DEVELOPMENT OF INTERACTIVE MATHS TEACHING TOOL FOR ENGINEERING EDUCATION

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Abstract

This research and development work is to develop interactive math teaching tool for engineering education which can be used as an interest inculcating tool among secondary school students towards mathematics and encouraging them to embark on engineering study. The objective is to develop an initial set of math software that can be used as basis for continuous development to realize a locally developed tool as an alternative to existing software that are used today. The agenda is to minimize dependency on foreign tool in engineering education teaching, learning and research. The approach used is teaching and learning strategy that employs technology that relates subjects to application in reality with simple clear and attractive examples. A number of basic interactive math functions are built together with examples application in telecommunication and mechanical and automotive engineering which form the norm of every human daily life examples. This work has indicated that an interactive math software imbedded with more than 25 math functions can be gradually developed and further improved by encouraging graduate students to be engaged in engineering math research and development work. This work can be orchestrated with a novel objective of ultimately the country does not be too much dependent on foreign software at primary, secondary and tertiary math education. The results of this work can be used as basis to do more research for better improvement. This bits of work has undergone two field trial exercises via 2 Interactive Math for Engineering Workshops and the feedback from 33 participating students at forms 3,4 and 5 levels are very encouraging. On average 16 out of 25 or 64 % of the topics derived from the software have ratings of good to excellent. On the overall rating, 21 out of 33 or about 64 % of the students voted the software to be between good to excellent.

Key words: interactive math, teaching, exploration, engineering education

Abstrak

Kerja penyelidikan ini ialah untuk membangunkan perisian matematik interaktif untuk pengajian kejuruteraan, sebagai pemangkin untuk menarik minat pelajar sekolah menengah terhadap pengajian kejuruteraan. Tujuanya adalah membangunkan satu perisian, secara amnya sebagai asas bagi pembangunan berterusan untuk mengadakan satu alternatif kepada perisian lain yang sedang diguna hari ini. Agenda usaha ini ialah untuk mengurangkan kebergantungan terhadap peralatan dari luar negara didalam pengajaran, pengajian dan penyelidikan dalam kejuruteraan. Pendekatan yang digunakan ialah strategi pengajaran yang menggunakan teknologi yang mengaitkan subjek bersama dengan kegunaan didalam kejuruteraan menerusi contoh yang mudah, jelas dan menarik. Beberapa fungsi matematik interaktif dibangunkan dengan pameran kegunaan dalam bidang telekomunikasi dan kejuruteraan mekanikal dan automotif yang merupakan kebiasaan harian dalam kehidupan. Penyelidikan ini telah mempamerkan lebih dari 25 fungsi matematik interaktif untuk pembelajaran kejuruteraan yang boleh dimajukan lagi secara beperingkat oleh pelajar lepasan ijazah. Kerja penyelidikan dan pembangunan ini bole digembeling dengan objektif untuk mengurangi kebergantungan negara kepada perisian daripada luar terhadap pembelajaran matematik peringkat sekolah rendah dan menengah serta pengajian tinggi. Peirisian terhasil dari kajian ini telah di uji melalui 2 Bengkel Matematik Interaktif untuk Pengajian Kejuruteraan. Hasil kajian borang tinjauan yang dipulangkan oleh 33 pelajar daripada tingkatan 3,4 dan 5 menunjukkan 64% atau 16 dari 25 topik yang dilalui mereka di nilai antara bagus dan cemerlang. Pada peringkat keseluruhan pula 21 dari 33 atau 64% pelajar mendapati perisian ini antara bagus dan cemerlang.

Kata kunci : ***matematik interaktif, pengajaran, penerokaan, pengajian kejuruteraan.***

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Special thanks also go to Embarcadero-Licensing for granting me Delphi 10.2 Tokyo Starter License on 14th Jan 2018 which allows me to start and progress with this work.

This work shall not be completed without field testings with the cooperations of the principals, teachers, tutors and students of Sekolah Menengah Sains Gua Musang (SMSGM) Kelantan and Pusat Tuisyen Galaksi Ilmu (PTGI) Pekan Pahang. Sincere appreciations go to Encik Ahmad Bin Tajab, Puan Mastura Binti Sulaiman, Puan Suhartini Binti Mahmood and the students of SMSGM without forgetting Cik Khor Ai Chia, Cik Nor Anis Aneza Binti Lokman, Cik Nur Ain Zakiah Binti Mohd Yusof, Cik Nurul Azwa Binti Osman, Cik Nurin Rashida Binti Mohamad Rozlan, Cik Siti Aishah Binti Safi and the students of PTGI.

Finally, I wish to thank my mother, sister, wife, sons and daughter for their prays, patience and supports at all time during the course of this study.

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List of Symbols and Abbreviations

AM	*Amplitude Modulation*
DBSB	*Double Sideband Suppressed Carrier*
FM	*Frequency Modulation*
PCM	*Pulse Code Modulation*
PTGI	*Pusat Tuisyen Galaksi Ilmu*
SMSGM	*Sekolah Menengah Sains Gua Musang*
SSB	*Single Side Band*
VCL	*Visual Component Library*

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Mathematic or in short math, is one of the subjects prerequisite to engineering education. An engineer should be well versed in math as most engineering subjects have math embedded by default or by design. This brief work is about designing an interactive math teaching tool for engineering education. It is developed with the intention of giving an alternative basic math learning tool among secondary school students to inculcate their interest to engineering education. The software is developed by using Embarcadero Rad Studio 10.2.2 Delphi software Starter which can be downloaded freely with a starter license from Embarcadero website.

1.2 Problem Statement

The government via the Ministry of Education has embarked on a program of distributing note books computers to secondary students but it turns out to be a failure due to lack of content for learning, teaching and exploration.

This initiative is to prepare a local version of interactive math learning, teaching and exploring software tool for inculcating engineering education interest among secondary school where teachers and students have a choice to use a Made in Faculty of Engineering University of Malaya interactive math software in relation to readily available software in the market such as Geometer Sketchpad and GeoGebra.

Ultimately not only basic interactive math functions are developed but examples of a few applications of math functions in telecommunications and mechanical engineering are shown for students' appreciation and exploration with the objective of inculcating interest in engineering education.

This bit of work has undergone field tests with two groups totaling 33 students in form 3, form 4 and form 5 on the 19th and 20th May 2019. Survey on students experience using the software indicated 64% of them ranked the software between good and excellent on the 5 level scale of Useless-Poor-Satisfactory-Good-Excellent.

1.3 Objectives of Research

1. To develop math learning, teaching and exploring tool for engineering education in the form interactive software.
2. To demonstrate immediate application of basic math functions studied at form 3, form 4 and form 5 in mechanical and telecommunications engineering.

1.4 Scope of Work

The first objective specifically mentioned about developing math learning and teaching tool for engineering education and the second objective specifically mentioned about demonstrating immediate applications of the basic math functions in two fields of engineering namely mechanical and telecommunications. Thus, based on the two objectives the scope of work would be designing and developing interactive math software with immediate examples of utilisation in that two fields of engineering. Since the target group of users are secondary students, the immediate application examples must be related to the basics math functions that they learn at form 3, form 4 and form 5 levels.

The math functions for circle and trigonometry receive special attention in this work. Circle is being presented in 3 modes of STATIC, GRAPHIC and MECHANIC. STATIC mode allows changing the radius and position of the circle and the radius can be rotated in 360 degree fashion by clicking a control button. In GRAPHIC mode, single and constellation of circles can be animated as stationary rotating objects or constellations of flying objects in space. In MECHANIC mode circle is shown as a locus of rotating points of the diameter making an object like a wheel or part of a mechanical engine where pistons and rods are attached moving in harmony according to engine cycles. A basic 4 stroke StrawRubberBand engine events of fuel and air mixture intake, compression followed by spark plug firing and combustion, power transfer pushing the piston that rotates the shaft and flywheel and lastly exhaust the carbon out are clearly shown. This is an example to show how trigonometry and circle are related but most importantly exposing what is happening in a motorbike or automotive engines which are very close to every students and teachers today.

To bridge knowledge gap between what is taught in the secondary class and the immediate application of trigonometry in the hands of almost every secondary teacher and students, trigonometric identities are shown as the basic math functions used in telecommunications engineering for analog and digital modulation schemes.

The students should be encouraged to know that trigonometric identities that they study at form 4 are the basic building blocks of math that enable the current modern communications system are built upon.

Hopefully the circle and trigonometry examples should be able to establish the reasons of studying the subjects at secondary levels, and at the same time deliver the prime intention of attracting students to like math and prepare themselves to embark on engineering education.

Up to this stage the software cannot cover all chapters of any math text book as it is only developed for a master of engineering research project which manages to cover basic functions used in engineering. However the present work can be a small contributor to start for future development. More math functions can be added on to this work by reusing any of the available math functions source codes and introduce new math functions coding according to the wish list of the future researcher or developer. The newly introduced math functions can be integrated into the current source code fairly easily.

Even though circle and trigonometry seem to receive special attention in the scope of work, that does not limit the overall development effort to go beyond these two fields as engineering is made up of chunks of basic and advanced mathematics.

1.5 Dissertation Structure

This dissertation is organized in 5 chapters and 3 Appendices. Chapter 1 introduces this work with description of problem statement, objectives for proposing it with the expected scope of work involved. Chapter 2 provides some literature review and establishing rational for embarking on this work. Chapter 3 discusses on the methodology, project planning and development and field testing phases. Chapter 4 shows results derived from the software and the results of school students feedback after conducting 2 workshops on interactive math for engineering education and Chapter 5 makes some conclusion and recommendation for future works.

Appendix A presents plots of students' feedback on using the software during a full day (19-04-2019 : 9.00-5.00) and a half day (20-04-2019 : 8.00-2.00) workshops held respectively at a tuition center Pusat Tuisyen Galaksi Ilmu, PTGI in Pekan Pahang and at a science secondary school of Sekolah Menengah Sains Gua Musang, SMSGM, in Kelantan.

Appendix B lists all the available functions and procedures that are developed and used in the present work. There are 116 functions and procedures grouped within the purposes of their utilization such as Common, Basic Math Functions, Trigonometry Basics, Angular Velocity, Trigonometric Identities, Application in Telecommunication and Boolean algebra usages.

Appendix C presents the user manual and self-learning guide to provide quick start to use the software. Section 1 of the manual introduces the Basic Math Functions Page which is equipped with functions such as linear, quadratic, cubic, circle, inverse, sine, cosine and tangent to be used and explored. The immediate use can be for teaching and instruction design in a typical secondary math classes. The section is also usable to students individually or in a group for learning and math exploration purposes. Section 2 is the Quick Start Tutorial document for the software.

Section 3 of the user guide presents a Telecommunication Virtual Mini Laboratory for teaching of basic telecommunication modulation techniques and frequency comparisons of two sinusoidal signals. This page basically shows how basic application of trigonometry is used in any radio and television equipment including mobile phones which are used by most population of the world including teachers and students. This minilab forms a typical example of relating trigonometric identities subject and their applications to students making them to realize how important trigonometry is in daily human life.

CHAPTER 2: LITERATURE REVIEW

2.1 Math learning methods.

Traditional math learning methods are still popular among teachers and learners where math textbooks with ready answer exercises are being used as main reference in any math class. Hybrid learning (Zhang & Jiao, 2011) which used the traditional material but accessed via computer, initiated the traditional non interactive math learning methods, introduced in the 1980s where desktops and laptops were available to teachers and students. Interactive math learning with exploring capability is a new approach offered by software like Geometer's SketchPad (Scher, 1999), (Jackiw, 2003) and Geogebra (Hohenwarter, Jarvis, & Lavicza, 2009). Traditional approach of learning math is also exploring, to certain extend, but for only the correct answers.

According to the United States Congressional Research Service (CRS) Report updated March 21, 2008 (Kuenzi, 2008), it was alarming that the US, being fore runner of science and technology innovation, does not have enough number of students, teachers, and practitioners in the areas of science, technology, engineering, and mathematics (STEM). Majority of secondary schools students fail to reach proficiency in math and science. Many students were taught by teachers that were lacking adequate subject matter knowledge. International assessment of 15 year old students indicated the US ranked 24th in math literacy and 28th in science. Adding to that it was found that STEM degree attainment by the US citizen was not consistent with the national science and technology advancement and they also found out that the US ranked 20th among nations of 24 year old that attained degrees in science and engineering. In response to the situation, studies were commissioned for recommendations and expert views. Among the so many reports gathered, the one from the National Academy of Sciences (NAS) —'Rising Above the Gathering Storm' received much influence. Clear targets and concrete programs laid out in the report point out 5 recommendation to improve STEM education which are to; quadruple middle- and high-school math and science course-taking by 2010, recruit 10,000 new math and science teachers per year, strengthen the skills of 250,000 current math and science teachers, increase the number of STEM baccalaureate degrees awarded, and support graduate and early-career research in STEM fields.

In Malaysia we have been planning for STEM since 1970s (Osman & Saat, 2014) where target of 60:40 ratio between science to art students enrolment in education. But recent report on students enrolment is going the opposite way. A review on 57 research articles (Jayarajah, Saat, Rauf, & Amnah, 2014) related to Malaysian STEM education from 1999-2013, revealed that little effort has been given to do research on the effect of multi discipline subjects integration in STEM education to students achievement while STEM promotes multidisciplinary contents to enhance learning effectiveness with real life examples. The forum of discussion on STEM (Bybee, 2010), (Kelley & Knowles, 2016), and issues on impact of ICT in the changing world of education system (Muniandy, Phing, & Rasalingam, 2007), (Ahmad, 2014) suggests that all countries shall exploit ICT for the education system (Han, Halim, Shariffuddin, & Abdullah, 2013), (Ghavifekr et al., 2014).

In contrast in Israel (Awad & Barak, 2014), 13-14 year old students were exposed via Problem Based Learning (PBL) to advanced content of signal amplification and sampling up to analog to digital conversion technique over 15 weeks period where multi subjects teachings were carried out and published results indicated full participation by students in PBL. At the end of the program the students expressed interest to further study in the areas of advanced data processing and modern communication system.

Educators and researchers across the world are continuously seeking for the best suitable methods to effectively part their non-technical, technical and engineering knowledge to their students at school up to graduate education. The research activities involved looking for new strategies, methods and teaching materials, experiments, survey, games and tournament teaching (Salam, Hossain, & Rahman, 2015), evaluations of teachers capability and capacity to acquire and create new knowledge (Chua & Jamil, 2014). The ultimate objective of the study is to find ways and means to improve students understanding and mastering the so called difficult and blurry but important for futuristic human development. Physics and mathematics are two closely linked subjects studied in science, technical and engineering education. Most secondary school students all across the globe find the two subjects are taxing to learn as they are abstract and require tedious exercise to appreciate the underlying knowledge and factual truth. There are numerous attempts done to find an effective ways of conveying the subjects to students.(Larkin-Hein & Budny, 2001).

Results of past research showed that by integrating and coupling concept in Physics, technology and learning styles can improve students' literacy and mastery. A study initiated to analyse the needs for a pedagogical module based on technology and learning style (PTechLS) for Form 4 Physic curriculum was carried out at rural schools locally (Alias et al., 2014). The study involved learning styles and level of technology usage among students. The results based on Index of Learning Styles (ILS) among 47 students showed and identified as (89.3%) active, (10.7%) reflective, (78.7%) sensing, (21.3%) intuitive, (95.7%) visual, (4.3%) verbal, (70.2%) sequential and (29.8%) global. In addition, a Technology Skills and Usage Questionnaires (TechSU) survey found that most students had access to computers, mobile devices and internet with percentages of (73.8%), (72.4%) and (42.6%) respectively. The results suggested that such group of students are ready to be served with learning mechanism that employs learning styles such as PTechLS.

