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The Use of Graphing Calculators in Teaching Mathematics: A Meta-Synthesis

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Abstract: The Use of Graphing Calculators in Teaching Mathematics: A Meta-Synthesis. **Objectives:** This study aimed to explore the use of graphing calculators as a tool in teaching and learning mathematics employing a meta-synthesis method. **Methods:** A meta-synthesis was used in this study. The final 16 articles used in this study were the result in using the Critical Appraisal Skills Programme (CASP) checklist and the PRISMA 2020 flow diagram**. Findings:** Six themes emerged from the data: (1) influences students' solving and basic skills; (2) the need for complex technical skills; (3) readiness in learning mathematics; (4) facilitative role of the teachers; (5) excellent aid for better comprehension and representation; and (6) increases students' cognitive achievement. The study's meta-theme emerged as the "exploration and navigation on the use of the graphing calculators". **Conclusion:** The use of graphing calculators was found very useful in teaching mathematics. It is recommended that a training the use of the graphing calculator be given to both teachers and student; the offering of elective subjects which deal on the use of different technologies useful in Math teaching/learning be considered.

Keywords: graphing calculators, meta-synthesis, systematic review, teaching mathematics

Abstrak: Penggunaan Kalkulator Grafik dalam Pengajaran Matematika: Suatu Kajian Meta-Sintesis. ***Tujuan:*** *Penelitian ini bertujuan untuk mengeksplorasi penggunaan kalkulator grafik sebagai alat bantu dalam pembelajaran matematika dengan metode meta-sintesis.* ***Metode:*** *Suatu kajian meta-sintesis digunakan dalam penelitian ini. Sebanyak 16 artikel terpilih yang digunakan dalam penelitian ini merupakan hasil penerapan checklist Critical Appraisal Skills Program (CASP) dan diagram alur PRISMA 2020.* ***Temuan:*** *Enam tema muncul dari data: (1) memengaruhi keterampilan dasar dan pemecahan masalah siswa; (2) kebutuhan akan keterampilan teknis yang kompleks; (3) kesiapan belajar matematika; (4) peran fasilitatif guru; (5) bantuan yang sangat baik untuk pemahaman dan representasi yang lebih baik; dan (6) meningkatkan prestasi kognitif siswa. Meta-tema studi muncul sebagai "eksplorasi dan navigasi pada penggunaan kalkulator grafik".* ***Kesimpulan:*** *Penggunaan kalkulator grafik sangat bermanfaat dalam pembelajaran matematika. Disarankan agar pelatihan penggunaan kalkulator grafik diberikan kepada guru dan siswa; penawaran mata pelajaran pilihan yang berhubungan dengan penggunaan berbagai teknologi yang berguna dalam pengajaran/pembelajaran matematika dapat dipertimbangkan.*

Kata kunci: *kalkulator grafik, meta-sintesis, reviu sistematis, pengajaran matematika.*

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INTRODUCTION

Technological advances have inspired many strategies to improve the teaching- learning process in general, and especially in Mathematics. Math teachers are encouraged to use technology to help students understand Math concepts meaningfully and to enable them to explore mathematical ideas (Ministry of Education in Malaysia, cited in Tajudin, Tarmizi, Wan Ali & Majid, 2007). "Technology is essential in teaching and learning mathematics, it influences the mathematics that is taught and enhances students' learning" (NCTM, 2000, p. 24).

There are many kinds of technologies considered relevant in teaching mathematics - from very powerful computer software like Mathematica, Maple, MathLab to less powerful technologies such as paper and pencil (Tajudin, Tarmizi, Wan Ali & Majid, 2007). Currently, the use of hand-held technologies such as the graphic calculators in teaching Mathematics has been encouraged due to its accessibility, affordability and ease of use (Kissane cited in Tajud, Tarmizi, Wan Ali & Majid, 2007). Graphic calculators can draw and analyze graphs, compute values of mathematical expressions, solve equations, perform symbolic manipulations, statistical analyses, computations, programmable, and communicate information between devices (Jones cited in Tajudin, Tarmizi, Wan Ali & Majid, 2007).

