory and distributed cognition theory. Therefore, this research will not try to explain and discuss any other theories than depicted above. The next research limitation is the instrument itself.

One of the instruments used in this research is the Calculus Mathematical Reasoning Test, which is an adapted instrument from the other research by Hunter (2011). This is because the adaptation of the instrument might help researchers to determine the validity and reliability of the existing instrument. In addition, there are several instruments in accordance with the requirements of the study that have been develop by the researcher based on the objectives of the study. The list of the instruments used were described in the next chapter of this thesis. Not only that, the limitation of the study also focused on the limited topic in the mathematics subject itself, which is only topics Integral and Application of Integration was chosen.

Mathematics and graphing calculators are studied to develop and gain new knowledge from this research. The limitation in mathematics is that only one subject

and one topic have been included in this study. The limitation of topic and subject from this study are proposed to lead the research to be more accurate and focused. At the same time, this research might add new knowledge to teacher, student and higher authorities such as curriculum developers to ensure there is a development on teaching and learning using graphing calculators across educational institutions. The next chapter discussed the created conceptual framework on the use of graphing calculators to enhance mathematics reasoning skills.

1.8 Conceptual Framework

The conceptual framework for this study can be referred in Figure 1.1 as below.

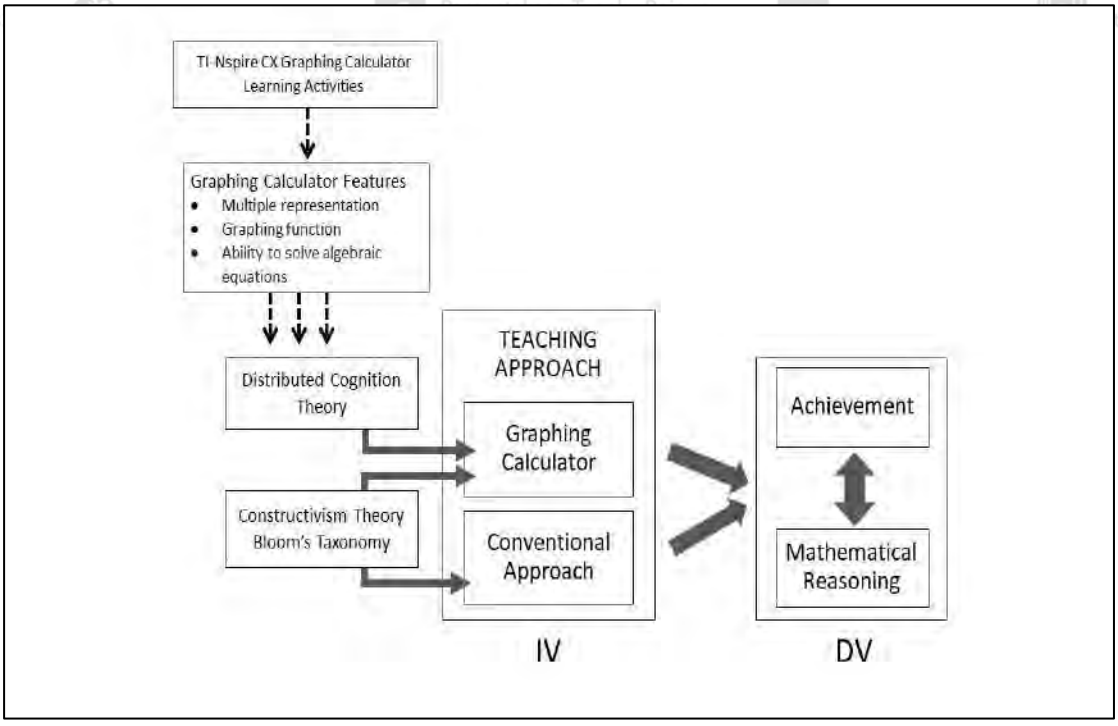

Figure 1.1. Conceptual Framework

Based on Figure 1.1, the independent variables (IV) in this study are elements of teaching approach used, namely the graphing calculator (GC) approach and the conventional approach (CA). These teaching approaches are studied with experimental methods in order to determine the effectiveness of certain mathematics tools. These approaches have been compared between two groups of pre-service mathematics teachers, namely the experiment group and the control group. For dependent variable (DV) in this study, there are pre-service mathematics teachers' Achievement and Mathematical Reasoning. Both of these DV are measured to determine the effectiveness of the used teaching approach, and it is measured based on the increasing level of mathematical reasoning skill and achievement of pre-service mathematics teachers involved.

