TECHNOLOGY IN MATHEMATICS: STUDENTS PERSPECTIVE

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Abstract

Technology is one of the current advances utilized in the learning and teaching of Mathematics. Recently, technology plays a vital role in various fields and aspects – particularly in mathematics. Technology is an advance paradigm of human civilization since it is one of the new inventions required in the modern world. We view that technology is a catalyst for critical thinking, a vehicle for integration and a tool for expediency. In recent years, mathematics educator employed technology and use it as part of teaching aids. The pedagogical notion of "pencil-paper" method has now been replaced by advance technological tool such as graphics calculator (GC). This suggests that technology enhance students' performance in Mathematics. This paper examines the role and use of technology in enhancing students' performance in Mathematics. Various examples including computer algebra system (CAS) and graphic calculator (GC) are discussed in order to support the idea of integration of technology in mathematics. In this paper, we will also identify the benefit of these current advances (i.e. technology) from many perspectives. Inter-dependent and collaborative learning are achieved by integrating conceptual mathematics with technology.

1. Technology, Trends and Current Advances

Technology has brought so many changes in our lives. In education sector, technology is seen as an important tool that can help in the learning and teaching of mathematics. First of all, before going into detail, let us define certain terms that need to be understood properly.

In general, one can define technology as *the study of the application of science and scientific knowledge especially to industry*. Furthermore, according to www.techweb.com, technology is defined as *applying a systematic technique, method or approach to solve a problem*. Thus, technological tool is referred to the tool, which incorporates scientific knowledge that can be used to ease up the tasks given (i.e. calculations).

In mathematics, technology is seen as a "tool" that plays a role in the teaching and learning of mathematics. Technology is not only limited to calculators, instead it extends beyond calculators. Such example includes graphics calculator, Internet, computer aided system (CAS) or sometimes known as computer algebra system, software and more. Technology is not only limited to one tool – instead, it is universal and adopted world-widely.

Technology is also one of the current advances in mathematics. A new and powerful technological tool has now replaced the old pedagogical notion of "pencil-paper" method. In addition, most mathematic tutors and professors have agreed that technology should be brought into the learning of mathematics.

Also, in some publication most mathematicians agreed that technology offers more insight towards mathematics. Indeed, by incorporating technology in the learning of mathematics, much knowledge can be explored. One example to illustrate this is by considering a graph. The old method (which is a time consuming method) uses pencil-paper method. Students need to draw every piece of graph and this is certainly not an effective way of understanding graph. Besides, by drawing the graph *manually*, less information is obtainable. Also, some of the limitation of drawing graph manually is that, no three-dimensional graphs (3D) can be drawn, as it is hard to sketch.

In opposite to that, student can understand graph better with technology. Some of the technological tools that can be used includes graphics calculator, mathematical software such as Maple, MathCAD, Mathematica, MATLAB etc. these tools offers much-more insight of understanding graphs and in addition, the learning of the graph can be easily taught by tutors. For example, consider sketching the graph defined as: $y = x^2 + y^2 + z^2$.
Indeed it is difficult to construct the graph manually, and this is where technology becomes handy in solving and drawing the graph. The advantage of technology in this scope is that the graph can be altered that is rotated and even animated. This is beneficial as the understanding of the graph increases.

Some of the technological tool used in the teaching and learning includes (a) Calculators [Normal; scientific and graphics calculator]; (b) Computer [Computer Aided System/ Computer Algebra System]; (c) Software [Mathematica, MATLAB, Maple, MathCAD]; and (d) Internet [Websites, Java application etc.]

2. Technology and Current Advances

The IRCMSA Conference's theme is "*Trend and Current Advances in Mathematics and Statistics*". Let us define and relate the topic discussed in this paper with the theme of IRCMSA Conference.

Trend is generally understood to be general movement. From mathematical perspective, trend is a movement towards changes that enhance the teaching and learning of conceptual mathematics.

Technology is thus fall in the "*trends and current advances*" category. As emphasized, technology is not only limited to one tool, instead, it covers and uses all of the available

tools. Thus, technology plays one of the most notable current advances that are significant in the teaching and learning process of mathematics.

3. Views on Technology

Technology is a necessary tool for developing strong meaning of numeracy. In addition, technology can serve as a catalyst to bring about the change necessary to transform our schools.