Many studies in developed countries have shown positive impacts from the use of graphic calculator in the classrooms and in examinations (Adams, 1997; Burill et al., 2002; Connors & Snook, 2001; 2000; Dunham, 2000; Dunham & Dick, 1994; Gage, 2002; Graham & Thomas, 2000; Hennessey, 2000; Hong et al., 2000; Horton et al., 2004; Noraini Idris, 2004, Noraini Idris et al., 2002, 2003; Kastberg & Leatham, 2005; Keller & Russel, 1997; Penglese & Arnold, 1996; Quesada & Maxwell, 1994; Ruthven, 1990, 1996; Smith & Shortberger, 1997; Waits & Demana, 2000). In Malaysia, the Curriculum Development Centre introduced the graphic calculator in the early of 1990s (Muhd. Khiriltitov Zainudin, 2003). However, the use of graphic calculators in Philippine schools is still in its infancy (Noraini Idris, 2004 - change), and therefore its use has yet to be fully explored. Thus, there is a need for further research in this area, specifically in the context of teaching mathematics at the Philippine secondary school level.

Education professionals need to adopt new teaching and learning approaches that incorporate active, integrated real-world applications as technological breakthroughs increase. The effective use of technology in the field of education has become one of the important research topics, along with the widespread use of technology in daily life. Mathematics teaching is one of the leading fields affected by technology when training and education activities are considered (Akkaya, 2016). The successful implementation of the targeted learning outcomes is supported by the use of technology in education because it improves student comprehension of the ideas or material being taught. The utilization of these instructional tools will also assist students in understanding abstract concepts, being creative, feeling confident, and being able to work alone or in groups. Tajudin and Zarkasi, (2014) also emphasized that the use of technology in mathematics instruction and learning has grown crucial since it aids in modernizing the educational strategy to foster a more engaging and fascinating comprehension of mathematical ideas.

Additionally, using technology in mathematics instruction improves student accomplishment and attitudes toward math, which in turn raises the quality and durability of teaching. Technology gives teachers the chance to extend their lessons beyond the confines of the classroom. The support of school administrators is necessary for teachers to feel empowered, for

example, by extensively funding educational technology resources and giving teachers opportunities to gain proficiency with these resources. Effective educators can maximize the possible benefits of technology to increase student competency in mathematics, foster student enthusiasm, and broaden student knowledge (TLS & Herman, 2020).

All facets of life should adjust to cutting-edge technologies in the digital age, but education should be a particular priority. According to the National Council of Teachers of Mathematics (NCTM, 2000), electronic technology, including computers and calculators, have replaced most other subjects in practically all classes in schools and colleges. Mathematical educational technology has evolved and become dynamic. A change in the technology available to math instructors and students has steadily improved; specifically, four applications for mobile technologies, computers, graphing calculators, function calculators, and scientific calculators (Montijo, 2017).

Math educators, curriculum designers, and teachers have recently shown a steadily rising interest in employing handheld devices, particularly graphic calculators. Students can investigate, model, and view several representations of mathematical issues by using graphing calculators while learning mathematics (Parrot, & Leong 2018). Tajudin and Zarkasi (2014) also supported, based on the results of their study, the pedagogical impact in incorporating the latest trends in mathematics education, namely, integrating the graphing calculator to maximize the mathematical and pedagogical benefits to students.

In the recent years, research on calculator use in the learning of school mathematics has tended to move from an emphasis on student learning to the influence of the teacher, recognizing their key role in the use of the device (Amanyi, et.al. 2016). Lee and McDougall (2010) studied the different learning experiences of students and instructors in their use in various topics in mathematics. The use of graphing calculators in the mathematics classroom is influenced by teachers' personal experiences and teaching practices, as well as students' technological proficiency. When graphing calculators are used effectively in the mathematics classroom, they can be a powerful tool in assisting teachers in creating an environment in which their students can construct their mathematical knowledge and understanding.