This research is investigated the effects of GC approach and conventional approach (CA), in the teaching and learning of Calculus, for the topic of Integrals and Application of Integration. The learning process for GC approach and conventional approach (CA) during the intervention period are based on the learning activities that were develop by the researcher, based on constructivism theory, where the pre-service mathematics teachers in both experiment group and control group will develop their understanding through their involvement in the learning activities provided.

Through the GC approach, the learning process is based on the learning activities that developed with the aid of graphing calculator namely TI-Nspire CX. Student-cantered learning is used in the implementation of these activities. Pre-service mathematics teachers will develop their knowledge and understanding through active

involvement in the activities provided, as well peer interaction while doing such activities. This process will help them to constructs their understanding by gaining new experiences and develop it based on their previous knowledge (Ernest, 2013; Iran-Nejad, 1995). With the use of graphing calculator as the cognitive tool, it will help to explore the concepts of the learning and thus lead the thinking process of the pre-service mathematics teachers, which is the subject in the cognitive system of the distributed cognition theory. By following the provided learning activities for experiment group, pre-service mathematics teachers could utilize the features of graphing calculator in learning Integral and Application of Integration topics. With the graphing calculator's features, they are able to explore and visualize the mathematics problems and thus give them more focus to the discussion activities that encourage their reasoning skill in solving the problems, which in turn will develop their knowledge and understanding for these topics.

Meanwhile, for the control group that applied the conventional approach, the process of learning Integral and Application of Integration topics is based on the learning activities that developed without using graphing calculator. Instead, this group is using scientific calculator and graph paper in performing the activities provided during the intervention period. The pre-service mathematics teachers will develop their understanding and conceptual knowledge through their participation in the activities and how they respond to the activities that doing together with friends.

In this study, the researcher will look at the effectiveness of the GC approach and conventional approach in developing mathematical reasoning and achievement of

the pre-service mathematics teachers for the Integral and Application of Integration topics. Besides the constructivism learning theory and distributed learning theory that underpinned the background for this study, the Bloom's Taxonomy is used in testing their understanding of these topics. The initial hypothesis produced by the researcher is the graphing calculators approach in the teaching and learning of Calculus for the topic of Integrals and Application of Integration will lead to the increasing in the level of pre-service mathematics teachers in mathematical reasoning, and thus will improve their understanding and level of achievement as well. It was also hypothesised that the use of conventional approach will not lead to the increasing level of pre-service mathematics teachers' mathematical reasoning and hence no increase in their achievement.

1.9 Operational Definition

There are several terms used in this study which are mathematical reasoning, achievement in mathematics, graphing calculator approach and conventional approach. The focus of this study is on the graphing calculator itself. The definition of graphic calculators refers to the graphical calculators. This calculator is capable of plotting graphs and solving equations. Those equations that can be solved by graphing calculators are also with the variables and this calculator also can be programmed as its own usage (Cox, 2008). According to Karadeniz and Thompson (2018) graphing calculators are known to be mathematical devices that can be handheld easily and portable. The function of these calculators is to illustrate graphs, computation, and

numerical solutions for equations and other functions involved. This tool is the focus of this study to examine the function and its effectiveness to involved respondents.

1.9.1 Mathematical Reasoning

Generally, mathematical reasoning is defined as the critical skill that enables a student to make use of all other mathematical skills. With the development of mathematical reasoning, students recognize that mathematics makes sense and can be understood. People who reason and think analytically tend to note patterns, structure, or regularities in both real-world situations and symbolic objects; they ask if those patterns are accidental or if they occur for a reason; and they conjecture and prove (NCTM, 2000).