The evolution of ICT allows accessibility to new data, information, knowledge and opportunities and tools. This scenario is reshaping our vision to mathematics learning and teaching, expectations from it and the way we use it. Textbook is still required in learning the subject, however it limits visualization of new concept and application, as book cannot revise its content at the rate new content and application are presented to the global network of internet. Thus to maintain the relevancy of mathematics among students and teachers in the new global era a study was launched aimed at exploring two important aspects of teaching and learning mathematics. Firstly to access the quality of teaching materials (Koparan, 2017) developed by prospective mathematics teachers and secondly note the teachers stands on developing teaching materials. It was found that prospective teachers have the skills and capability to prepare materials and use the teaching technologies satisfactorily. New knowledge, skills, and attitudes gained in the material development course give knowledge and skills advantage in their teaching profession. Thus prospective teachers have positive views and attitudes to general teaching technologies and material development.

A study on intention of using GeoGebra among Malaysian teachers (Belgheis & Kamalludeen, 2018) shows that teachers with experience in using the software has high potential intention of using it in their mathematics classes while teachers who has not been using GeoGebra indicate low intention of using the software in their classes. This indicates that teachers with experience in using such software appreciate the usefulness of technology in teaching mathematics. However for those who has never tried the software before find it difficult to attend continuous professional development training organized by the Ministry of Education. On the other hand there are positive reports on students' exposure to dynamic software in teaching and learning math. The use of GeoGebra (Shadaan & Leong, 2013) tested on teaching of Circle to form 3 indicated that students exposed to GeoGebra outperformed students that are kept with traditional teaching method. Geometer's SketchPad (Leong, 2013) tested on teaching of graph to form 6 students indicated that students exposed to SketchPad performed better in understanding of graph and math functions. Other tool that have been used by teachers are G-Reflect and S-Reflek courseware developed by using Geometer's Sketchpad (Han et al., 2013). G_Reflect can be used to teach Translation, Rotation, Dilation, Polygons, Perimeter and Area, Coordinates, Graphs of Function, Circle, Trigonometry and Linear Equations.

The teachings of engineering subjects at college, polytechnics and university levels are well supported by the use of math based simulation tool like MatLab, PSpice, PowerSim, Microwind and Comsol, just to name a few, and the delivery of most engineering subjects and research activities are well supported by tool box of MatLab and a few other simulation tool. (Azad, 2005), (Ghassemlooy & Saatchi, 1999), (Artis, 2011), (Özer, Çimen, & Akbal).

In conclusion, this chapter examines what were and are happening in attempting to embed knowledge such as math and physics in the mind of school students to prepare them for STEM education which dictates multi facets and disciplines needs of future society. The discussions are trying to find the best strategy and approach to ensure STEM subjects of mathematics and physics should be seen as attractive to be acquired by all students from all levels of capability as modern technology are available to make the hard of math and physics seen easy. The modern tools used for math education are quite a number but the most well accepted two are Geometer SketchPad and GeoGebra. Among the two, Geogebra is well accepted for being a free package based on open source platform. This project is an attempt to produce a local version of interactive math teaching tool for engineering education which may be seen as a local initiative to produce local version of open source math software participated by Malaysian graduate students, teachers and engineers.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter discusses the methodology to build the software as listed in Table 3.1, Table 3.2 and Table 3.3. These tables describe the minimum requirement the software should have. The flow chart in Figure 3.1 is the main guiding methods to realize what are listed in these tables. However one should note that processes listed in Figure 3.1 are also followed for other programming of other parts of the software such as creation of the pages and functionalities of the display area such as display grids, scales and zooming in and out capabilities embedded and available in the software. Paragraph 3.2 provides overall specifications for the software.

Table 3.1 The list of Math Functions to be coded into software

No	Functions	No	Functions	No	Functions
1	CIRCLE	10	POWER	19	RAMP**4***
2	COS(X)/X	11	PRBS	20	RAMP**5***
3	COSINE(X)	12	PULSE	21	SIN(X)/X
4	COSINE(2*pi*X)	13	QUADRATIC1 (Second Order)	22	SINE(X)
5	INVERSE1	14	QUADRATIC2 (Second Order)	23	SINE(2*pi*X)
6	INVERSE2	15	CUBIC (Third Order)	24	TANGENT(X)
7	INVERSE3	16	RAMP**1***	25	TANGENT(2*pi*X)
8	LINEAR	17	RAMP**2***	26	
9	Ln(x)	18	RAMP**3***	27	

Note*: These RAMP functions are still under development and need improvement. They are listed to indicate that they can be developed by using the existing basic math functions.

Table 3.2 Math Functions and Applications Examples

No	Functions	Applications
1	Circle and Trigonometry	Mechanical Engineering 4 Stroke Engine Events
2	Trigonometry	Telecommunication Engineering Virtual Laboratory

Table 3.3 Boolean Functions

No	Logic Functions
1	AND
2	EXCLUSIVE OR
3	EXCLUSIVE NOR
4	INVERTER
5	OR
6	NAND
7	NOR

Having the above list, this part describes the processes and methods of building the software. The explanation that follows refers to Figure 3.1 which is the main flow chart for the work.

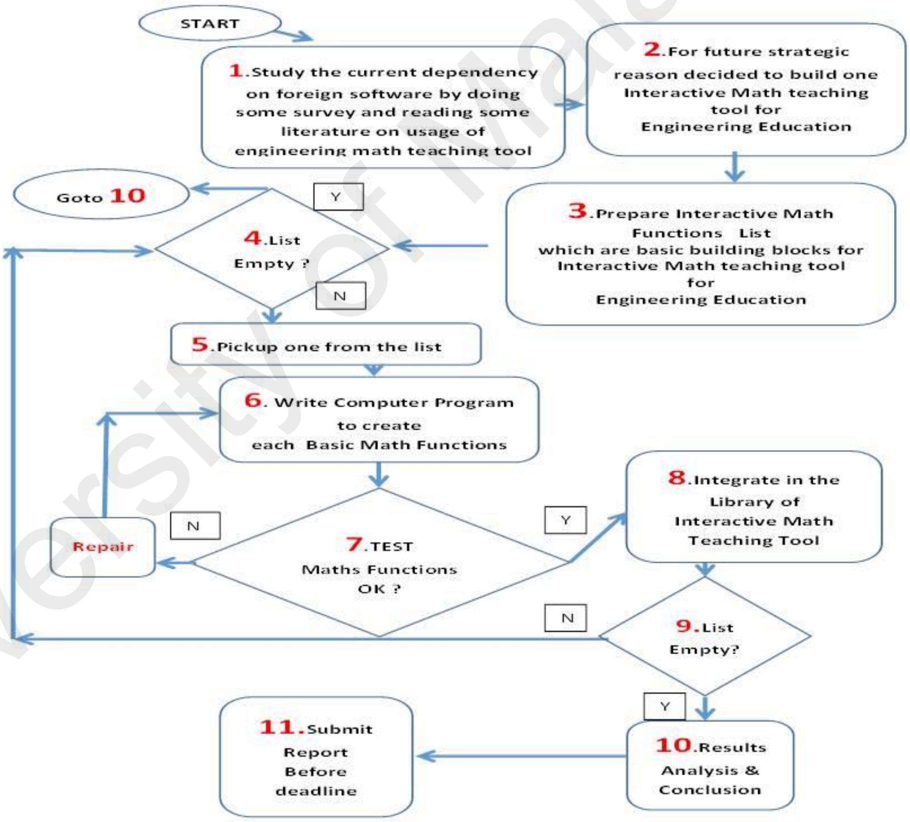

Figure 3.1 Main flow chart

3.1.1 Method No1.

On starting the project, the methodology begins with studying on the status of STEM education and literature review particularly on the topic of teaching and learning of mathematics. This has been done and explained in Chapter 1 as an attemp to gauge the dependency on foreign software for teaching and learning math. A range of software available in the market which are being used by the teachers and Lecturers at schools, colleges and universities. The schools are dealing with G-Reflect, S-Reflek, GeoMeter Scatch Pad (GSP) and Geogebra. While engineering Subjects at college and universities are always supported by Mat lab, PowerSim, PSpice, Microwind and Comsol just to name a few. Some come free while some require license fees. We are always aiming to soar upwards but working with technology that comes from outside. How about slowly building own capability ? This is the ultimate aim of this project which can be successful overtime.

3.1.2 Method No 2

Decision to submit a proposal to develop an interactive math teaching tool for engineering education as a Master of Engineering Research Project is the result of the study mentioned in para 3.1.1. The base developing tool is decided to be Embarcadero Delphi Tokyo 10.2 Starter license granted on Jan 14th 2018.

3.1.3 Method No 3

Prepare a list of basic math functions to be coded. The decision is to come up with a number of basic functions such as linear, quadratic, cubic, circle,sinusoid, inverse function and etc. While working on the math functions, a vital consideration is to include control functionalities to display the function such as are zooming in and out, animation capability, sound effect, number of traces on the display and also divide by zero protection if the function involved division by another function which may be zero at certain instance. After identifying the display functionalities then the math functions are listed with the requirement of control buttons and switches to control the properties of the functions and the display area.

3.1.4 Method No 4

This is a check point how many math functions are left to be coded from the list prepared in **Method No3**. If the list is not empty then go to **Method No 5**. If the list empty or exhausted then go to **Method No 10** to proceed with the next task of field tests, results analysis and conclusion.

3.1.5 Method No 5

This is just a picker to pick which functions to be coded next by passing to **Method No 6** where the coding is done.

3.1.6 Method No 6

This is the computer programming part. Assuming that the display and the control buttons are already decided, function $y = mx + c$ is going to be coded where $m = a/b$. The formula used is $y = (a/b)x + c$. From the formula, y has a gradient (a/b) and a constant c. Function y needs 3 parameters a, b and c as inputs from the user. The user does not have to key in the values for a, b and c, but to set the values from a set of three updown buttons that give the values of a, b and c repectively. The range of values of a, b and c can be -100 to +100. When user make a selection of a linear function by default the formula $y = (a/b)x + c$ shall take the values of a, b and c as set by the user. Thus if $a = 4$, $b = 3$ and $c= 0$, $y = (4/3)x + 0$. As variable x changes from -7 to 7 the values shall have a range from $y = (4/3)(-7) + 0$ to $y = (4/3)(7) + 0$ which gives -28/3 and +28/3. The linear function shall be plotted with values (-28/3) to (28/3) passing point y = 0, x = 0 where we have a straight line of a linear functions as shown in Figure 3.2.

3.1.6.1 The Code for the Linear Function

The code for the linear function is shown here as an example for programming of the math function in Delphi Integrated Development Environment.

```
function linear(a,b,c,xUnitValue,yUnitValue : real, bitbtn28caption : string) : integer;

   begin
   if b <> 0 then  m  := round((a/b)*yunitvalue)      else   m  := 1000000;
     {zero divide protection which may create a software crash if not taken care }
   if bitbtn28Caption = 'ORIG' then linear := round( m * xunitvalue + c);
            {       Original               }
   if bitbtn28Caption = 'DIFF'  then linear := m;
            {        df(x)/d(x)          }
  if bitbtn28Caption = 'INTG' then linear :=
  round( m * sqr(xunitvalue)/2 + c*xunitvalue);
            {   Integrate f(x)d(x)      }
   end;
```

Samples of functions and procedures for other math functions are listed in Appendix B.

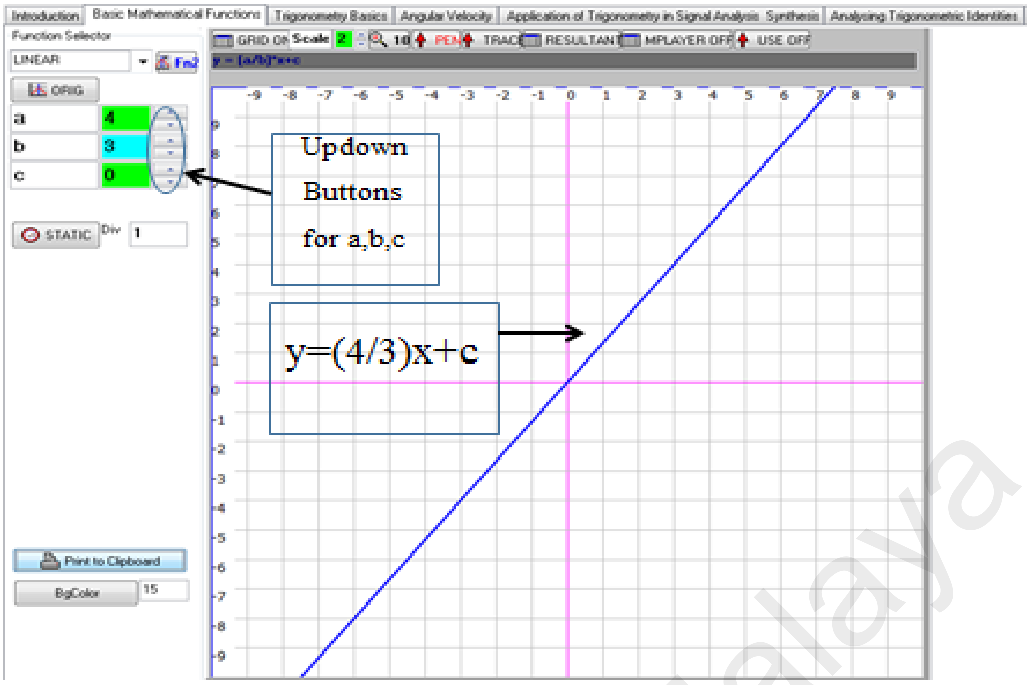

Figure 3.2 A plot of a linear function

y = (a/b)x + c = 4/3(x) + 0 where a = 4, b = 3 and c = 0
Note that when x = 0, y = 0 when x= 3, y = 4 and when x= -3, y = -4

3.1.7 Method No 7

This is where the newly developed module is tested. In fact as program is developed in **Method No 6**, the testing is continuous as it is interactive, the programmer, the author, must know what to expect and remedy to the code is done when the output goes unexpected. It must be remedied until no more error found. If no error is found the newly coded software for the math function is passed to **Method No8** for integrating with the main software for Interactive Math Teaching Tool for Engineering Education.

3.1.8 Method No 8

Once the code is functioning as it is specified then it is integrated into the system as a new math function which can be field tested before it is used for teaching and learning.

3.1.9 Method No 9

This is another check point if there is another functionality need to be coded by inspecting the list of undone function. If there are still uncoded functions in the list then go to **Method No 4** where another check point is done. If there still exist functions to be developed then go to **Method No 5** to pick up the new function and pass to **Method No 6** for programming to be carried out. If the check point here finds that no more function to be coded then proceed to **Method No 10** where field tests, results analysis and conclusion are done.

3.1.10 Method No 10

This stage deals with doing analysis and evaluation of all the programming results of the math functions and other functionalities done in the development phase. After all the results are compiled and analysed conclusion can be made whether the system can do what it is supposed to do within the limitation and if it is no mistake done. Field tests needs to be carried out with the target users such as students at secondary education who are aiming to pursue engineering at polytechnic, college or university levels. Once field test s are carried out the work can proceed to the next stage of report writing for submission to the examiners. The results of field tests are discussed in Chapter 4.

3.1.11 Method No 11

This is the final stage of the project for compilation of all the works, tasks and results to be presented to the supervisor and examiners.