Calculators are now widely used in math classes. Ellington (2003) concluded in a recent meta-analysis of findings from 54 research studies that when calculators were used as part of testing and instruction, students' operational skills and problem-solving skills improved. When calculators were not used in the assessment, the results for both skill types were mixed, but calculator use did not hinder the development of mathematical skills in any case. Calculator users had more positive attitudes toward mathematics than non-calculator users. More research on the retention of mathematics skills after instruction and the transfer of skills to other mathematics-related subjects is required.

Despite the fact that many qualitative studies were conducted, no systematic synthesis was conducted in summarizing the experiences of the informants. Through the different scientifi literature and theories mentioned in the preceding paragraphs that this systematic review was employed. Hence, this study aims to explore the use of graphing calculators as a tool in teaching and learning mathematics employing a meta-synthesis method using available scientific literature which conducted qualitative studies across the different journals.

METHODS

Research design

This study used a meta-synthesis research strategy that aims to interpretatively synthesize findings from many connected studies (Walsh & Downe 2005). According to, it is the systematic review and integration of information from qualitative studies (Lachal et al., 2017).

Search Strategy

Through the use of Publish or Perish software, Google Scholar, Semantic Scholar and some academic publications connected to the Use of Graphing Calculators in Teaching Mathematics were found in an electronic database for scholarly research. All research published between 2000 and 2021 that are pertinent to the use of graphing calculators in teaching mathematics have been downloaded and examined. Further, the descriptors or keywords entered in the software were as follows: graphing calculators and experiences. The keywords mentioned earlier were selected to draw out articles. A flow diagram using PRISMA 2020 was then utilized to sort out the screened data.

Inclusion and Exclusion Criteria

Inclusion and exclusion criteria provide a basis on which the reviewer draws valid and reliable conclusions (Meline, 2006). Included studies were selected on the basis of inclusion criteria protocol: (a) must include studies related to the use of graphing calculators; (b) must utilize qualitative design; (c) must be written in English; (d) must qualify using the Critical Appraisal Skills Programme (CASP). Selected papers were screened with the set inclusion criteria. The figure below shows the search strategy of the included studies.

Data Analysis

The emerging themes were determined using the thematic analysis procedure described by Clarke and Braune (2013). It is a qualitative data analysis technique that entails reviewing a data collection and looking for themes that run across the data. The six steps of thematic analysis are as follows: (1) familiarizing oneself with the data; (2) creation of initial codes; (3) topic search; (4) theme evaluation; (5) theme representation; and (6) result interpretation.

RESULTS AND DISCUSSION

The findings are interpreted in accordance with the study's objective, based on a meta-synthesis of the selected studies. Exploration and Navigation on the Use of the Graphing Calculators was identified as the meta-theme. Consequently, nine sub-themes emerged from the meta-theme, namely, influences students' solving and basic skills, the need for complex technical skills, readiness in learning mathematics, facilitative role of the teachers, excellent aid for better comprehension and representation, and increases students' cognitive achievement.

There were three (3) stages of the research paper selection using the PRISMA Flow Diagram. The three stages are the following: Identification, Screening, and Included. On the identification stage, One Hundred Fifty (150) studies were registered in Google Scholar, and Twelve (12) studies were registered in the Crossref database totaling to One Hundred Sixty Two (162) studies on the initial screening using the Publish or Perish software.

The teaching and learning experiences in using the Graphing Calculators were used to generate initial codes highlighting the 16 studies considered in the meta-synthesis. Table 1 reflects the title of the study and its corresponding authors with the generated codes used for thematic analysis.