Mathematics and sciences are proved to be important in today's world challenges. In this context, the ability of students to reason logically and express their honest arguments has been proven to be vital. Mathematical reasoning is the way of students to analyse defined objects and notions using this step to find certain and timeless conclusions. The benefits of this operation are that it does not require external validation by any authority. Students learn mathematics through reasoning and assumptions that have been properly implemented. With this requirement, students have confidence in acquisition results on a wide variety in real life context (Zahid, 2020).

There are six important concepts to understand the notion of mathematical reasoning. These concepts start with understanding quantity, number systems and their algebraic structure. Mathematical reasoning also focused on abstraction power and their symbolic representation. Students also have to understand the concept of regularities in mathematical structures. Furthermore, the function of every relationship is focused and recognised among quantities. The last concept is the use of mathematical models which can be seen on behavioural sciences, biological, social, economic and physical are the lens of viewing the real world to recognise the variation of statistics (Zahid, 2020). In this context of study, mathematical reasoning is defined as the ability of mathematics pre-service teachers in solving mathematics problems involving calculation using the TI-Nspire CX calculator. The evaluation of their ability is measured based on five main elements of reasoning as stated by NCTM which are analysing a problem, initiating a strategy, monitoring one's progress, seeking and using connections, and reflecting on one's solution.

1.9.2 Achievement

Achievement is measured through the semester grades, grade point average, scores on standardized exams or marks in individual assignments (Parker, 2007). Academic achievement is defined as the mastery of knowledge and skills at a level according to the size of the examination. In this study, the pre-service mathematics teachers' achievement is measured by their scores in the Calculus Achievement Test to identify their understanding of the topic Integrals and Application of Integration.

In this study, conceptual understanding refers to the pre-service teachers' understanding of the concept of Calculus, for the topic of Integrals and Application of Integration. The conceptual understanding will be measured by the scores of the Calculus Achievement Test (CAT). Conceptual understanding is knowing more than isolated facts and methods. Students with good conceptual understanding will understand mathematical ideas, and have the ability to transfer their knowledge into new situations and apply it to new contexts. It shows the ability of students to interpret, explain, and to apply mathematical concepts in a variety of situations and translate between verbal statements and mathematical expressions. The conceptual understanding needs students to apply their content knowledge to understand the given problem, construct the dynamic figures, make conjectures, verify the conjectures, and solve similar problems (Haja, 2005).

1.9.3 Graphing Calculator Approach (GCA)

Graphing calculator approach in this study refers to the usage of TI-Nspire CX graphing calculator in the teaching and learning of Integrals and Application of Integration topic. The use of TI-Nspire CX graphing calculator is defined as the incorporation of the graphing calculator in teaching the topic of Integrals and Application of Integration for both computation and exploration using features such as the table, the graphing feature, the trace feature, and the calculate function.

For the context of this study, GCA is referring to teaching and learning methods with the help of TI-Nspire CX graphing calculator based on teaching activities that integrate the use of the TI-Nspire CX graphing calculator. These well-designed activities have been prepared as modular lessons for use throughout this intervention period. Through this method, pre-service mathematics teachers will follow the Integral and Application of Integration learning based on the teaching activities that have been built, namely TI-Nspire CX Graphing Calculator Learning Activities, as attached in the Appendix A.

Throughout the learning period using the GCA approach, students will be exposed to the use of a graphing calculator in the learning process, that is, in the activity phase where students have to solve given problems using a graphing calculator. In addition, the activities of discussion, exploration, calculation and graph visualization all use the graphing calculator.

1.9.4 Conventional Approach (CA)

The conventional approach in mathematics starts step by step moderated by teachers in their progression of learning. Conventional approach starting with teachers' explanation about the topic or content of the mathematics. Teacher explains algorithms and formulas in a conventional approach different from other approaches. The other approaches might start with the explanation on contextual problems (Fauzan, Musdi & Yani, 2018).