3.1.12 Final Note on Methodology

The Flow chart in Figure 3.1 is applicable to all coding of the 8 pages of the software. If description from paragraph 3.1.6 is used for basic math function coding for linear function on Basic Math Function Page, the same method is applicable to all other functions and on that pages as programming is generic. What make the different is the functions and procedures used for the functionality of the software, the inputs and the parameters passed to the function and the expected output. In addition to the methods explained above the following paragraph 3.2 discusses the basic functional specification of the final software.

3.2 Building The Software

The software is built by using Delphi programming with a few examples of Build Methods shall be explained here.

3.2.1 Build Method No 1 : Prepare Subscription Checking.

On starting, the system checks for subscription status of the user. If the subscription is expired a message appears asking for renewal. If the user wants to renew the free license the user send a message or call an administrator in the champion office for a renewal by mentioning the date of expiry shown on the message on the user computer. When the administrator receives the date he/she shall input the date into the renewal module to get a renewal pass to be sent to the user by message or phone call. On receiving the renewal pass the user just key in the renewal pass into the subscription check message input edit field. On keying the renewal pass, the user system shall do validity checking and proceeds the launching of the software if the renewal pass is valid. If the launching is successful the user can proceed with the page selection method explained in Table 3.4. Figure 3.3 shows the programming steps to enable subscription checking.

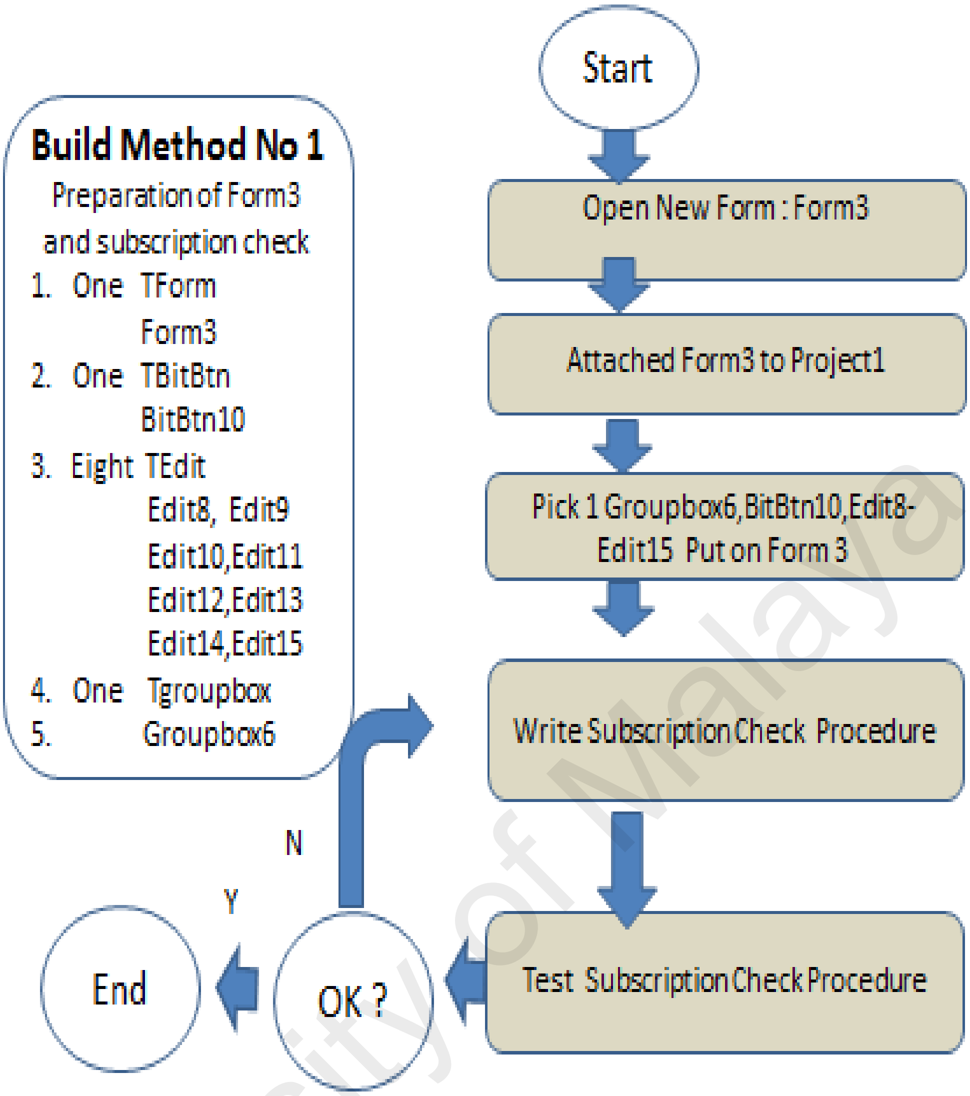

Figure 3.3 Build Method No 1 The Startup or Launching and Subscription Check .

3.2.2 Build Method No 2 : Prepare Page Selection.

Page selection method starts after subscription check has passed and it waits for a page selection from any of the tabbed inputs selections as shown in Table 3.4. The output is a selected page and the input is a mouse click on a TabbedNotebook tab. Figure 3.4 shows the dialog on page selection. Figure3.5 shows the current active page which is Basic Math Functions Page with a Linear and an Inverse functions shown on the display, an Image chosen from the VCL (Visual Component Library) Component list.

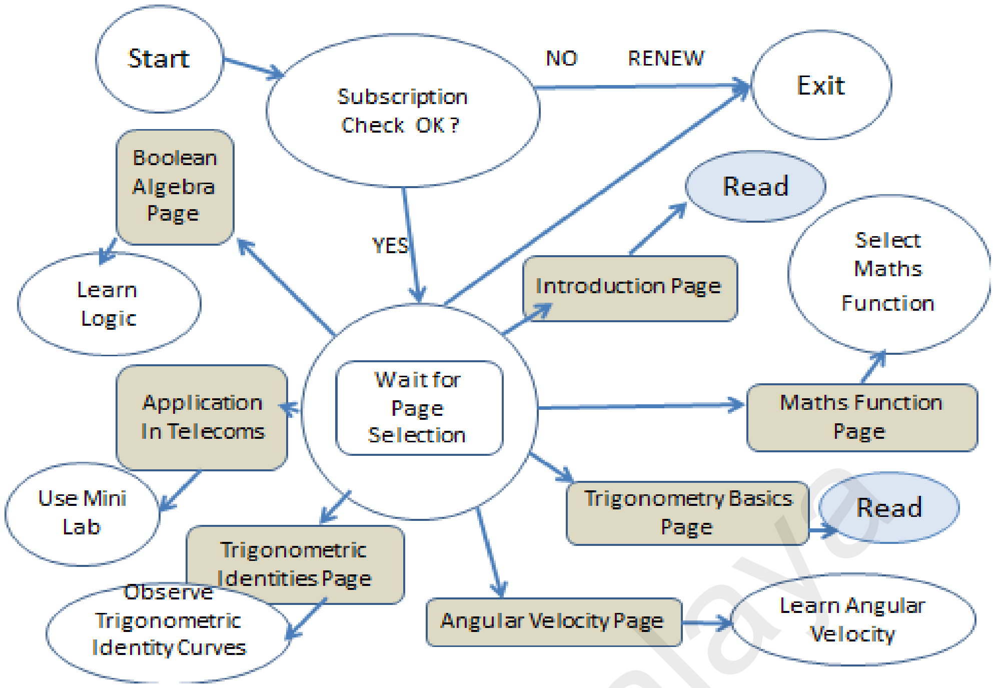

Figure 3.4 The dialog events beginning from launching, subscription check and waiting for page selection.

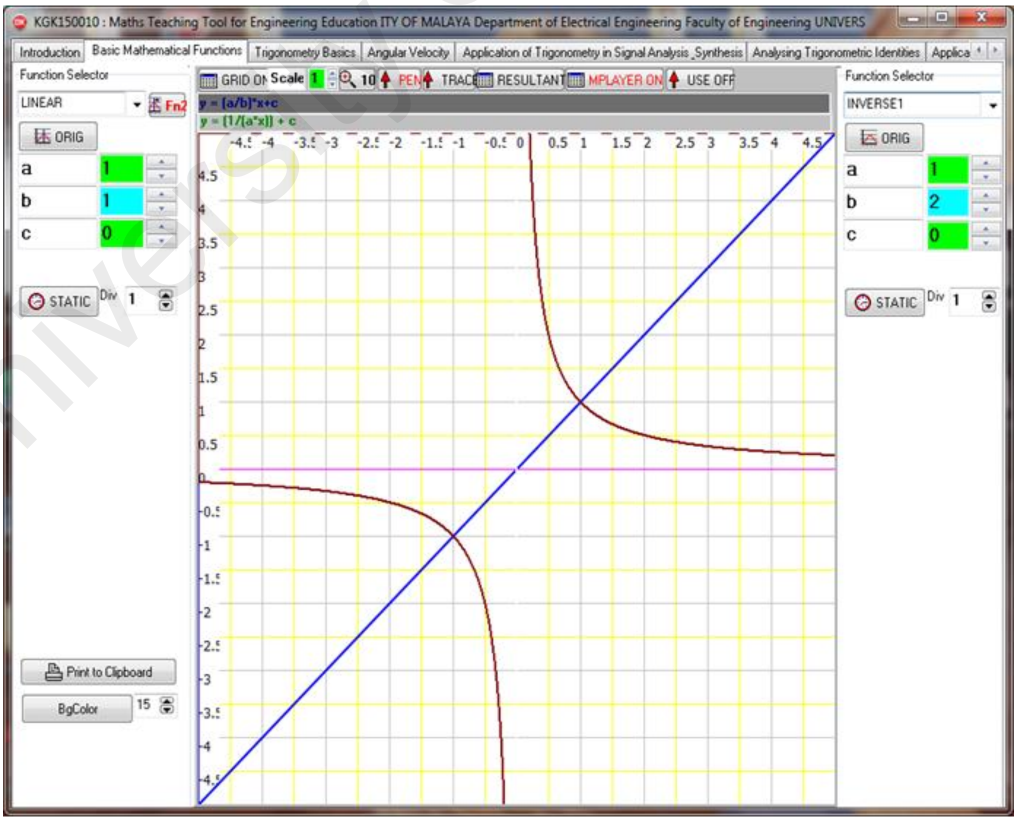

Figure 3.5 A typical active page of TabbedNotebook which is Basic Math Functions Page.

Table 3.4 Inputs and Outputs of Page Selection Method

NO	Inputs	Output on Tabbed Notebook
1	On Mouse Click From Software Icon	Default Page Basic Math Function Page
2	Mouse Click on Introduction Tab	Introduction Page
3	Mouse Click on Trigonometry Basics Tab	Trigonometry Basic Page
4	Mouse Click on Angular Velocity Tab	Angular Velocity Page
5	Mouse Click on Signal Analysis And Synthesis Tab	Signal Analysis and Synthesis Page
6	Mouse Click on Trigonometric Identity Tab	Trigonometric Identity Page
7	Mouse Click on Application in Telecommunications Tab	Application of Telecommunication Page
8	Mouse Click on Boolean Algebra Tab	Boolean Algebra Page

3.2.3 Build Method No 3 : Prepare Math Function Display Area.

Figure 3.6 shows the steps to prepare the display area on newly created working Form1. The VCL components used are Form, Image, Panels, Updowns and Bitbtns. Only major steps are mentioned to keep the explanation as brief as possible but keeping the objectives of creating a display area. The inputs are all the VCL components mentioned and the output after compilation is a display area for the selected Math Functions to be plotted with a reference grid. The grid can be zoomed in and out accordingly.

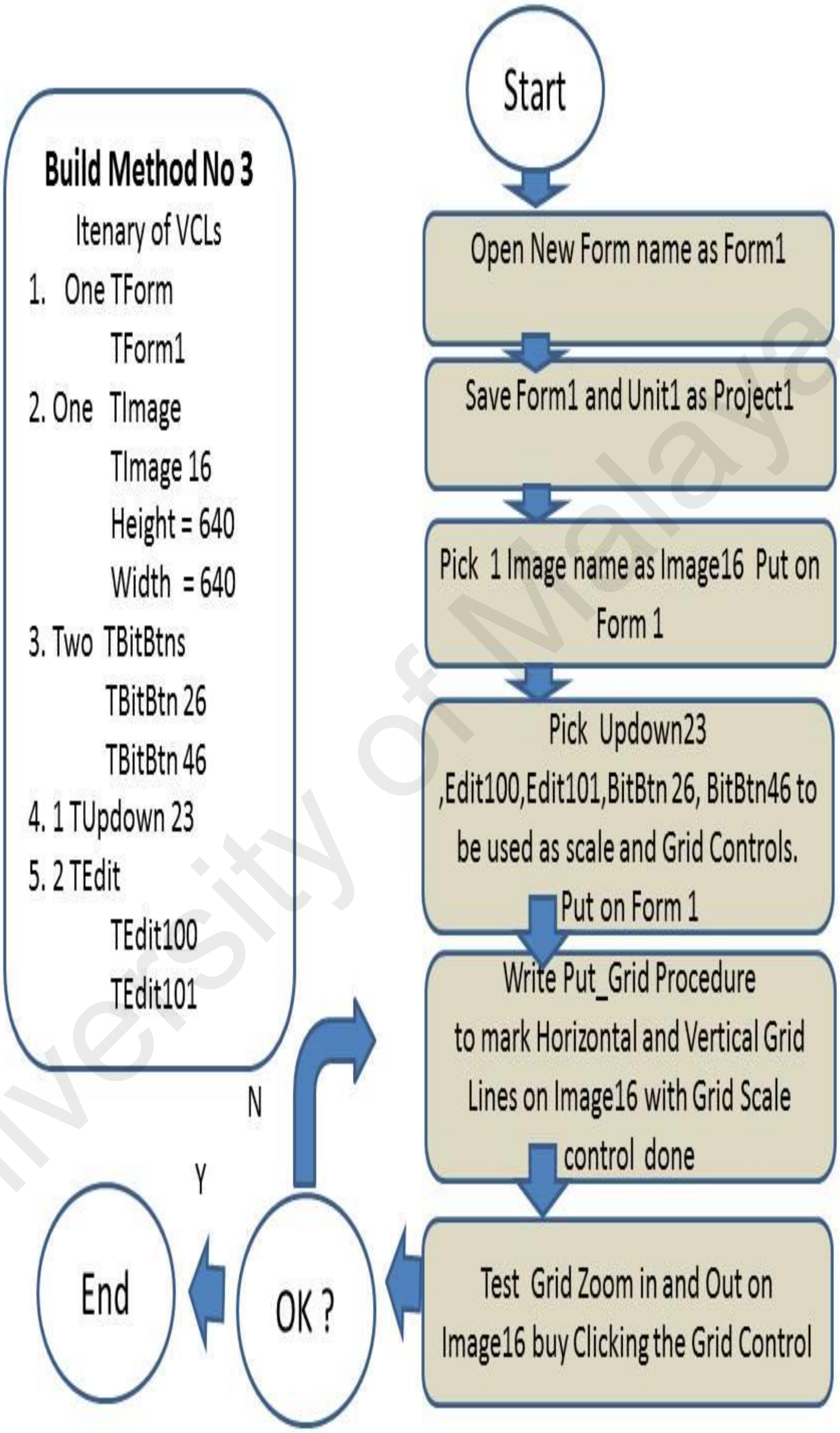

Figure 3.6 Build Method No 3 : Preparing Image Display Area

3.2.4 Build Method No 4 : Displaying Math Functions.

This paragraph shall explain the methods of interacting with Basic Math Functions after the page is selected or by default displayed on launching.