As we move into the technology era, people often employ technology in their workplace. As in education sector, technology is employed in the science and mathematics subject in order to simplify the ever-going calculation. Moreover, technology is not only limited for calculation purposes, rather it is universal in nature and can be applied for all types of purpose.

One example of supporting the notion of beneficiary technology is by considering transportation. In the past, people use animal for transportation. Then, slowly, as the time changes, vehicles such as cars, bicycle, truck and other transport have been designed. This shows that technology is emerging and always developed and improved from time-to-time.

In the education sector, technology is employed to assist the teaching and learning of a subject. For example, many types of technology is used and it served as teaching aids and this includes over-head projector (OHP), Power Point Presentation (PPP), radio, television, internet etc.

Let us examine thoroughly the specific use of technology in the learning of mathematics. In the past, when mathematics was first discovered, the use of technology is limited. People at that time use the pedagogical method of learning mathematics that is, by using pen-pencil-paper method. Later on, Chinese people – using a tool known as abacus, have introduced another method of computing arithmetic. The tool is used for counting and performing simple-to-complex arithmetic such as addition, subtraction, multiplication and even division. Later in the century, when calculator was invented, it eases calculation — and more complex calculation can be computed.

The calculator technology has then emerged ever since. From the normal and simple calculator, calculator has been intelligently developed and today we have scientific and graphic calculator. The advantage of these type calculator is obvious – to simplify and compute complex calculation. In addition, graphic calculator provides visual representation of graph.

4. Technology and Visualization

A picture speaks a thousand words. This expression is synonym in the art stream. We will now focus on the art of graphical visualization in mathematics.

> Visualization and exploration are key factors in concept formation in mathematics and the powerful graphing features of CAS can be suitably exploited for this purpose. [1]

The above statement clarifies the needs for visualization in understanding conceptual mathematics. Moreover, in achieving this understanding, technology such CAS is needed. Visualization is very important in the learning of mathematics. It has been said that the excellent way to understand mathematic is to visualize (or use imagination) the problem.

Adem Kiliçman emphasize the importance of visualization in one of is outstanding abstract. He mentioned that:

> The graphics are very important tools in every day of our life especially in engineering applications such as automotives and aerospace, in order to quickly visualize newly designed shape. By using graphics and diagrams we can also illustrate many result in mathematical sciences usually such graphics are not considered mathematical and logical proofs. However, before an actual proof id developed, it is a good idea to form mental picture in our mind for this process might be very significant tool as well. [2]

In addition, James W. Wilson also states that:

> The underlying psychology theme is the use of visual reasoning in mathematical discourse. The technology has enable students to construct visual and symbolic representations of ideas and incorporate these into their approaches and thinking about problems. The technology-enabled visualizations are not the end product but rather a means to facilitate students' mental images that help them to form, relate and organize mathematical concepts. [3]

Furthermore, in helping students to understand mathematics, the Ministry of Education in Singapore (MOES) has highlighted the importance of visualisation in the process of learning mathematics. This is apparent where MOES views that the function of visualisation and simulation is *to facilitate learners in recognising patterns/trends/relationships and in visualizing or simulating abstract mathematical phenomena* [4]. Moreover, in achieving the maximum understanding of mathematics, alternative method has been introduced. In the class room, *student could use spreadsheet software to get better understanding of mathematical concepts by being able to explore what if scenarios* [4].

In a case studies done by the researchers at Institute for Research Mathematics (INFORM) Universiti Putra Malaysia (UPM) have concluded from their observation that during their teaching, graphs and visual representation needs to be drawn. This is to help the student to imagine the problem and the mathematical concept that they are trying to teach. An example of technological tool, which provides visual representation, includes computer aided (algebra) system and graphic calculator. More on graphic calculator will be discussed later.

5. Technology and Curriculum

The quality of learning can be achieved by designing a syllabus that meets certain criterion. Different subjects have different outcomes – however, these outcomes determine the quality of learning.

In the case of mathematics, the objective of learning mathematics is to develop conceptual understanding of mathematics, solve the problem systematically, interpret and justify the solution to the problem. In addition, mathematics should be applied in all fields including engineering, literature and business.