In the conventional approach, teachers start with giving the formula and the next step is giving the examples. After that, teachers start with giving students exercise to indicate whether a student has started to master their learning or not. In this conventional approach, similar questions are given to the student regarding the examples given. But the limit of this approach is that teachers provide students with the answer and the result from the exercise given. The ability of students in problem solving is limited only to the contextual problem with examples and not with informal knowledge (Anggraini, & Fauzan, 2018).

For the purpose of this study, the conventional approach happens when the whole class instruction is given by the researcher. The pre-service mathematics teachers in the control group were not exposed to the use of TI-Nspire CX graphing calculator. All teaching and learning processes during this intervention period were implemented using conventional methods, which is through lecturers' lectures and group exercises, where each exercise only helped with graphs and scientific calculators to make calculations. This learning process is based on a lesson plan that has been developed specifically for the control group, namely Lesson Plan for Integration and Application of Integration as in Appendix B.

1.10 Delimitation of the Study

Delimitation of a study refers to the characteristics that arise from the limitations of the scope of a study (Simon and Goes, 2013). Essentially, this delimitation results from the

determination made by the researcher himself. In order to achieve the goals and objectives of the study, a researcher will set a feasible study plan where the decision to include or exclude certain elements in the study is at the discretion of the researcher himself. In other words, delimitations are any outside elements that will not be done by the researcher, not because they have any constraint to do it, but they already set the boundaries of their study. This is to improve the quality of the research findings and the interpretation of the evidence presented. Thus, it is important to be aware of the wide range of the delimitations as well as limitations of the study and any possibilities should be need to be address them early in the research process.

According to Theofanidis and Fountouki (2018), in order to identify the delimitations of a study, it requires the researcher to challenge the research assumptions that have been made and identify the shortcomings that could happen before addressing them effectively. There are several factors that contribute to the demarcation of a study, namely the selection of research objectives, the setting of research questions, research variables that want to be studied, the selection of the theory that wants to be used, as well as the selected population for the research. All of these factors were set to their boundaries by the researcher.

In the context of this study, delimitation can be discussed in terms of the setting research objectives, research questions, research variables, selected theories as well as the selected population and sample. The main objective of this study only focuses on the effectiveness of using the TI-Nspire CX graphing calculator in improving achievement and mathematical reasoning among pre-service mathematics teachers. The

developed research question is based on this objective, where it only focuses on the effects of using the TI-Nspire CX graphing calculator model, not on other calculator models. In addition, the variables studied were only pre-service mathematics teachers achievement and mathematical reasoning. Researcher did not study the possibility of other variables that can be studied from this study such as student motivation as well as the differences in the effects of the use of graphing calculators on male and female students. Next, the second objective that has been set is to study the relationship that exists between the variable achievement and mathematical reasoning only, not to other factors.

In addition, the chosen theories for the perspective in this study only involve constructivism theory and distributed cognition theory. These two theories are the most appropriate to use since the constructivism theory refers to pre-service mathematics teachers learning activities based on the lesson plans that have been developed for the control group and the experimental group. Meanwhile, the distributed cognition theory is to see the role of teaching tools used, namely graphing calculator in improving achievement and mathematical reasoning. This study does not look from the perspective of cognitive load theory although the use of this graphing calculator affect the cognitive load of students.

For the population of this study, only one public university was included and the university was chosen because it offers the most educational program and has more students in educational field compared to the others. However, this study does not cover sample from all the education program. The selection of the population is the students

from the mathematics education degree program, where this group of undergraduate students are in the preparation to become a mathematics teacher upon graduation. While the selection of the sample for this study is focused on the needs of the study that is semester one students who take calculus subjects only.

1.11 Conclusion

This chapter discuss the development of technology in the fields of mathematics, especially in technology development of graphing calculators as well as its requirement to meet the current mathematics curriculum. The specific use of graphing calculators in improving students' mathematical reasoning was also discussed. Reviews of literature concerning the TI-Nspire graphing calculator and its impact towards developing mathematical reasoning will be discussed in the next chapter.