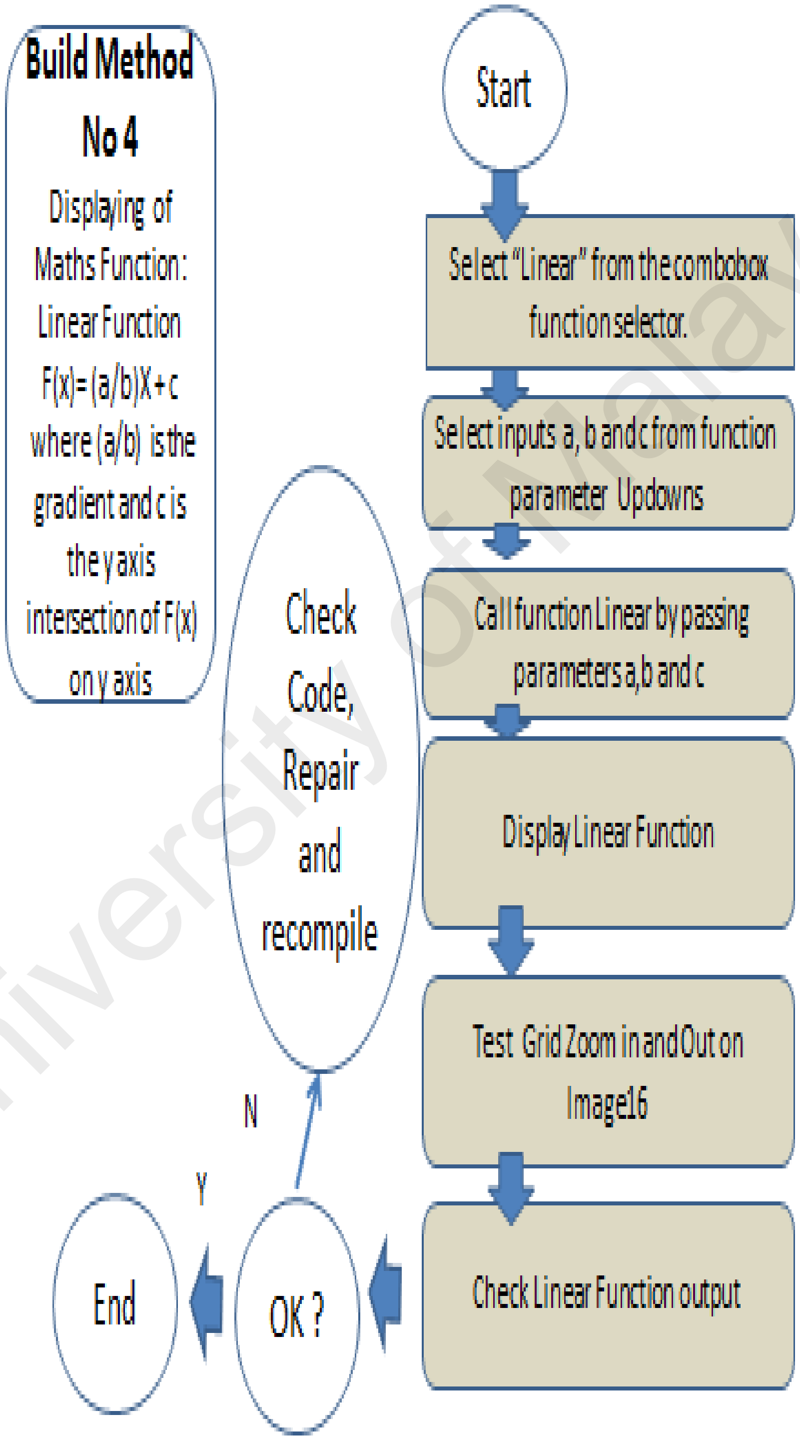

Figure 3.7 Build Method No 4 : Displaying a Linear Functions

3.2.5 Build Method No 5 : Displaying $\frac{dy}{dx}$ of a Linear Function by changing status button 'ORIG' to 'DIFF'.

The following build method to show one way of displaying dy/dx of a Linear Function.

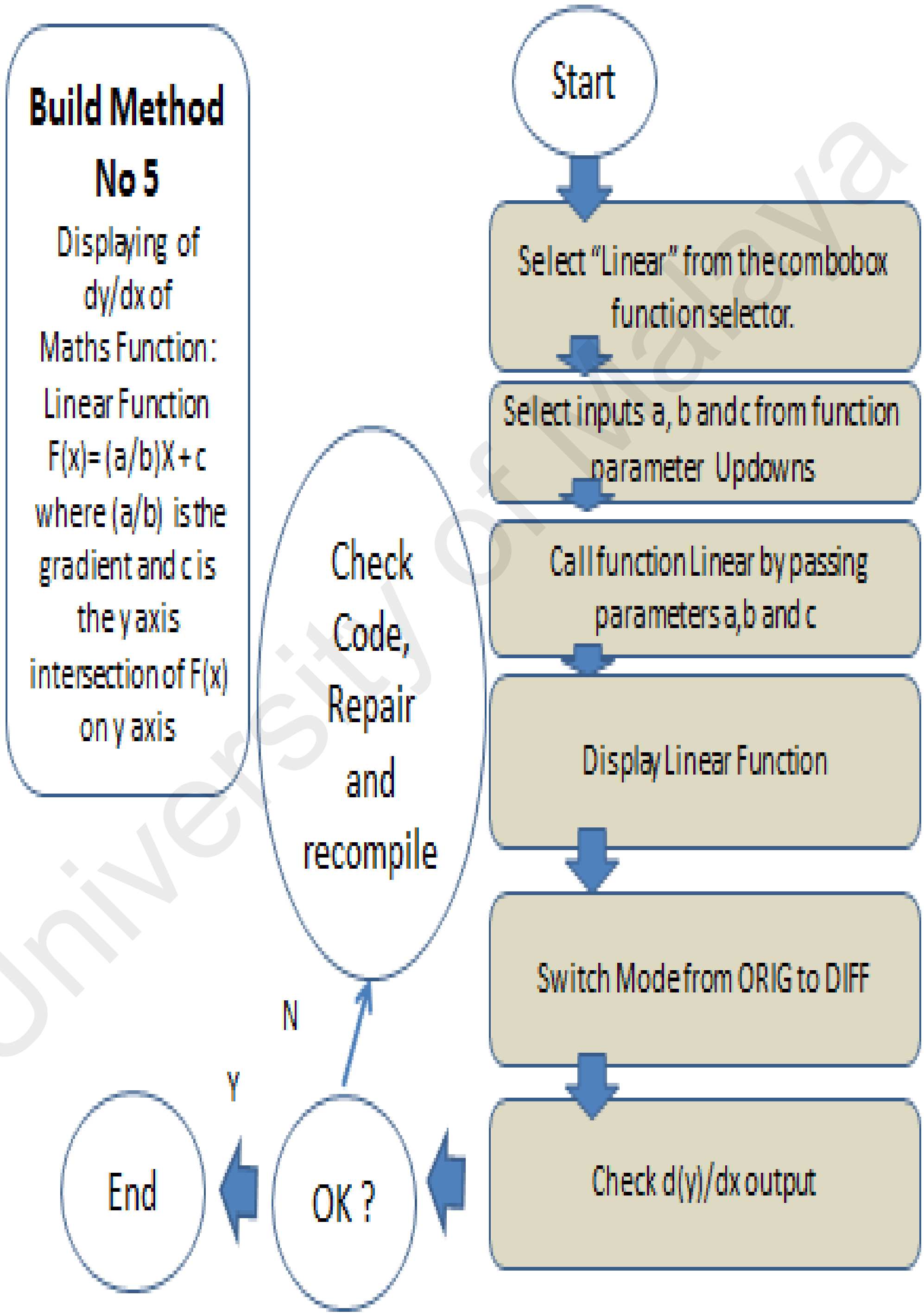

Figure 3.8 Build Method No 5 : One method of displaying $\frac{dy}{dx}$ of a Linear Function.

3.2.6 Build Method No 6 : Displaying $\frac{dy}{dx}$ and $\int y\,dx$ of a Linear Function by changing trace checkbox status.

Paragraph 3.2.5 shows a build method to display $\frac{dy}{dx}$ of a linear function by clicking a button. This **build method No 6** explains on using trace check/uncheck buttons to display the diffential and integral of the function.

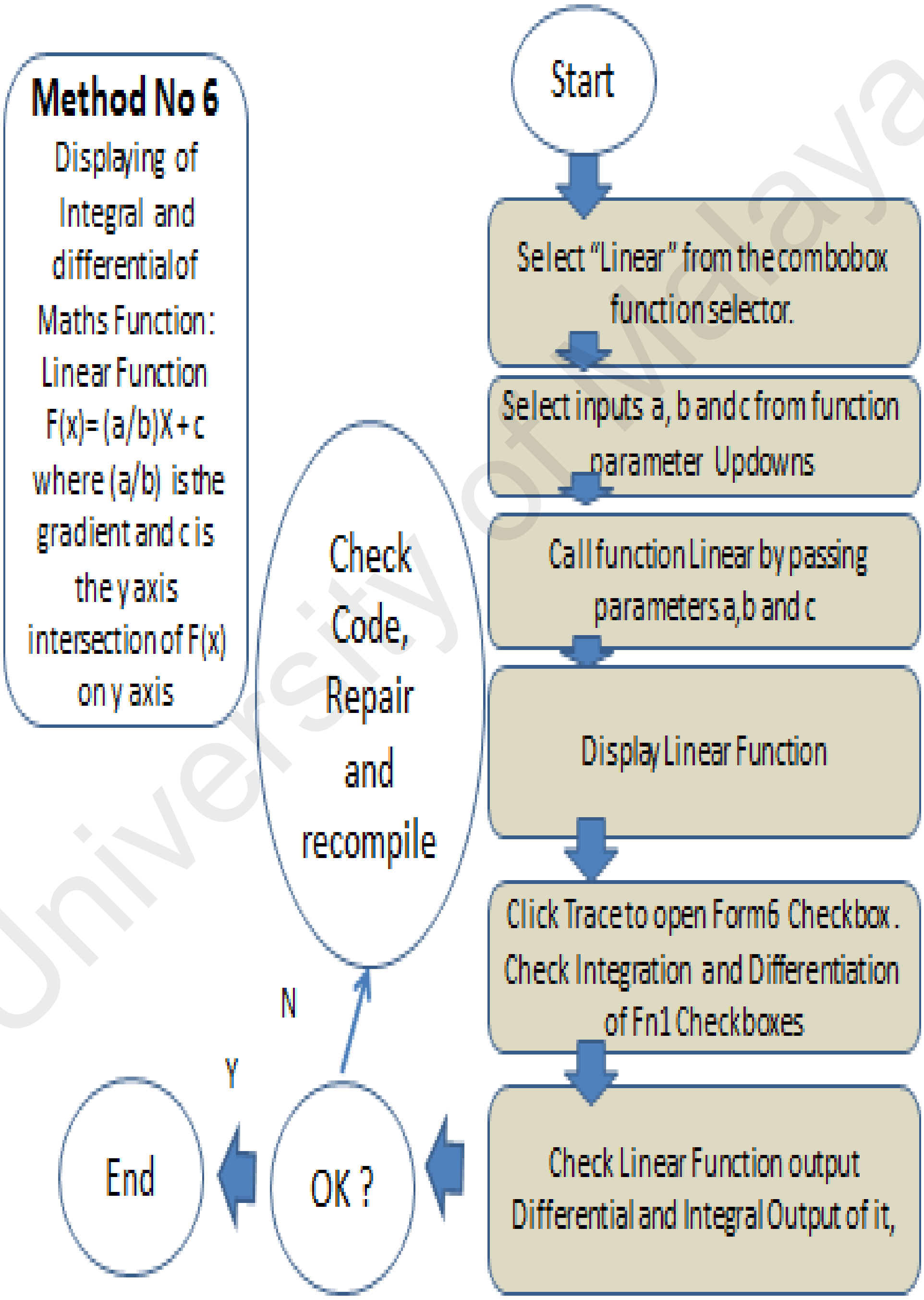

Figure 3.9 Build Method No 6 : Displaying $\frac{dy}{dx}$ and $\int y\,dx$ of a Linear Function

3.2.7 Build Method No 7 : Displaying a Sine (2πX) function

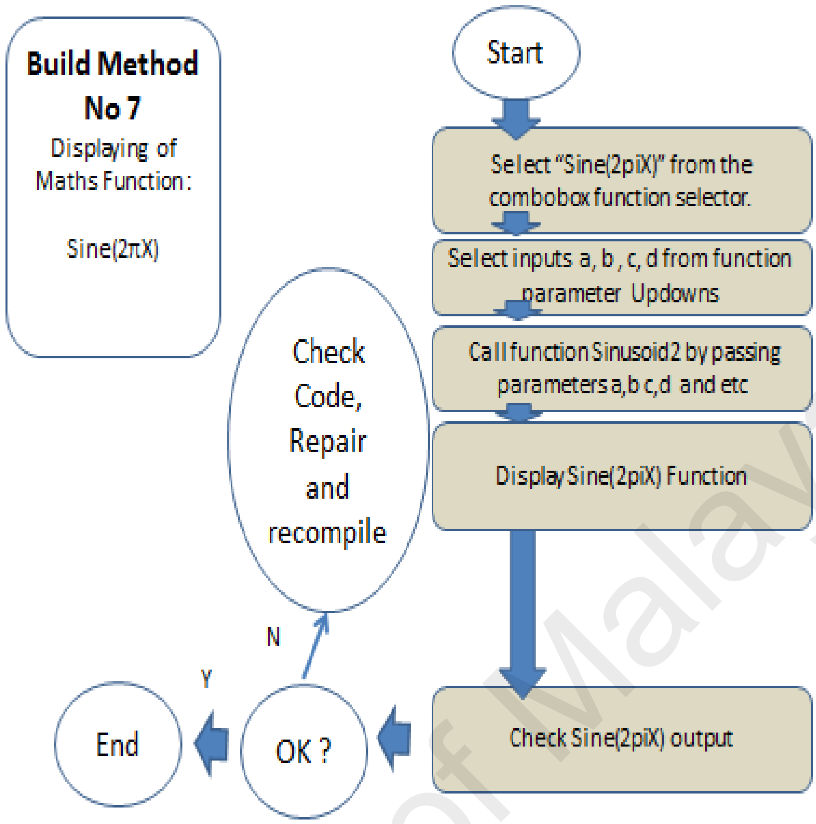

Figure 3.10 Build Method No 7 : Displaying Sine (2πX)

3.3 Development Criteria

An important ciriteria for the software is to include the application of the math functions in engineering as a show case to attract the secondary school students to engineering education.

Other criteria are specifying the nature of the user interaction, the engineering of the software in terms of data structure and display format, the base software for development and the target machines and operating system to launch the software.

The math functions to be developed are listed in Table 3.1, while Table 3.2 lists applications of two selected math functions of circle and trigonometry in engineering. In addition Table 3.3 lists the basic logic functions to be included in the development works.

Table 3.5 Relationship of Features, Functions and Application

No	Features	Functions	Application
1	Problem Solving	Linear Quadratic	Instructional Design
2	Usage	Linear	Amplifier Gain Control
3	Beauty Vector Graphics	Trigonometry PRBS	Graphic Design Structural Graphic
4	Mechanical Engine	Circle Trigonometry	4 Stroke Engine Events
5	Telecommunications	Trigonometry	Virtual Telecom Lab with Signal Generators and Oscilloscope and VectorScope Monitors

3.3.1 Determination of User Interaction

The software should be interactive so that the users, can interact with the software as they like. This statement specifies that the software should have the element and features of problem solving, gaming and exploration. Exploration features could be a situation where functions under studied are further manipulated mathematically through a process of addition or subtraction or multiplication or division or differentiation or integration to obtained additional math function which can be used for similar or different applications. Another useful feature is attractiveness of the software which can be seen as ability to produce beautiful graphics and animation capability. Typical application of the function in industries shall be another advantage point as user can immediately relate the function to applications in their daily life. The current version of the software offers the features as listed in Table 3.5.