In relation to the goal of learning mathematics, Zalman Usiskin, in his paper states that:

> The goals of mathematics learning are competence with problems, understanding of the mathematics, and communication of that mathematics to others, and the ability to use deductions to demonstrate the validity of mathematical results. Skills obtained by any technology, paper and pencil or electronic are only means to those ends. [5]

Furthermore, according to James W. Wilson of University of Georgia, the standards for employing technology in mathematics is to build mathematical power consisting of conceptual understanding of mathematics, problem solving strategy, reasoning and judging logically, connection building, communicating and self-confidence developing. [3]

In Wilson's paper, the President's Committee of Advisors on Science and Technology mentions that *the underlying pedagogical theme* [of learning mathematics] *is to experience mathematics as problem solving, communication, reasoning and building connections* [3].

In achieving understanding of conceptual mathematics, technology is needed as it helps in clarifying and visualizing the problems. Usiskin, in his paper has agreed that technology should be student's best friends as it promote in understanding mathematics.

> In the meantime, my belief that technology helps in the learning of mathematics has not waned one iota. I believe that technology has to be a partner if we are serious as a society about bringing significant mathematical competence to all our students. If we truly wish to improve the use of mathematics in society, we have a moral obligation to further the use of instruments that can give so much power to people. [5]

In another views, social interaction also helps in achieving the aim of learning mathematics. Besides, technology is used to give a visualization of the problem. From this, learners can interact, discuss and communicate with other upon achieving the maximum efficiency of understanding mathematics. Alagic (2003) and Hung (2002) proposed that:

> The appropriate use of IT *[which is part of technology]* can increase the level of sophistication in students understanding by supporting the development of mathematical concepts, procedures and processes through connecting new

knowledge to students' prior knowledge and experiences in meaningful ways that are situated in appropriate social interaction involving peers and teachers with digital manipulative. [4, 6]

Technology is indeed important and useful in accompanying learning mathematics. Several aim and goals have been designed in order to enhance the use of technology in mathematics. According to Wilson, the standards for employing technology in mathematics are to build mathematical power consisting of conceptual understanding of mathematics, problem solving strategy, reasoning and judging logically, connection building, communicating and self-confidence developing. [3]

Moreover, Wilson has suggested some of the goal and objective of integrating technology in mathematics are:

(a) Promote innovative practices in the tool uses of technology in mathematics teaching and learning
(b) Revitalize mathematics teaching and learning by modelling, then applying innovative technology-enhanced approaches
(c) Support reform of mathematics teaching and learning mathematics classrooms
(d) Establish the human and technological infrastructure needed to sustain meaningful reform of mathematics instruction. [3]

Hopefully, by implementing technology in the learning of mathematics, students are able to *ask smart questions, to work in teams, to acquire life-long-learning skills, to construct higher order knowledge and perhaps above all, to be able to tackle new, complex problems in intelligent and creative ways.* [7]
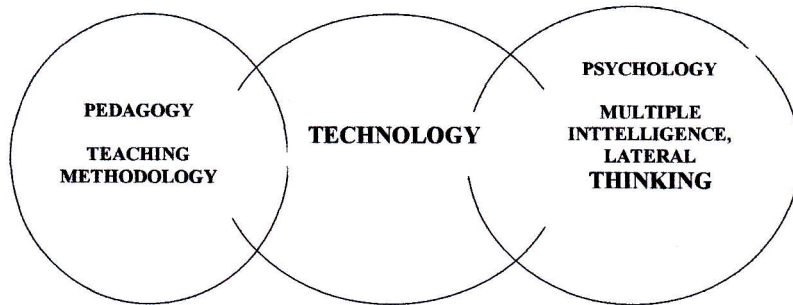
6. Technology and Learning

Critical thinking is about evaluating conclusions by logically — and systematically examining the problem, evidence and solutions. Critical thinking is the core and fundamental of learning. Additionally, learning is influenced more by the content and instructional strategy in a medium, than by the type of medium.

In viewing this, we conclude that technology is closely tied and related to critical thinking. Critical thinking is a high-level of thinking requires a person to be able to examine and solve the problem systematically and logically.

The application of technology does not need to be powerful; however, it needs to organize one strategy that integrates teaching methodology with the psychology of learning. Should this strategy is incorporated in the teaching of mathematics, and then the maximum efficiency of achieving effective learning is obtained. The model below illustrates the relationship between *pedagogy of teaching*[1], technology and psychology.