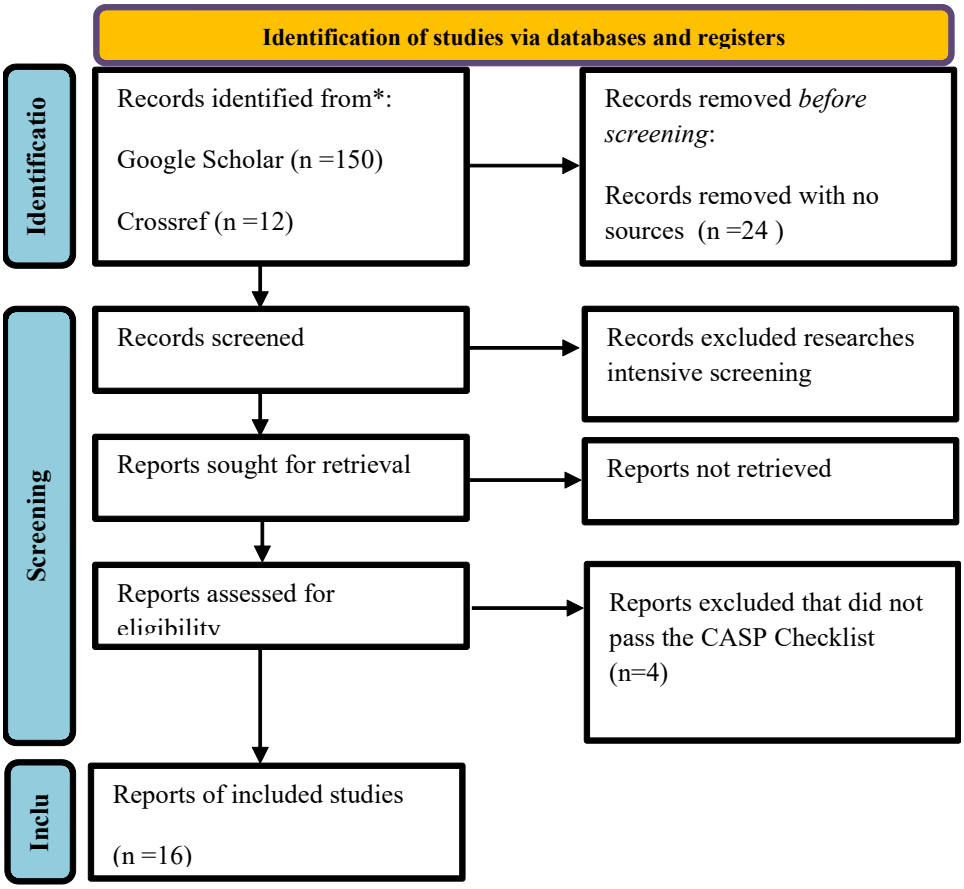

Figure 1. Search strategy using prisma

Table 1. Studies highlighting the use of graphing calculators in teaching mathematics

Article	Author/s & Year Published	Generated Initial Codes on the Use of Graphing Calculators in Teaching Mathematics
1	L. Ndlovu, M. Ndlovu (2020)	• Graphing Calculator (GC) assisted them to understand quadratic inequality problems better • Learners indicated that GC provided them with opportunities of employing more than one approach to solve quadratic inequalities • Using a GC potentially raised learners' cognitive achievement in quadratic inequalities, in particular as they were able to observe the different representations connected to the concept.
2	Kandemir, M.A. & Demirbag Keskin, P. (2019)	• Productive, and more concrete • Graphical calculator program made learning both fun and efficient • The thing that I liked was that the teacher knew the graphics calculator software very well
3	Ndlovu, L. (2019)	• The graphing calculator shows the solutions and the graph which makes it simpler for me to understand the inequality. • I used to have fear with quadratic inequalities and this topic was always very difficult. I never did well in quadratic inequalities. The use of the GC helped me to gain confidence in learning quadratic inequalities as it uses graphs to show the solutions of quadratic inequalities. • After the use of the GC my comprehension has increased