Table 3.6 Possible number of traces on the Display Area

N0	Trace No	Trace of
1	1	Function 1
	2	Differential of Function $\mathbf{1}^*$
	3	Integral of Function $\mathbf{1}^*$
2	4	Function 2
	5	Differential of Function $\mathbf{2}^*$
	6	Integral of Function $\mathbf{2}^*$
3	7	Function 3 Resultant of applying math operation on Function 1 and Function2
	8	Vector of Function 1 and Function 2
	9	Vector of Function 1 and Function 3
	10	Vector of Function 2 and Function 3
	11	Vector of Functions 1,2,3

*Applicable to Linear, Quadratic and Cubic functions only

3.3.2 Determination of Display Space

The display shall be subdivided to several pages for chapters or sections selection and where graphics are to be displayed the image shall have grid reference and zooming in and out capability with multimedia player for animation background sound effect.

3.3.3 Determination of Data Structure to be used in the software.

Due to the nature of interaction which may display more than one functions and the associated traces due to mathematical operation of two functions, the number of traces can be multiple as shown in Table 3.6. Thus the data structure should be a flexible multidimensional array and flexible link list.

3.3.4 Base software selection

As mentioned earlier the base software selection is also important factor. This is vital as the ultimate machine that runs the software is a critical consideration as one should aim for the most number of machines in the market place. It would be the best decision if the software can run on almost all machines with any operating system such Microsoft Windows, Unix, Apple, Android and any other operating system on any mobile gadget. However for the purpose of producing a limited number of usable software this work uses Embarcadero Rad Studio 10.2.2 Delphi software Starter Pack and compiled on a machines with Windows 7 and Windows 10 Operating System. There are a few obvious reasons for making these two important choices :

1- The development environment is done with a machine with Windows 7 and 10 Operating System with final code .exe extension is backward compatible to Windows 7. Thus users with Windows 7 Operating System still can use the software.

2- Another important decision is Embarcadero Rad Studio 10.2.2 Delphi software Starter allows object pascal code be converted to C or C and C++ code. Thus should the final software needs to be converted to C or C++, it would be possible.

3.4 Implementation Plan

The work at this stage is to determine the software functional specifications. Based on the basic specifications deliberated from paragraph 3.1 and the associated paragraphs, the functional specifications can be summarised as in Table 3.7.

Table 3.7 Software Functional Specification.

<table>
<tr><td>No</td><td colspan="2">Software Specification</td><td></td></tr>
<tr><td>***A***</td><td colspan="2">***Development Environment***</td><td>***Decision***</td></tr>
<tr><td>1</td><td colspan="2">Operating System</td><td></td></tr>
<tr><td>1.1</td><td colspan="2">Development Operating System</td><td>Windows 10</td></tr>
<tr><td>1.2</td><td colspan="2">Operation Operating System</td><td>Windows 7, Windows10</td></tr>
<tr><td>2</td><td colspan="2">Development Environment</td><td></td></tr>
<tr><td>2.1</td><td colspan="2">Integrated Development Environment (IDE)</td><td>Embarcadero Rad Studio 10.2.2 Delphi Starter Pack Software</td></tr>
<tr><td>2.2</td><td colspan="2">Final Application Prototype Working Environment</td><td>Windows Application</td></tr>
<tr><td>2.3</td><td colspan="2">Programming Language</td><td>Object Oriented Programming with Object Pascal</td></tr>
<tr><td>***B***</td><td colspan="2">***User Interaction***</td><td>***User Input***</td></tr>
<tr><td>1</td><td colspan="2">Basic User Interaction</td><td></td></tr>
<tr><td>1.1</td><td colspan="2">User Input Event for
a. Launching and Exiting of Application
b. Display Page Selection
c. Working on any Page</td><td>Mouse Click</td></tr>
<tr><td>***C***</td><td colspan="2">***Software Output***</td><td>***Changes on Display***</td></tr>
<tr><td>1</td><td colspan="2">On Launching</td><td>Application appears with default a Page</td></tr>
<tr><td>2</td><td colspan="2">On Page Selection</td><td>Application changes to new selected Page which can be any of the followings
<table>
<tr><td>Page No</td><td>Page Title</td><td>Interactive (Y) or (N)</td></tr>
<tr><td>1</td><td>Introduction</td><td>N</td></tr>
<tr><td>2</td><td>Basic Math Functions</td><td>Y</td></tr>
<tr><td>3</td><td>Trigonometry Basics</td><td>N</td></tr>
<tr><td>4</td><td>Angular Velocity</td><td>Y</td></tr>
<tr><td>5</td><td>Signal Analysis and Synthesis</td><td>N</td></tr>
<tr><td>6</td><td>Trigonometric Identities</td><td>Y</td></tr>
<tr><td>7</td><td>Application in Telecommunications</td><td>Y</td></tr>
<tr><td>8</td><td>Boolean Algebra</td><td>Y</td></tr>
</table></td></tr>
<tr><td>3</td><td colspan="2">On Selection of
a Non Interactive Page</td><td>Memo containing information is displayed for the user to read</td></tr>
<tr><td>4</td><td colspan="2">On Selection of
an Interactive Page</td><td>An interactive Page is displayed for user to interact</td></tr>
<tr><td>5</td><td colspan="2">On Click of a Control Button on
an Interactive Page</td><td>The Software shall respond accordingly.</td></tr>
<tr><td></td><td>***Page No***</td><td>***Page Title***</td><td>***Response***</td></tr>
<tr><td></td><td>2</td><td>Basic Math Functions</td><td>A selected Math Functions with associated attributes specified by function parameters is displayed.
Optionally two Math functions allows two selected functions be displayed to</td></tr>
<tr><td></td><td>4</td><td>Angular Velocity</td><td>Plots of Sine,Cosine and Tangent functions are displayed
In accordance to a Rotating Radius of a Circle in a number of 2π radian cycles depending on the value of frequecy (angle in radiant) selection.</td></tr>
<tr><td></td><td>6</td><td>Trigonometric Identities</td><td>A selected Trigonometric Identity and Partner with associated attributes specified by function parameters is displayed</td></tr>
<tr><td></td><td>7</td><td>Application of Trigonometry in Telecommunications</td><td>Selected Signals with the with associated attributes and Modulation Scheme specified by function parameters are displayed.</td></tr>
<tr><td></td><td>8</td><td>Boolean Algebra</td><td>A Logic Output of either TRUE or FALSE is displayed with depending on the Logic Input(s).</td></tr>
</table>

3.5 Software Main Structure

The software main structure can be described by the structure chart shown in Figure 3.11. Basically the structure shows all together there 8 pages for user selection after launching the software.

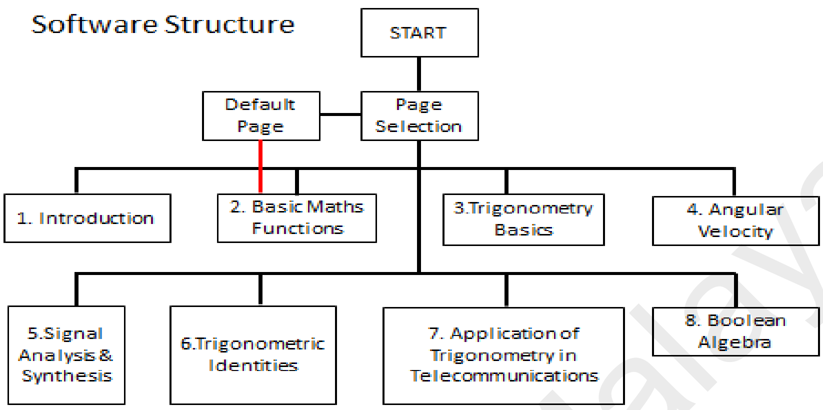

Figure 3.11 Software Main Structure Chart

3.6 Page Selection Dialog.

Once launched the software is by default waiting for a user input, which is basically an event to happen, before it gives a response. Once the user clicks any control button the software shall give a response. Application changes to new selected page which can be seen as boxes numbered 1 to 8 in Figure 3.12.

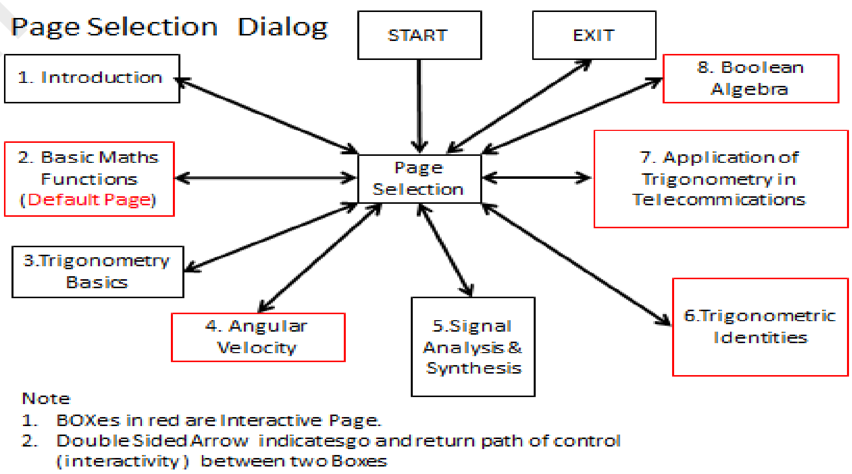

Figure 3.12 Basic User Dialog on launching and making page selection where Basic Math Functions Page is the default page

The main man and machine dialog can be described by referring to Figure 3.12 which is basically the basic software state diagram immediately after launching and passes subscription checking. At this stage there are two possible main options for the user to choose, either proceed with the dialog on the default page of Basic Math Functions or make another page selection. The interaction for the Basic Math Function shall be reffered to user manual in Appendix C, while at this stage the description of user interaction is only on making a page selection among the available 8 pages as shown in Figure 3.12.

Table 3.8 The available Pages developed

Page No	Page Title	Interactive (Yes/No)	Functionality
1	Introduction	No	Showing Memo text for user reading
2	Basic Math Functions	Yes	Selections of more than 25 Math Functions for user selection
3	Trigonometry Basics	No	Showing Memo text for user reading
4	Angular Velocity	Yes	Showing Concept of Angular Velocity
5	Signal Analysis and Synthesis	No	Showing Memo text for user reading
6	Trigonometric Identities	Yes	Showing plots of Trigonometric Identities
7	Application of Trigonometry in Telecommunications	Yes	Showing Vitual Telecommunications Laboratory Set where selections of Signals for Modulation Techniques Study and Signal Detection
8	Boolean Algebra	Yes	Showing Basic Loogic Operation

Table 3.8 describes all the selectable 8 pages with each page attribute of either interactive or not as well as the functionality of each page. The user just gives a mouse click to the intended Page tab then the selected page shall appear on the display for further user interaction on the selected page. From Table 3.8 it is clear that pages 1, 3 and 5 are non-interactive. Thus no user dialog except for reading the material written in

the Memo boxes on the respective pages. However for the remaining pages which are interactive, user interactions have to be designed accordingly. Thus the dialog for pages of 2,4,6,7 and 8 shall be described by the respective diagrams accordingly.

3.6.1 Introduction Dialog

Since Introduction Page is non interactive, on entering the page the user just make a selection for reading the information in the Memo box of the page.

3.6.2 Basic Math Functions Dialog

The main objective of the dialog is to allow user to make a selection of a mathematical function listed in a selection box. Once selected, the function shall be displayed for further user interaction of learning and exploring by changing the effective controls for the functions. Table 4.3 lists all the available functions to be selected.

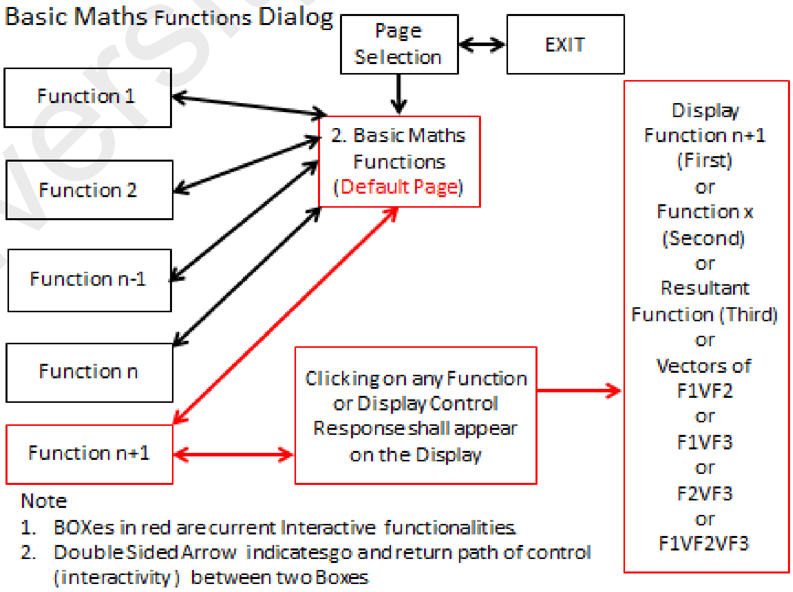

Figure 3.13 Basic Math Functions Dialog

3.6.3 Trigonometry Basics Dialog

Since Trigonometry Basics Page is non interactive, on entering the page, the user just make a selection for reading the information in the Memo box of the page.

3.6.4 Angular Velocity Dialog

The user is introduced to concept of angular velocity which is mostly applied in mechanical, electrical and control engineering. The user can interact on this page by changing and the uptown control button of angle or frequency and give a mouse click to either Click ONCE or STEP buttons to see what happens to a circular motion of two rotating arms separated by 90 degrees and the corresponding Sine, Cosine and Tangent plots on the page.

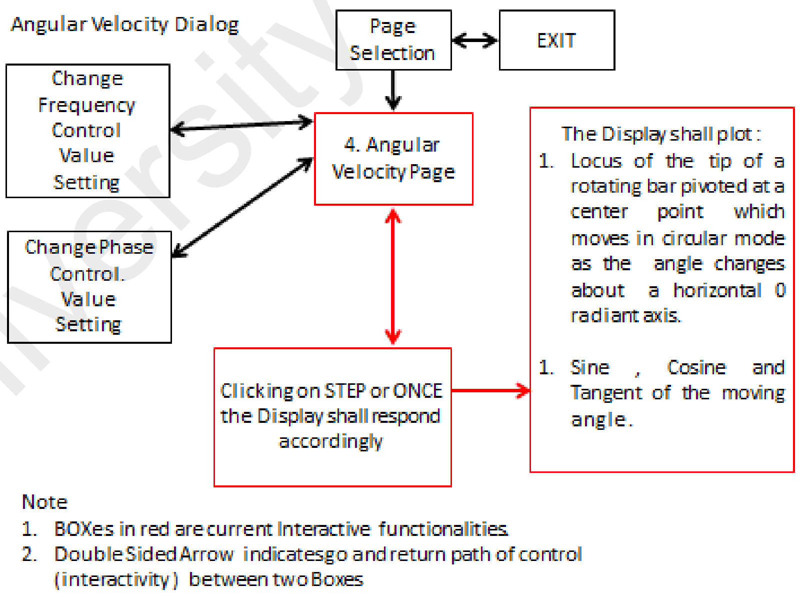

Figure 3.14 Angular Velocity Dialog

3.6.5 Signal Analysis and Synthesis Dialog

Since Signal Analysis and Synthesis Page is non interactive, on entering the page the user just make a selection for reading the information in the Memo box of the page which is basically explaining the concept of analyzing signals attributes and how the signals are exploited to create other signals other math functions for knowledge enhancement and engineering applications.