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[1] *Pedagogy of teaching* is a mean of conveying the information to others. Sometimes, it is commonly known as the teaching methodology. Examples of available tools that functions as teaching aids includes CAS and Graphic calculator

The model above showed how effective learning could be achieved – i.e. by using technology together with pedagogy and psychology of learning. Some of the suggested and available technology that can be used in achieving effective learning includes OHP, CAS, Graphic calculator, Power Point Presentation (PPP) and other type of multimedia. Here, technology is seen as a vehicle in driving to the peak of achieving effective learning.

7. Current Technology: Graphics Calculator

Besides being a multi-functional tool, technology can also generate visual representation. Nowadays, there are many tools, which have graphic representation. Such example includes computer aided (algebra) system (CAS) and graphic calculator (GC). We will now focus on graphics calculator since it is one of the current advances in mathematics.

Graphing calculators, first introduced in 1986 by CASIO, started a revolution in the teaching and learning of mathematics in the United States and in many other countries as well. Graphing calculators are really inexpensive [in the western countries] hand-held computers with built-in numerical solvers and graphing software. Graphing calculators could be viewed as computers available to students because of their low cost, ease of use and portability. [8]

Furthermore, Krongthong Khairiree in his paper describes that *graphing calculators are small, pocket size computers with built-in graphing capabilities. They have the ability to draw and analyse graphs, carry out complex computations, perform matrix algebra, calculus and carry out statistical analyses.* [9]

There are many types of graphic calculator produced by different companies such as Casio, Hewlett-Packard and Texas Instrument. The most widely used are the CASIO.

8. Views on Graphics Calculator

Calculators are generally understood to simplify calculation hence reducing the mount of time to solve the problem. The rationale for using calculators is that the considerable

amount of time saved using a calculator will enable the teacher and student to explore many more formulas, relationship between formulas and real problem that they wouldn't have had time for otherwise [10].

Furthermore, a panel discussion[2] on *A Global View of Curriculum Issues on Mathematics with Technology*[3] has emphasized their view on graphic calculators. In the paper, it is mentioned that:

> From practical point of view, manual calculations are slow and do not allow to perform sufficient amount of calculations such as for realistic modelling or "mathematical experiment" in which students study various variants of solutions of the same problem in their efforts to find the most appropriate one. [11]

Furthermore, the panel also concluded that:

> The graphics calculator's numerical, graphical and statistical capabilities have offered many new and exciting ways of doing and learning school mathematics. For doing mathematics, these capabilities have created an increase in the range of feasible methods to solve problems and converted solution methods previously only possible in principle to methods now possible in practice. [11]

According to Jeffrey P. Smith, graphic calculators have many functions and it can use as: (1) a tool for expediency; (2) amplifiers for conceptual understanding; (3) catalysts for critical thinking; and (4) vehicle for integration [4].

Bert K. Waits and Franklin Demana in their paper views that *students must use computers on regular basis for both in-class work and for homework outside of class is there are to be significant changes in mathematics that students learn today. The introductions of the first graphing calculator by CASIO in 1986 ... are all extremely significant. Here for the first time in their eras were serious "portable and affordable" computers with pedagogical software designed to enhance the teaching and learning of mathematics* [8].

In June Jone's paper, *Carter (1995) in his thesis founds that the graphing calculator seemingly led to improved problem solving, as less time was consumed with algebraic manipulations. He also reported that the students used the calculators as monitoring aid while solving word problems* [12].

Overall, the South East Asian Ministry of Education and Regional Centre for Science and Mathematics (SEAMEO RECSAM) have come up a resolution that *if graphing calculators are appropriately employed, they can enhance students in developing their relational understanding in mathematics* [9].

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[2] The panellists are Prof. Wei Chi Yang (Moderator); Douglas Butler, Peter Flynn, Jozef Hvoercky, Masami Isoda, Prof. Hee Chan Lew and Wee Leng Eng.
[3] This paper has been presented at the Asian Technology Conference in Mathematics (ATCM) 2004 at Singapore.