4	Roorda, G., Vos P., Drijvers, P, & Goedhart, M. (2016)	• The idea that use of the GC encourages students to create links between graphical and symbolical representations
5	McCulloch, A., Kenney, R., & Keene, K.A. (2013)	• Confidence in their mathematical abilities • I never trust the graphing calculators answer if it doesn't match mine. However, if they don't match, I check both my work and what I input in the calculator. • The calculator does not show all the steps and it is easy to make mistakes when putting information into the calculator.
6	Tan, C.K. (2012)	• User-friendly. It is not surprising that majority of students had found the GC easy to operate. • GC enabled them to perform several types of calculations that cannot be performed by other calculators. • Students also felt that the lessons with the use of GCs were more interesting and enjoyable as they were more involved and more interactive. They constantly communicating, discussing, comparing and exchanging views on the solutions that they obtained with the use of GCs. • The GC is perceived as a crunching machine as it saved students the tedious calculations, sped up as well as made the calculations easier.
7	McCulloch, A. (2008)	• Reflect on the multifaceted role of the calculator in their problem-solving process.
8	Gerren, S. S. (2008)	• Realizes how helpful a calculator can be to help understand the material, to verify work, to visualize problems, to prepare for tests to succeed on tests, and to ease test anxiety • Overwhelmed with its use in the lesson • Helpful and relieved a lot of mathematical stress. • The instructor played a vital role in initiating, promoting, and supporting student behaviors during integrated instructional activities that led to the establishment of graphing calculator use and related interactions as classroom norms • Enhanced understanding, solution strategies, saving time, making problems easier, visualization, improved test performance
9	Reznichenko, N. (2007)	• GC makes easier doing mathematics by removing lengthy calculations and other demanding mathematical tasks • Using the calculator takes less time • To me, it [learning mathematics] would find it more difficult without using a calculator • believed that with the constant use of GC, some mathematical skills were unused and then forgotten • by using a calculator, you lose your basic skills? Yes, that's harder for me to remember, like multiplying, because you're so used to plugging it in, and doing multiple things, you can lose the basic skills of what you have learned in the past.

10	McCulloch, A.W. (2007)	• I feel more comfortable with the calculator next to me • No more computations • change the cognitive demand of a task • Engage in a playful mathematical activity • Manage time
11	Dreiling, K. (2007)	• Encourage students to use the graphing calculator • The graphing calculator is a necessity • In order to help give the students a visual perspective on the logarithmic properties and concepts that we are currently studying in this lesson • Reinforce the use of graphing calculator • Graphing a function lets students actually 'see' the concept
12	Noraini Idris (2006)	• Beneficial in terms of students' level of understanding, communication skills, and achievement • Encourage students to participate in classroom discussion • Creating a climate for success.
13	Horton, R. M., Storm, J., & Leonard, W.H. (2004)	• Inappropriate use of calculators may cause students not to learn what they should • Observe and assess their students' achievement carefully and consistently
14	Ng Wee Leng (2005)	• An important tool in teaching and learning mathematics
15	Roorda, G.; Vos, P.; Drijvers, P.; Goedhard, M. (2016)	• The graphing calculator can have complex and subtle effects. • Connection between symbolical and graphical representations remains weak
16	Robova, J (2002)	• A helpful tool for mathematics teaching and learning • The actual result depends on teachers themselves • The visualization can help the student to understand and remember better the mathematical abstract concepts via their graphic representations

As shown in table 1, the initial codes on the use of the graphing calculators in teaching mathematics were generated to search for themes. The general codes were analyzed using the thematic analysis approach, which emerged with six (6) themes and one (1) meta-theme. The themes generated are the following: (1) influences students' solving and basic skills; (2) the need for complex technical skills; (3) readiness in learning mathematics; (4) teachers' role in the facilitation; (5) excellent aid for better comprehension and representation; and (6) increase students' cognitive achievement;

Challenges of Using the Graphing Calculators

This category describes the challenges encountered in using graphing calculators in teaching mathematics. The following themes under this category were discussed below:

Theme 1: Influences Students' Solving and Basic Skills

Studies acknowledged how using a graphing calculator can improve students' conceptual comprehension, but studies also mentioned how it would deskill students.