3.6.6 Trigonometry Identities Dialog

This dialog allows the user to verify graphically that identities are identical and basically it is an introduction to signal synthesis simulation. The user selects an identity, observes the formulae in the partnership and sees the plots are identical for the partner.

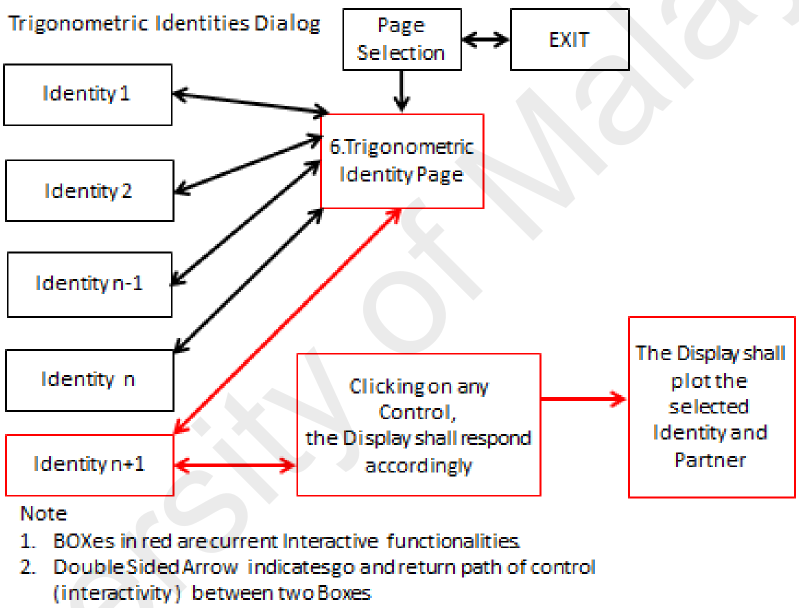

Figure 3.15 Trigonometric Identities Dialog

3.6.7 Application of Trigonometry in Telecommunications Dialog

The basic telecommunication virtual mini lab is introduced here where basic signal modulation and detection is shown interactively.

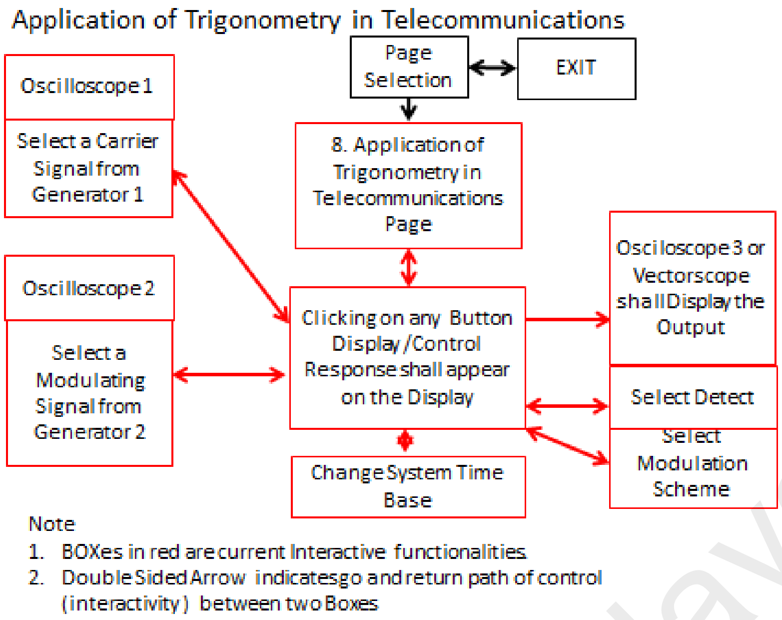

Figure 3.16 Application of Trigonometry in Telecommunication Dialog

3.6.8 Boolean Algebra Dialog

The dialog in Figure 3.17 allows the user study basic Boolean Algebra Logic. This part of the software allows user interaction with sound effect if the Multimedia Player switch is ON.

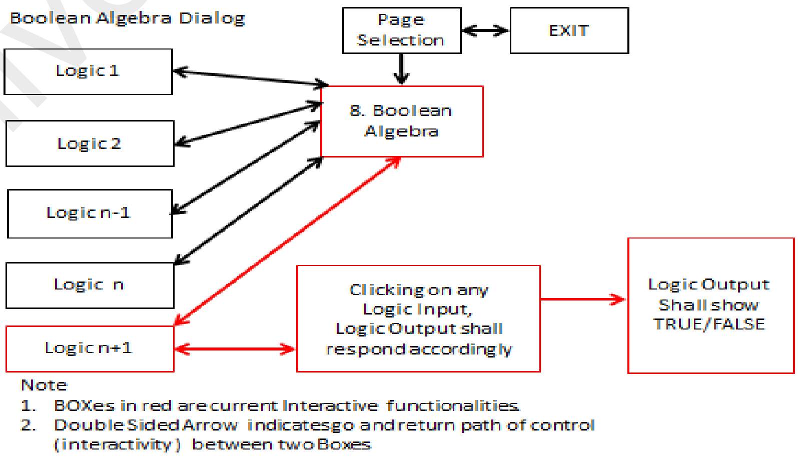

Figure 3.17 Boolean Algebra Dialog

To conclude this section, all the development work for each of the pages mentioned here are part of the vital scope of work to design and develop the software.

3.7 Field Test Planning and Methodology

Just like any newly developed product, it is mandatory for a software to be tested with potential users before commercialization or distribution to intended users. The software engineer shall practice the best to make any design working as expected, however nothing is perfect until tested, as test results dictate many things such as areas for improvement and most important are user perception and feeling of using the product.

For this work the intended users are students in secondary education who need to be exposed to the usage of the topics related to engineering education. This section discuss about the planning of doing test at secondary school. The author planned to oragnise test sessions in the form of workshop on interactive math for engineering education. The following charts are all the processes that need to be completed before, during and after the test sessions.

The first chart in Figure 3.18 is the planning stage where workshop material, survey forms, time table, handouts to students and also preparation for letter of application to do the workshop to the school principal.

The second chart in Figure 3.19 is to initiate application to all the identified schools. Upon their response with agreement, the author has to go and ensure all the computers are working to ensure the software is running smoothly during the workshop. All workshop materials must be printed so that all participants have everything in hand during the workshop.

The third chart in Figure 3.20 is the activity for the day the workshop is organized. It starts with an orientation to interactive math for engineering education by knowing the control buttons to plot the respective math functions which last between 10 to 15 minutes. After that the students are ready to follow each program during the session. After finishing all the programs, the students are required to fill up the feedback form form A5 as attached in Appendix A.

The forth chart in Figure 3.21 is the data processing part where the findings of the survey are evaluated and a report is prepared for an important part of thesis submission.

3.7.1 Test Form Design

Test form was developed based on Likert like format but using 0-Useless, 1-Poor, 2-Statisfacotory, 3- Good and 4- Excellent. The whole idea is to simplify in term of student decision while filling up the survey forms after the workshop session. Students are familiar with the term useless, poor, satisfactory, good and excellent and useless is always associated with zero.

There are more than 25 items on the form but for the purpose of this simple survey to capture on their perception and feelings after using the software, 25 is adequate as 25*33 students the form should be able to obtain a total of 825 basic data. However there are cases that no voting was done on a particular item, so in that case the vote shall be assumed as at useless location. Thus the total votes collected are still 825. In another word if one student did not vote for topic or item X it means that no vote can be collected either on useless or poor or satisfactory or good or excellent. In this case the one vote will go to useless as the vote.

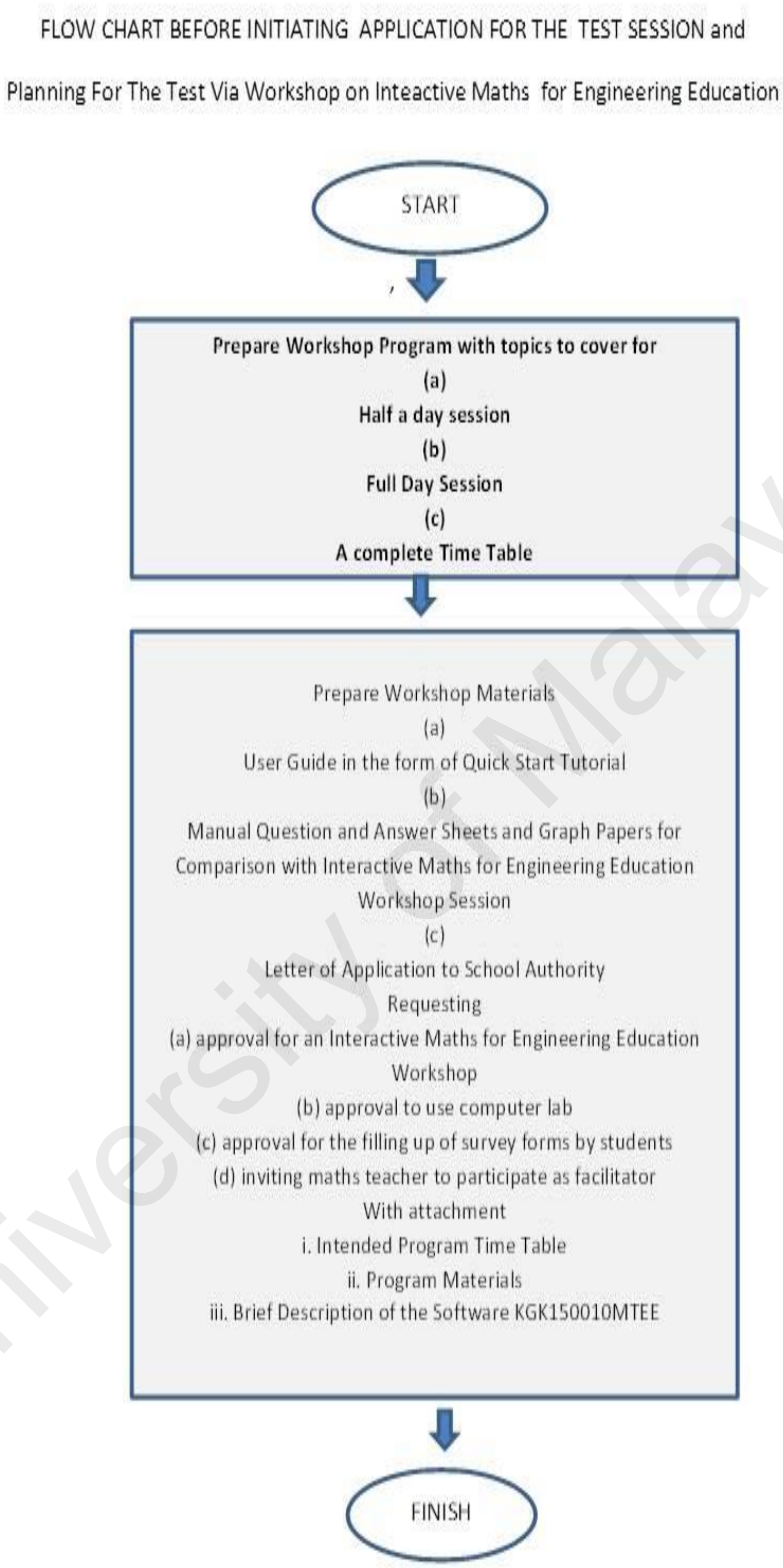

Figure 3.18 Planning For Interactive Math for Engineering Workshop

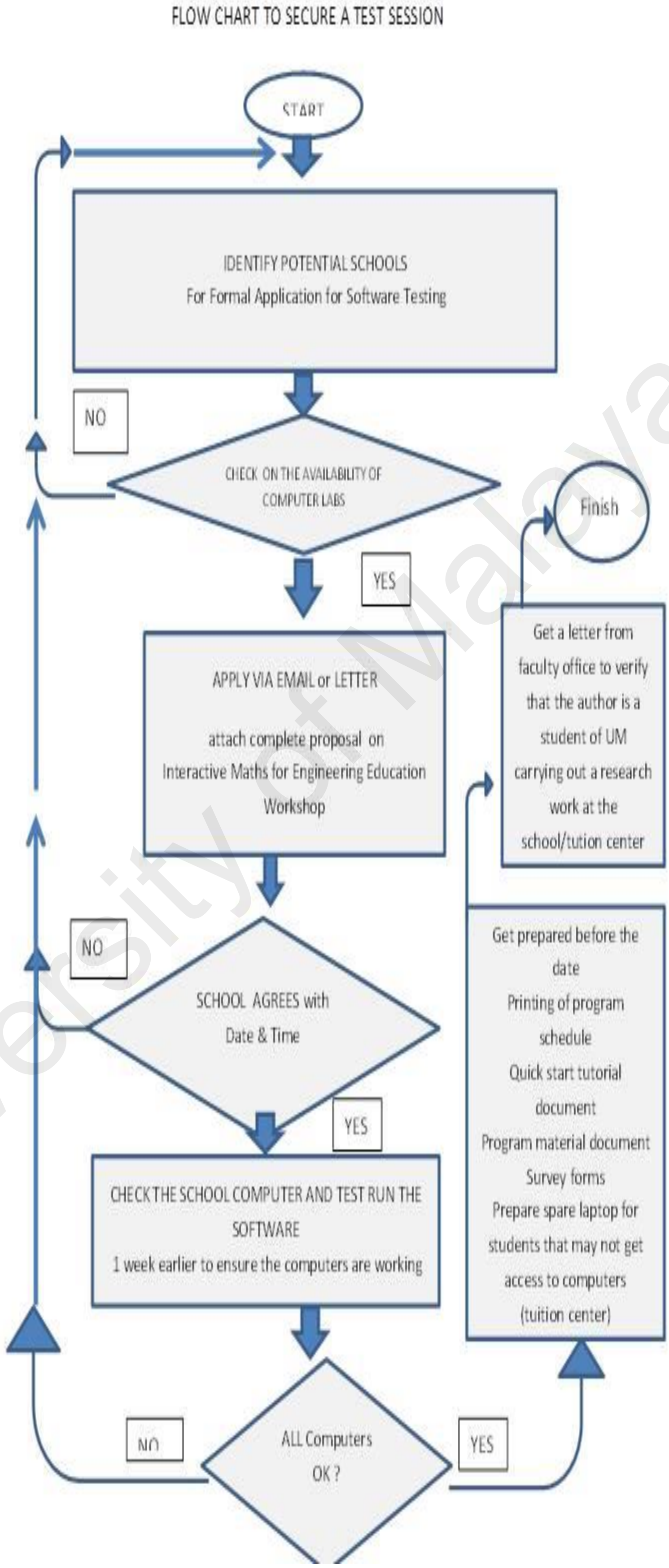

Figure 3.19 Applying for a place for the Interactive Math for Engineering Workshop