Appropriate use of graphics calculator results in a success in mathematics – if we balance the use of graphic calculator with traditional[4] method. Waits and Demana [8] suggest their approach of using graphic calculator. Their approaches are

> (a) Solve analytically using traditional method and then supports [confirmed] the results using graphic calculator; [or]
> (b) Solves using graphic calculator and then confirm analytically the result using traditional method; [or]
> (c) Solves using graphic calculator when appropriate

Furthermore, upon computing the mathematical problems, the integration of mental, traditional and technological method is preferred as it combines the critical and lateral thinking element [8].

9. Technology: Students' Perspective

Many researches have shown that students are accepting the integration of technology in learning mathematics.

In Malaysia, the use of graphic calculator is limited as compared to other world. Currently, the Ministry of Education allows the student at high school to use scientific calculators only. In comparison to Australia, graphic calculator is widely used throughout. Students were exposed to the graphic calculator since Year 8 (13 years old). This allows more time for the student to explore many function and capabilities with the calculator. Furthermore, the Curriculum Council of Western Australia[5] has designed and review mathematics syllabuses in order to integrate the use of graphic calculator in learning mathematics. The examination question was therefore set to be a computer-friendly question without neglecting the traditional/pedagogical practices.

The author has personal experience of using the graphic calculator whilst he was learning mathematics and calculus at a high school[6] in Perth, Australia. The author founds that graphic calculator is a timesaving tool and it also helps in the visualizing of the function – particularly useful when learning derivative and integral. Also, the plot of the derivative and integral function can be viewed using the calculator's screen — taking over the advantage of scientific calculator. In addition, complex calculation such as those involved with complex numbers and trigonometric functions can be calculated easily and in a short

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[4] Traditional method is a way of solving mathematical problem by using paper and pencil method. It's very much neglect the use of technology in obtaining answers. Sometimes, the traditional method is termed pedagogical method. The author views that this method is old, instead upon renewing the method, the integration of technology with traditional/pedagogical method should be implemented in achieving maximum efficiency in mathematics.

[5] The Council is responsible for designing educational syllabus at school level. For more information on the rationale of integrating technology in education (particularly mathematics), please visit http://www.curriculum.wa.edu.au

[6] The high school is Hamilton Senior High School, Purvis Street, Hamilton Hill, Western Australia 6163, Australia. The author attends the school since the year 2000 until June 2004.

amount of time. Moreover, matrix operation can be computed easily. Due to this the "proof questions"[7] can be deduced and verified easily since the graphic calculator will be of great advantage in verifying the answer.

Rosihan M. Ali [*and others*] has conducted a survey (at School of Mathematical Science, USM [SMS USM]) on the advantage of graphics calculator in understanding the topic. This survey requested information on students'[8] perception of their understanding and impression of each topic [13]. The results were tabulated as follow.

TOPIC	% ON HOW GRAPHIC CALCULATOR HELPS IN UNDERSTANDING THE TOPICS
Calculus	92.5
Linear algebra	91.3
Differential equations	81.8
Statistics	66.6

The result above shows that more than 60% of the student found that graphic calculator helps in the understanding of the mathematical topic taught.

In another views, the Year 12 student from Delhi Public School, India, has given their thought on the usage of CAS in learning derivative. In their response, they actually found that Mathematica has helped them in understanding derivative. As we all know, in order to understand derivative, we need to first understand their graphs and functions. Hence, Mathematica has enables them to achieve maximum understanding of derivative. Their comments on Mathematica are stated below:

- *Mathematica has given me a visual feel for the derivatives of various functions. Although (without using Mathematica) I could find the derivative by first principles, these were only symbols to me.*

- *Mathematica helped me to actually see how* $\dfrac{f(x+h)-f(x)}{h}$ *approaches derivative function for smaller and smaller value of h.* [1]

In another case, the Year 11 students from Delhi Public School also views that by using Mathematica, they have achieved maximum understanding of quadratic.
- *These lab sessions with Mathematica have truly reinforced our concepts, which in our view, holds greater importance than performing routine calculations. The very fact that a dry subject like quadratic equations can be made lively and realistic through graphs and exploration, has immensely broadened our view of mathematics.* [1]

The above views has clearly indicates that by using technology (such as Mathematica), our views on mathematics are broadened. Hence, mathematics will therefore not be considered

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[7] The "proof questions" is a question that asks students to verify statements and equations. For example: Proof that: $\sin^2 x + \cos^2 x = 1$.