Reznichenko (2007) found that some participants in his study claimed that using graphing calculators can lead to calculator dependency and deskilling because some mathematical skills were unused and forgotten. Additionally, Gerren (2008) cited Hennessy et al. (2001) that the usage of a graphing calculator may lessen the cognitive load in doing mathematical operations by handling the mechanics of the translation procedures so that the user may concentrate on comprehending the topic. Students can focus on understanding the problem sets but not training them to master the process and the solving skills. This is congruent with the findings of Quesada (1994) that during the introduction of calculators, most of the students had lack of understanding of some basic concepts of graphs already. Graphing calculators, according to Roorda, et al (2016) had not improved the symbolical and graphical representations of students in mathematical concepts. This was the same with the findings of Boers and Jones (1993) that graphing calculators had not helped students in reconciling the graphs in calculus in its algebraic information.

Although this negative effect of using graphing calculators remains a great debate among researchers, it is suggested that proper integration of the use of this technology should be implemented in the classroom for it to be effective.

Theme 2: The need for complex technical skills

One of the challenges encountered by students in using graphing calculators in the classroom is its need for mechanical and technical skills. Using graphing calculators entails students to memorize some key pressing steps and mechanical processes. According to Ndlovu & Ndlovu (2020), although learners acknowledge the potential of graphing calculators in assisting them in their learning, they also mentioned that they experienced some technical difficulties in setting the right windows of the tool. McCulloch, et al (2013) also found that some students easily experience mistakes in inputting information into the calculator making it difficult to trust the results. Hong et. al (2001) also cited that some studies demonstrated that there are really some difficulties associated with using graphing calculator, just like using incorrect syntax for formulas leading to wrong results. As Ocak (2008) also found out that students without proper experience on using graphing calculators lead to struggles on the technical details of the graphing calculators. Moreover, he concluded that students' prior experience and knowledge on the mechanical and technical aspects of the graphing calculators they are using can affect their attitude and their understanding as well as the tasks given to them.

This is the reason Gerren (2008) suggested that students should have prior exposure and experience in using graphing calculators before integrating its usage in the class. In order for students to better retain and apply the procedures and understand the practical value of calculator use, Steele (2007) also recommended that specific lessons on calculator keys, functions, and procedures be planned; that skills that are required for particular problems be reviewed prior to each lesson; and that the calculators be used in other subjects, such as social studies and science. These strategies are important for students who have learning problems to succeed in using calculators for mathematics.

Success of using the Graphing Calculators

This category describes the positive and successful experiences in using graphing calculators in teaching mathematics. The following themes under this category were discussed below:

Theme 3: Readiness in Learning Mathematics

Among all of the research articles for this study, four of them indicated that the experience of the students while using graphing calculators provided them with the sense of confidence in learning the subject matter (Ndlovu, 2019; McCulloh, 2007; Tan, 2011; & McCulloh, et.al., 2013). Confidence refers to the feeling or belief that one can rely on the calculators as a tool in answering problems or re-checking values along their solution process. The use of calculators made them feel comfortable in learning. Furthermore, they could also depend on them on complex operations and multi-step solutions. Graphing calculators have been used in the mathematics classroom for speed, to leap hurdles, to make connections among representations, and to permit realism through the use of authentic data (Horton, et. al., 2004). However, the usage of calculators can depend on the knowledge that a student has on how to use them. This drawback oftentimes causes the misuse and mistreatment of calculators in solving mathematical concepts (Horton, et. al., 2004).

In the study of McCulloh in 2007, students viewed graphing calculators as a tool that improved their comfortability in their classes. The presence of the device helped them in accomplishing complex tasks and calculations. According to Keiner, et.al, in 2014, if a student feels comfortable in their environment, they will do their best work. When learning becomes hard, these feelings of significance, belonging, and fun will motivate a student. Students can produce at a higher level if they feel this. Furthermore, using GCs help students feel comfortable with technology. The use of such tools enables the students to have more options to make tasks easier and improve accuracy.