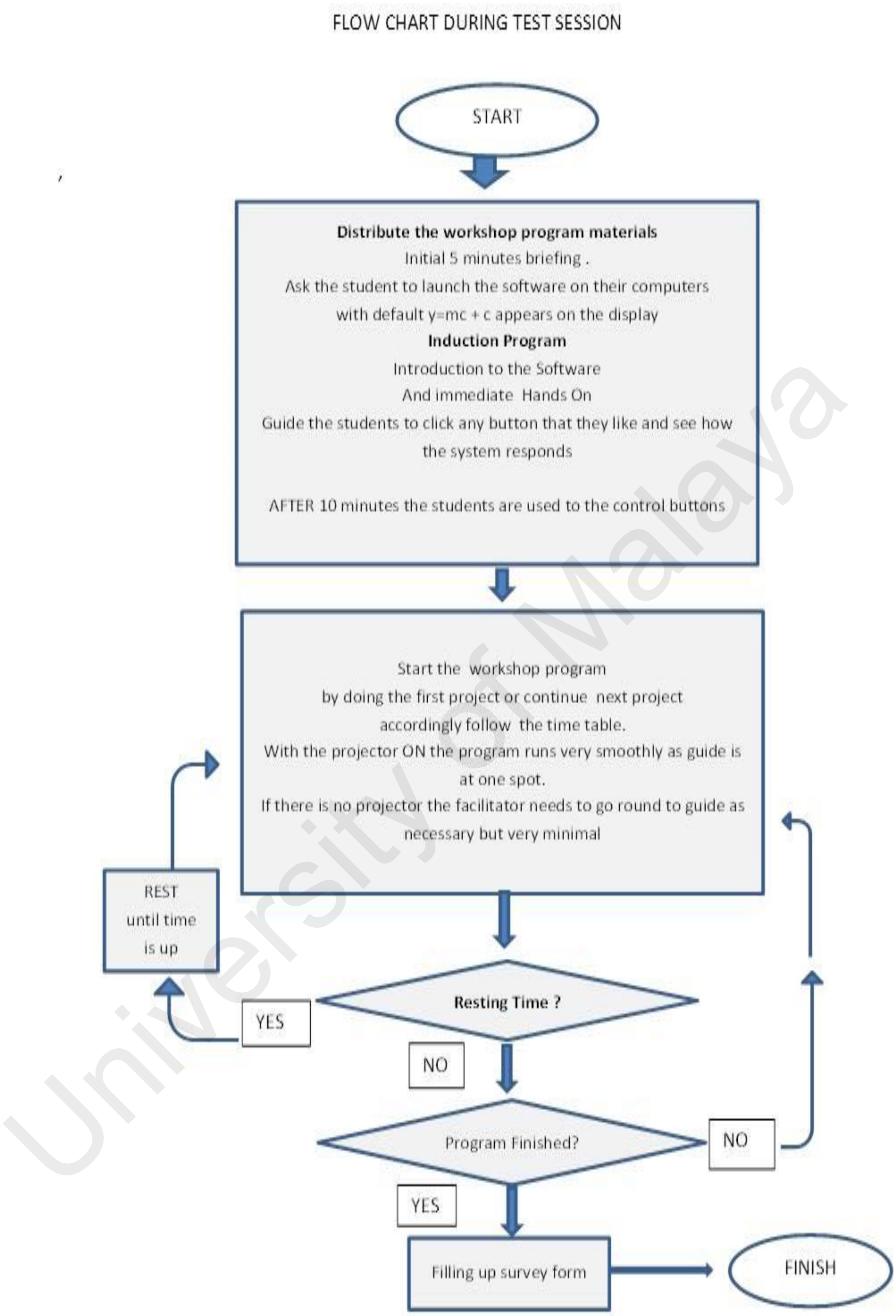

Figure 3.20 During the Interactive Math for Engineering Workshop Session

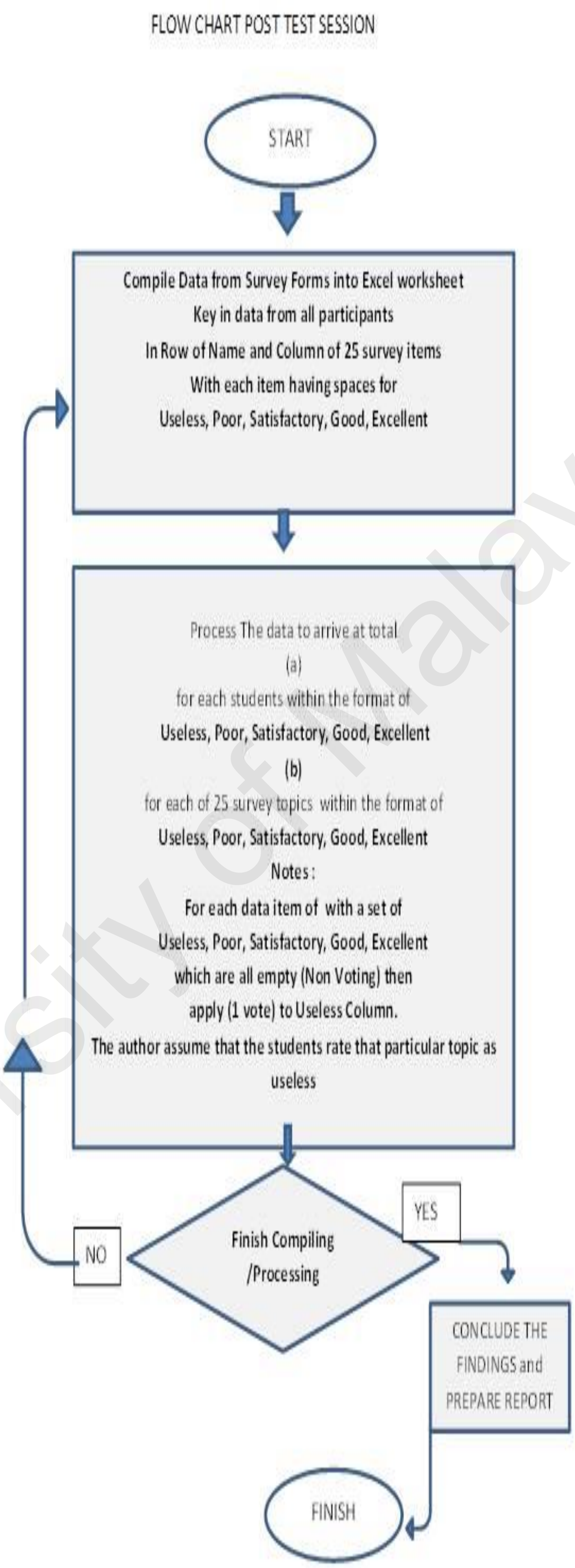

Figure 3.21 Preparation of Report for Interactive Math for Engineering Workshop Session

CHAPTER 4: RESULT AND DISCUSSION

4.1 Introduction

This page describes the results of this work after applying the methodology in Chapter 3 and the associated specification described from paragraph 3.3 up to paragraph 3.6. The Interactive Math Teaching Tool for Engineering Education software produced by this work is designed to have 8 tabbed pages as specified in Chapter 3. To make these 8 pages running as a laboratory usable version, the software is supported by 8 modules which make up the 8 tabbed pages as described in Table 4.1. The 8 modules are served by 116 functions and procedures hardcoded by using Embarcadero Rad Studio 10.2.2 Delphi software Starter Pack licensed to the author on Jan 14th, 2018.

4.2 Modules List

To make it functional and workable the software is made up of a number of 6 main modules namely, Common Module, Basic Math Functions Module, Angular Velocity Module, Trigonometric Identities Module, Application in Telecommunication Module and Boolean Algebra Module. These modules are served by 116 functions and procedures. Table 4.1 gives a summary of the number of functions and procedures serving the modules. Introduction Page and Signal Analysis and Synthesis Page do not require any function and procedure as they are only providing information for user reading.

Table 4. 1: Software Main Modules

No	**Modules**	**Interactive (Yes/No)**	**Number of Functions /Procedures Used**	**Table No In Appendix B**
1	Common Module		12	Table 3.6.1 A
2	Introduction	No	Nil	
3	Basic Math Functions	Yes		
	Linear, Quadratic, Cubic etc..	Yes	47	Table 3.6.2 B1 Table 3.6.2 B2 Table 3.6.2 B3
	Circle Common Static Graphic Mechanic	Yes	 4 1 6 14	 Table 3.6.2 B4 Table 3.6.2 B4 Table 3.6.2 B4 Table 3.6.2 B5
4	Trigonometry Basics	No	3	Table 3.6.2 CDE
5	Angular Velocity	Yes	6	Table 3.6.2 CDE
6	Signal Analysis and Synthesis	No	Nil	
7	Trigonometric Identities	Yes	4	Table 3.6.2 CDE
8	Application of Trigonometry in Telecommunications	Yes	19	Table 3.6.2 FG
9	Boolean Algebra	Yes	3	Table 3.6.2 FG
	TOTAL		116	

Common Module is developed based on 12 functions and procedures. Basic Math Functions Module has a total of 72 where 25 are used for Circle Function while other Math Functions has 47. Trigonometry Basics, Angular Velocity and Trigonometric Identities each has 3, 6 and 4 respectively making a total of 13. Lastly Application in Telecommunications and Boolean Algebra each has 19 and 3 with a total of 22.

4.2.1 Common Modules Function and Procedures

The 12 functions and procedures for Common Module are shown in Table 3.6.1 A in Appendix B.

4.2.2 Basic Math Function Modules Function and Procedures.

The 72 functions and procedures for Basic Math Functions are shown in Tables 3.6.2 B1, B2, B3, B4 and B5 in Appendix B.

4.2.3 Trigonometry Basics Module.

Table 3.6.2 CDE in Appendix B shows the 3 functions and procedures for Trigonometry Basics Module.

4.2.4 Angular Velocity Module

Table 3.6.2 CDE in Appendix B shows the 6 functions and procedures for Angular Velocity Module.

4.2.5 Trigonometric Identities Module.

Table 3.6.2 CDE in Appendix B shows the 4 functions and procedures for Trigonometric Identity Module.

4.2.6 Application in Telecommunication Module.

Table 3.6.2 EF in Appendix B shows the 19 functions and procedures for Applications in Telecommunication Module.

4.2.7 Boolean Algebra Module.

Table 3.6.2 EF in Appendix B shows the 3 functions and procedures for Boolean Algebra Module.

4.3 Introduction Page

This page is an introduction page that tells what this software is all about.

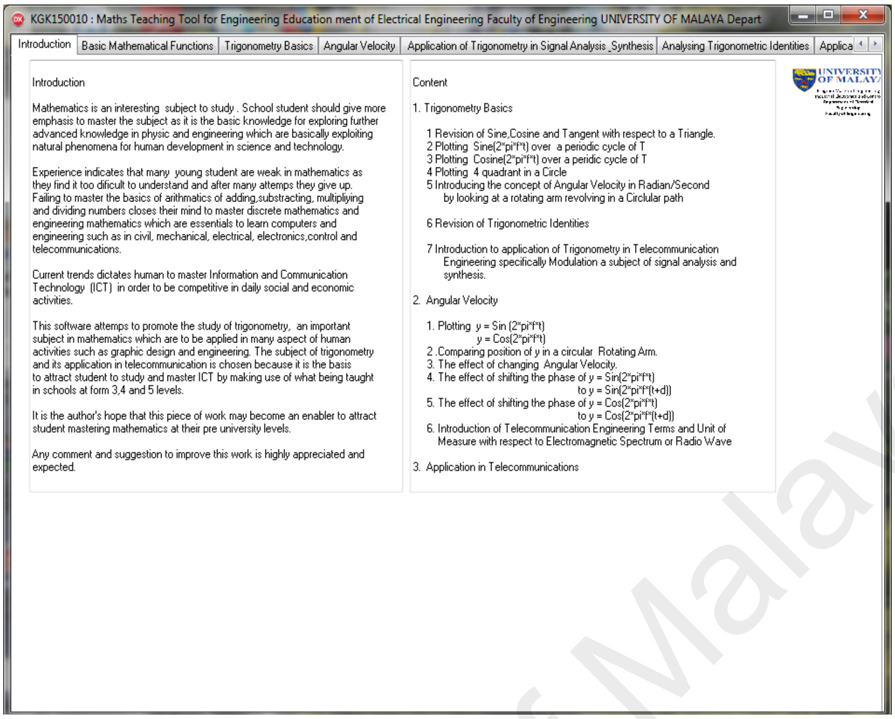

Figure 4.1 Introduction Page

4.4 Basic Math Functions Page.

This is the Basic math Function Page where all math functions are selected.

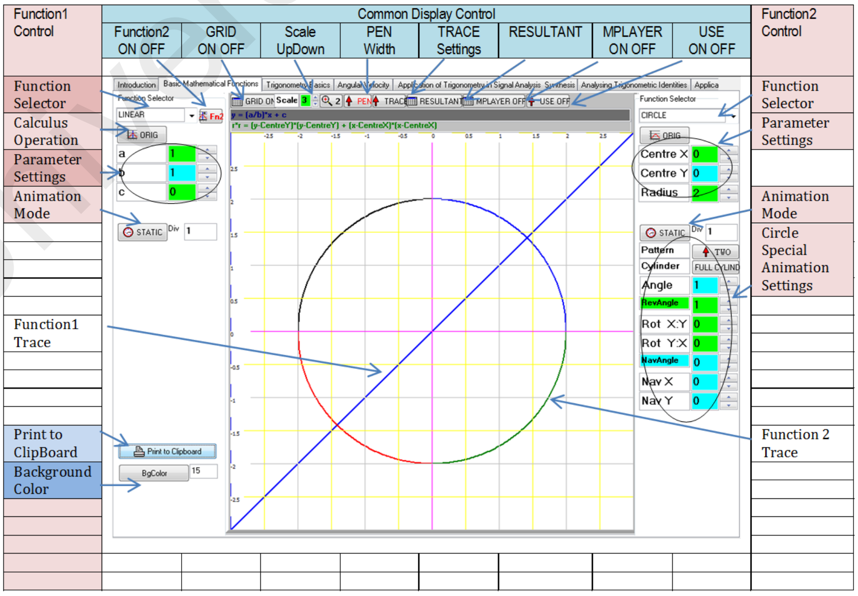

Figure 4.2 Two maths functions shown with all the control buttons

4.4.1 Output from Basic Math Functions.

The software gives a typical default page shown in Figure 4.2. In this case it shows 2 functions being displayed. Function 1 is the blue trace as pointed by the arrow marked as Function1 Trace. Function 2 Trace shown by the arrow on the right of the display pointing to a circle. Function 1 controls are on the left of the display and Function 2 controls are on the right of the display. On top of the display are all the common controls for the display. Brief description of the controls buttons and switches are shown in Table 4.2. The working details of the software are extensively explained in a user manual or self-learning guide document in the form of QUICK START TUTORIAL in Appendix C.