[8] The students are pre-service teachers and mathematics students.

as a tough a boring subject – instead mathematics is viewed to be interesting and appreciated by others.

In a graphic calculator workshop (involving Form 5 students in Malaysia) conducted by Khairiree [9] on the topic of polynomial, he has received a good feedback from the students. Some of them include:

- *Using graphing calculator is more accurate and powerful*
- *I think using graphing calculator saves a lot of time, faster and convenience*
- *Graphing calculator can make our learning in mathematics much more easier and interesting*

From the above (students' perception), we clearly see that most students learn maths better with using graphing calculator. With the use of technology, the graph of a function can be visualized and student will therefore gain maximum efficiency in understanding conceptual mathematics.

Upon leaning more on graphing calculators, SMS USM offered *a special topic course on the integration of hand-held technology into the teaching and learning of mathematics. The course is thought in an-inquiry based format that highlights explorations and applications of mathematics in a data rich modelling environment. In addition the course addresses issues related to the effective integration of such technologies into the strategies that have been implemented in the course and summarizes students' reaction to the innovating learning mode* [13].

Moreover, SEAMEO RECSAM at Penang also offers courses in using graphics calculator. *The participants were exposed to the knowledge on the use of graphing calculator as a tool in teaching and learning mathematics* [9].

10. Benefits of Technology

As we have discusses, it is indeed clear that technology helps in the process of teaching and learning of mathematics. Although technology is in their infancy, however, many benefits have been shown and students are gaining maximum understanding of conceptual mathematics.

Many of the students are scared in hearing the word maths. Probably, when speaking of mathematics, students will think about complex equations that use Xs and Ys and other notations. Indeed, the philosophy of mathematics is not about scaring students; however it is about finding and solving the problem. Positive attitude towards maths can be developed by the appropriate used and integration of mathematics.

Overall, we have now seen that technology encourage students to (a) become a successful user; (b) achieve deeper understanding of mathematical concepts and (c) posses more positive attitude towards learning mathematics [11].

Furthermore, technology offers numerical solutions for a definite operation. Also, technology offers a new and exciting ways of doing and learning mathematics. The traditional method is integrated with technology so that maximum understanding of conceptual mathematics is achieved. Besides, with technology the critical thinking skills of

a student increases and hence rising the congruence between the real and school mathematics [11].

"Communication of mathematics to others" is an important principle in the teaching of mathematics. However, in order to communicate, one must interact with another. Hence, it is clear that by using technology in the learning of mathematics, interpersonal skills will improve and students will interact with others upon achieving conceptual understanding.

Most people hate to do the task in a long period of time. Therefore, with technology, more times are saved and more production is obtained. The problem can now be solved quicker and at the same time, conceptual understanding is gained. For example, in finding the solution to a differential equation: (a) if we choose to use traditional method, it will take quite a long time and hence less problem can be solved; or (b) if we use technology such as graphic calculator, we will obtain the answer in less than one-minute! This is an advantage. Therefore, we can see that by using technology more production (that is skills gain) are gained and less time will be taken in order to just solve the problem!

With technology, the assessment question can be upgraded (making it hard), thus requiring critical thinking skills in approaching to solve the problems. Also, by integrating technology, more application of the question can be applied to various fields. If we consider the application of matrices in electrical circuits, we can use many matrix operations (such as row reduction or Gaussian elimination method) in finding the current flowing into the network. Hence, more complex network can be analysed.

11. Practising Technology

Having observing the student's response on technology in Mathematics, we now would suggest how it (technology) could be implemented in the classroom.

Firstly, we can start introducing students with graphic calculator, and explain to them the advantage of graphic calculator (GC). Explain to the student on the benefit GC. Next, we can show them how to plot the function and visualize the graph of that particular function. From there, teachers can incorporate graphic calculator in understanding mathematics.

For a higher level of mathematics, we can even use power point in order to show the graph of a function. Furthermore, we can also use mathematical software (projected by LCD projector). We can use MAPLE, Mathematica, and MathCAD etc. These are absolutely useful in showing the graph of a function.

With technology, we can even show to the student how to compute complex calculation – such as integrals and differentials.

Acknowledgement and Dedication

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