The qualitative results of the study of Ndlovu (2019) found out that students have negative feelings regarding the Mathematics subject, however, the use of GCs lifted their fear of numbers and gained positive feelings that enabled them to solve complex problems. From time to time, tools are used and the pedagogical aspects of teachers are changed in order to meet the needs of the students. The use of calculators is one way of bridging the gap between the subject and the students. Mathematics has always been one of the most difficult subjects in the curriculum worldwide. Having interactive tools such as GCs can provide motivation for students to learn more and be confident in their mathematics class (Rodriguez, 2019).

Theme 4: Facilitative Role of the Teachers

All of the articles of the study highlight the importance of the teacher's role in the use of calculators in the classroom. The effectiveness of the implementation of this tool in the classroom is not independent of the teaching strategies of the teachers. As Gerren in 2008 described that the instructors play a vital role in initiating, promoting, and supporting student behaviors during integrated instructional activities which can lead to the establishment of graphing calculator use and related interactions as classroom norms. This notion was supported by the study of Horton et.al. in 2004 which indicated that the inappropriate use of calculators may cause students not to learn what they should and that teachers should observe and assess students' achievement carefully and consistently throughout their activities.

Introducing innovation in teaching requires that the teachers involved demonstrate a positive attitude towards the innovation because they play a crucial role in technology integration into instruction (Amanyi, et.al., 2016). However, in this same study in 2016, there were impeding hindrances on its implementation. The results showed that factors that the obstructions on the

use of calculator at the secondary level include the lack of calculator know how, lack of competence in using calculator, lack of skills in the use of calculators, teacher's phobia in calculator's usage, time factor as well as lack of confidence in calculator usage. Therefore, it is a must to equip teachers with the experiences and technical knowledge on the use of GCs to be integrated in the class. This will be the first step in the successful facilitation of GCs in individual classes of the teachers.

To summarize, the varying experiences of teachers and students in the use of GCs in the classroom had proved the underlying importance of the intercession of teachers towards the use of them. The importance of the teachers' role in this innovation paved the way for students to appreciate the use of GCs in their math class experiences. More so, a teacher can only give what they have. With this, the importance of training and field experiences of the instructors in the use of the GCs helped in the proper utilization that led to greater results in students' performance. As the study of Kandemir in 2019 highlighted, teachers having wide knowledge on the use of GCs was a feature liked by the students in class.

Theme 5: Excellent Aid for Better Comprehension and Representation

Several studies using GCs in mathematics instruction enhance students' abilities to solve algebraic problems in practical contexts, comprehend graphs, and demonstrate broad cognitive comprehension. As cited by Ndlovu & Ndlovu (2020), students who use GCs can have relative advantage while solving mathematical problems. Furthermore, students that use GCs consistently exhibit greater creativity, speed, and accuracy in their problem-solving techniques, as well as superior reasoning in their responses and better representation of graphs and abstract concepts. The use of a GC can also potentially improve learners' organization of written work, and the correct use of notation and symbols (Shahriari, 2019). Additionally, learners using GCs can consistently display more innovation, speed and accuracy in their problem-solving strategies as well as better reasoning in their answers and better visualization of graphs and abstract concepts (Ndlovu & Ndlovu, 2020).

The use of graphing calculators as cited by DeLoach (2013) may facilitate learning by increasing students' abilities to recognize and organize mathematical concepts in an abstract manner, leading to an increased level of understanding.

Towers (2018) also noted that in education, there are a number of technological tools that can be used in order to increase student achievement in mathematics: One of those tools is the use of the graphing calculator in the classroom. The graphing calculator is a tool which enables students to have the ability to supply answers with confidence in mathematics in both classroom instruction and assessment.

Theme 6: Increases Students' Cognitive Achievement

When it comes to increasing student achievement, there are numerous theories. Each individual has a unique sense of accomplishment, making success unique. The path to achieving this individual success is also unique to each person based on their unique life circumstances. Calculators help bridge the gap for students who struggle with mathematics. A calculator can not only be seen as an intervention for struggling students but also one for students who achieve success in mathematics (Doller, 2018).

Using a GC potentially raised learners' cognitive achievement in quadratic inequalities, in particular as they were able to observe the different representations connected to the concept. The varied representations (algebraic,

arithmetic, geometric, number pattern) of quadratic inequalities helped learners to gain insight into the big ideas in mathematics (Ndlovu and Ndlovu, 2020). According to Towers (2018), graphing calculator increased students' achievement in the all class models; that anticipated outcome occurred as was demonstrated by the scores on assessments. In mathematics, the role of computers and calculators as cognitive tools is the most useful in the development of thinking skills and for problem solving.

In the study of Tan (2012), findings showed that the use of GCs benefits students of all levels, that is, high, average and low mathematics achievers. Qualitative data provides a more lucid picture of how GCs aid in improving understanding and performance.

As cited by Ndlovu & Ndlovu (2020), several researchers report that the use of GCs in mathematics education improves learners' achievement in solving algebra problems in applied contexts, interpreting graphs and general cognitive understanding. In the study of Kandemir and Demirbag-Keskin (2019), graphing calculator program supported transformation mathematics instruction has made a meaningful difference in the academic achievement of students.

Meta-Theme: Exploration and Navigation on the Use of the Graphing Calculators

Graphing calculators are portable technological devices that are currently used in mathematics classrooms. The application of GCs in classrooms has proven to be a useful technological tool to enhance teaching and learning and as a result, improve students' mathematical understanding (Kissi, et.al, 2016). When technology, such as graphing calculators, is used effectively, it has been shown to improve student motivation, attitude, and achievement (Tan, 2012; & Rodriguez, 2019). Similarly, Dibble (2013) reported that students had a better attitude toward problem solving when the graphing calculator was used. GCs also provide an alternative way of learning for teachers to employ and students to undergo. It was proven to be advantageous because the multiple representation of a concept enhances clarity and understanding (Parrot & Leong, 2018). This emphasizes that calculators support students' learning through visual representations and making an abstract concept to be an observable one.

Integrating technology in the mathematics curriculum has become a necessary task for curriculum developers as well as mathematics practitioners across the world and time (Kharuddin & Ismail, 2017). In general research studies, seeking a better understanding of how best to integrate mathematics analysis tools with mathematics subject matter normally observe mathematics lessons to be taught in classrooms conducive enough for GCs to be integrated such as computer, science, or mathematics laboratories. Results of the study of Tan (2012) indicate that the GC instruction approach is an alternative to the conventional approach, especially in some topics of mathematics that involves understanding of concepts and tedious calculations.

The experiences of the students in this study mostly proved that GCs have the potential to affect the students' performance. Students appreciate the use of it in various situations that need complex computations. Moreover, GCs also promote visual learning and improved manipulative skills through the manual encoding of data. Graphs help students visualize the information and problems that they are solving. Hence, the integration of the use of GCs is much likely recommended in teaching and learning mathematics.

CONCLUSIONS

All aspects of life should adapt to cutting-edge digital technologies, but education should be a top priority. As technology advances, educators must adopt new teaching and learning strategies that include active, integrated real-world applications. Mathematics education is one of the areas where various forms of technology should be used because it helps to modernize the educational strategy and foster a more engaging and fascinating understanding of mathematical ideas. One application of technology is the use of graphing calculators in mathematics education. Handheld devices, particularly graphic calculators, have recently piqued the interest of math educators, curriculum designers, and teachers.

RECOMMENDATION

It is recommended the use of graphing calculators as a tool in teaching mathematics considering the proper supervision of teachers, without compromising the quality of learning. Also, providing enough training on the use of the graphing calculator especially to those who have not experienced yet on how to navigate the said device. Lastly, consider the offering of elective subjects which deal with the different technologies useful in Math teaching/learning.

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