Table 4. 2 Math Function Controls and brief description on the functionalities

<table>
<tr><th>No</th><th>Control</th><th>Component Type</th><th>Description</th></tr>
<tr><td>A</td><td colspan="3">Math Function Controls</td></tr>
<tr><td>1</td><td>Function Selections</td><td>Combo Box</td><td>One Function Selection Button</td></tr>
<tr><td>2</td><td>Formula Parameters</td><td>UpDown</td><td>One Set of Formula Parameter Buttons</td></tr>
<tr><td>3</td><td>Calculus Operation</td><td>Switch</td><td>One Mathematical Calculus Operation which can be switched to any function mode either :
<table>
<tr><th>Options</th><th>Description</th></tr>
<tr><td>ORIG</td><td>Original Function</td></tr>
<tr><td>DIFF</td><td>Differentiate</td></tr>
<tr><td>INTG</td><td>Integrate over short period</td></tr>
<tr><td>INTP</td><td>Integrate over a Periodic Period</td></tr>
<tr><td>INTL</td><td>Integrate over a Long Period</td></tr>
</table>
for certain selected functions</td></tr>
<tr><td>B</td><td colspan="3">Common Control for Display Options</td></tr>
<tr><td></td><td>Fn2 ON OFF</td><td>Switch</td><td>For switching Function 2 ON OFF</td></tr>
<tr><td></td><td>GRID ON OFF</td><td>Switch</td><td>For switching ON OFF Display Grid</td></tr>
<tr><td></td><td>SCALE</td><td>Switch</td><td>For setting Display Screen Scales Options</td></tr>
<tr><td></td><td>PEN</td><td>Switch</td><td>For switching Graphic Pen Size (Thin/Thick)</td></tr>
<tr><td></td><td>TRACE</td><td>Switch</td><td>For ON/OFF traces of math functions or their derivatives/Integrals or results of math operation of MULTIPLY, DIVIDE, ADD, SUBSTRACT and also VECTOR of any two functions</td></tr>
<tr><td></td><td>RESULTANT</td><td>Switch</td><td>For switching math operations of MULTIPLY, DIVIDE, ADD and SUBSTRACT on Function1 and Function2</td></tr>
<tr><td></td><td>USE ON OFF</td><td>Switch</td><td>For switching ON OFF immediate usage of selected functions.</td></tr>
<tr><td></td><td>Printing to Clipboard</td><td>Switch</td><td>For printing the math functions on the Display and paste it to any Microsoft Words or PowerPoint document</td></tr>
<tr><td>C</td><td colspan="3">Animation Mode Control</td></tr>
<tr><td></td><td>Function Animation</td><td>Switch</td><td>
<table>
<tr><th>Options</th><th>Description</th></tr>
<tr><td>STATIC</td><td>Static Mode</td></tr>
<tr><td>GRAPHIC</td><td>Graphic Mode for all functions</td></tr>
<tr><td>MECHANIC</td><td>MECHANIC Mode for Circle only</td></tr>
</table>
</td></tr>
<tr><td>D</td><td colspan="3">Peak to Peak and True Value for Sinusoid</td></tr>
<tr><td></td><td>PEAK to PEAK</td><td>Switch</td><td>For switching the peak value of Sinusoid of either TRUE value or PEAK to PEAK value.</td></tr>
<tr><td>E</td><td colspan="3">CIRCLE Special Animation Controls</td></tr>
<tr><td></td><td>PATERN</td><td>Switch</td><td>For selection of circle graphic pattern options</td></tr>
<tr><td></td><td>CYLINDER</td><td>Switch</td><td>For selection of radius ratio size, FULL, HALF, QUARTER sizes</td></tr>
<tr><td></td><td>ANGLE</td><td>UpDown</td><td>For selection of angle displacement about the centre of circle and the horizontal 0 degree line.</td></tr>
<tr><td></td><td>SPEED</td><td>UpDown</td><td>For selection of speed of rotation value a multiplier to REV ANGLE</td></tr>
<tr><td></td><td>REV ANGLE</td><td>UpDown</td><td>For selection of unit rotation displacement angle.</td></tr>
<tr><td></td><td>ROT X Y</td><td>UpDown</td><td>For setting Rotation Angle around Y axis.</td></tr>
<tr><td></td><td>ROT Y X</td><td>UpDown</td><td>For setting Rotation Angle around X axis.</td></tr>
<tr><td></td><td>NAV ANGLE</td><td>UpDown</td><td>For setting Navigation Angle.</td></tr>
<tr><td></td><td>NAV X</td><td>UpDown</td><td>For setting Navigation Speed along X axis</td></tr>
<tr><td></td><td>NAV Y</td><td>UpDown</td><td>For setting Navigation Speed along Y axis.</td></tr>
</table>

Table 4. 3 List of math Functions available for selection.

No	Functions	Formula Employed	Y/N
1	AMCOS(2*pi*X)	'y = a*(1+ 0.005*a*Cos(2*pi*(0.1*b*x + 0.05*c)))*(Cos(2*pi*(b*x + 0.05*c))) + d'	y
2	CIRCLE	'r*r = (y-CentreY)*(y-CentreY) + (x-CentreX)*(x-CentreX)'	y
3	COS(X)/X	'y = a*Cos(x*b+c)/x + d'	y
4	COSINE(X)	'y = a*Cos(x*b+c) + d'	y
5	COSINE(2*pi*X)	'y = a*Cos(2*pi*(0.1*b*x + 0.05*c)) + d'	y
6	COSINE(2*pi*X)+	'y = a*Cos(2*pi*(0.5*b*x + 0.05*c))+ a*Cos(2*pi*(0.1*b*x + 0.05*c)) + d'	y
7	COSINE(2*pi*X)++`	'y = a*Sum[Cos(2*pi*(0.1*n*b*x + 0.05*c))] + d where n = 1,2,3,4,5 '	y
8	COSINE(2*pi*X*(B+C))	'y := a*Cos(2*pi*0.1*(b+c)*x + 0.01*c) + d'	y
9	COSINE(2*pi*X*(B-C))	'y := a*Cos(2*pi*0.1*(b-c)*x + 0.01*c) + d'	y
10	FMCOS(2*pi*X)	'y = a*Cos(2*pi*b*x+0.5*Cos(2*pi*0.1*b*x+0.05*c) + 0.05*c) + d'	y
11	FREQUENCYSWEEP	'y := a*Cos(2*pi*0.1*(b-c*0.5*n)*x) + d where n = 0 to 600'	y
12	HARMONICOSINE	'y = SUM[(0.5*a/b)*Cos(2*pi*(0.1*b*x + 0.05*c))] + d ; b = 1 to b'	y
13	HARMONICSINE	'y = SUM[(0.5*a/b)*Sin (2*pi*(0.1*b*x + 0.05*c))] + d ; b = 1 to b'	y
14	INVERSE1	'y = (1/(a*x)) + c'	y
15	INVERSE2	'y = (1/(a*x*x)) + c'	y
16	INVERSE3	'y = (1/(a*x*x*x)) + c'	y
17	LINEAR	'y = (a/b)*x + c'	y
18	Ln(x)	'y = (a/b)*Ln(c*x) + d'	y
19	POWER_FRC	'y = (a/b) power x + c'	y
20	POWER_INT	'y = (a/b) power x + c'	y
21	PRBS	'y = a*(127 bits PRBS) + d, clocked by Sin(2*pi*(2*b*x+0.5*c))'	y
22	PULSE	'y = Pulse Generated by a*Sin(2*pi*(0.1*b*x + 0.05*c)) + d'	y
23	QUADRATIC1	'y = (a/b)*x*x + c' (Second Order Polynomial)	y
24	QUADRATIC2	'y = a*x*x + b*x + c' (Second Order Polynomial)	y
25	CUBIC	'y = a*x*x*x + b*x*x + c*x + d' (Third Order Polynomial)	y
26	RAMP1	'y = Sq Fn of a*Sin(2*pi*(0.1*b*x + 0.05*c)) * LongIntegral of Sq Fn of Sin(2*pi*(0.1*b*x + 0.05*c))+ d'	N
27	RAMP2	'y = (a/b)*(round(x) mod c) + d'	N
28	RAMP3	'y = a*Cos(2*pi*(0.1*b*x+0.05*c)) * Sq Fn of Cos(2*pi*(0.1*b*x+0.05*(c+5))) + d'	N
29	RAMP4	'y = (a/b)*(x mod round(1/(0.2*c)) + d'	N
30	RAMP5	'y = SqFn of a*Sin(2*pi*(0.2*b*x+0.05*c))*Long Integral of SqFn of Cos(2*pi*(0.1*b*x+0.05*c)) + d'	N
31	SIN(X)/X	'y = a*Sin(x*b+c)/x + d'	y
32	SINE(X)	'y = a*Sin(x*b+c) + d'	y
33	SINE(2*pi*X)	'y = a*Sin(2*pi*(0.1*b*x + 0.05*c)) + d '	y
34	SINE(2*pi*X)+	'y = a*0.5*(127 bits PRBS) + a*Sin(1*pi*(2*b*x+0.5*c))+d'	y
35	SINE(2*pi*X*(B+C))	'y := a*Sin(2*pi*0.1*(b+c)*x + 0.01*c) + d’	y
36	SINE(2*pi*X*(B-C))	'y := a*Sin(2*pi*0.1*(b-c)*x + 0.01*c) + d'	y
37	TANGENT(X)	'y = a*Tan(x*b+c) + d'	y
38	TANGENT(2*pi*X)	'y = a*Tan(2*pi*(0.1*b*x + 0.05*c)) + d'	y

The following figures are a few samples of the output derived from the software. To illustrate the potential use of the basic math function in learning and teaching is explained here in solving simultaneous equations. The examples in solving for x and y at points of intersection(s) are explained here.

4.4.1.1 Solving 1 Linear and 1 Quadratic Equations

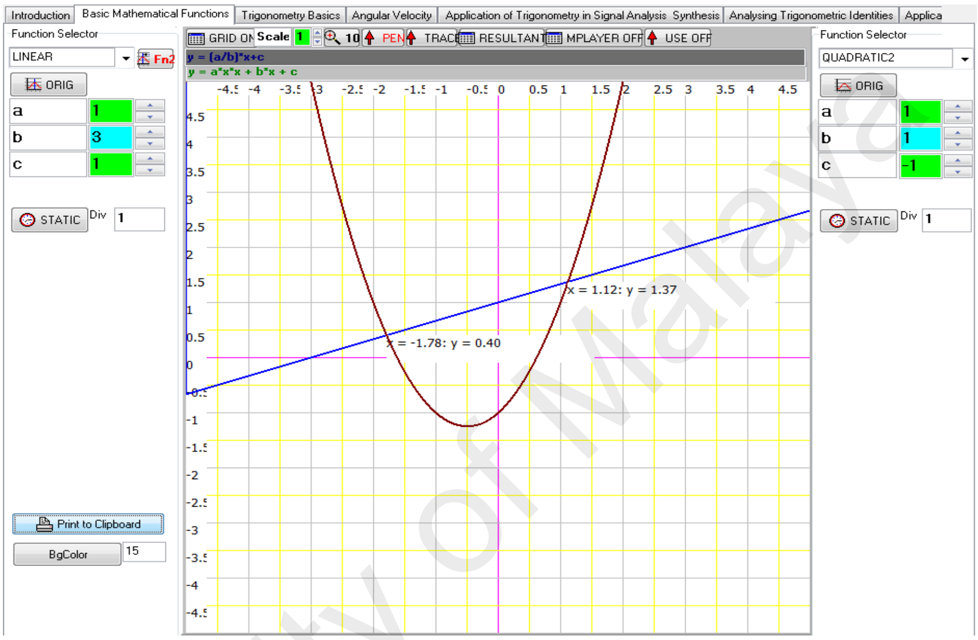

Figure 4.3 Quadratic and Linear Functions Intersection

Figure 4.3 shows Function 1, a linear function, as shown by the blue straight line and Function 2 is a quadratic as shown by the brown line. Function 1 controls show a = 1, b = 3 and c = 1, thus the linear function y = (a/b)x+c = (1/3)x+1, has the gradient of 1/3 which can be seen from the plot that for 1 section of y on y axis there are 3 sections of x on the x axis. The quadratic function has a = 1, b = 1 and c = -1, giving y=ax*x+bx+c = x*x+x-1. The points of intersection between the two functions show that they meet at point (x = -1.78, y = 0.04) and point (x = 1.12, y = 1.37).

If user need to solve the quadratic equation, a mouse click at the points where y=0 shall show the roots of the quadratic equation. As shown in Figure 4.4 and Figure 4.5, mouse click at y = 0 gives values of x = 0.62 and x =- 1.62 which are the roots of the quadratic equation. However mouse click may not be exact due to human error. This indicates that points of intersection at y = 0 should be programmed in the next phase of software development to provide another alternative of solving quadratic equations using this software beside using the normal manual method to seek for the answers which can be compared in term accuracy.

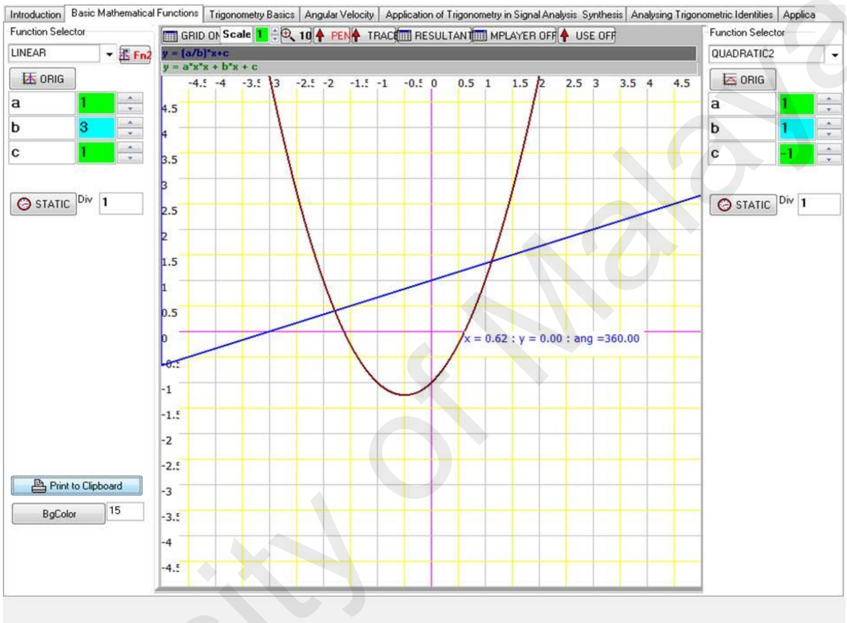

Figure 4.4 showing one root of the quadratic equation at x = 0.62

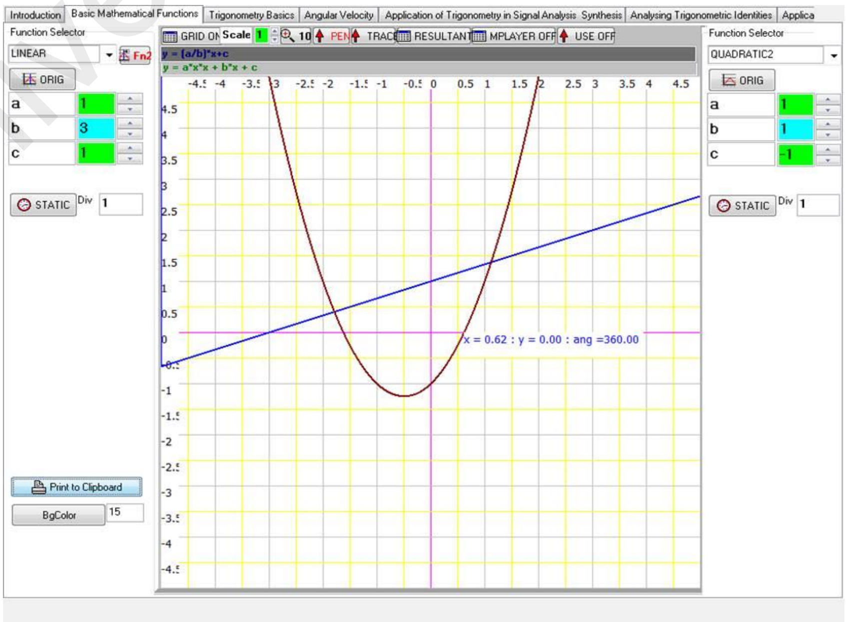

Figure 4.5 showing another root of the quadratic equation at x = -1.62

4.4.1.2 Solving 1 linear and 1 Circle Equations

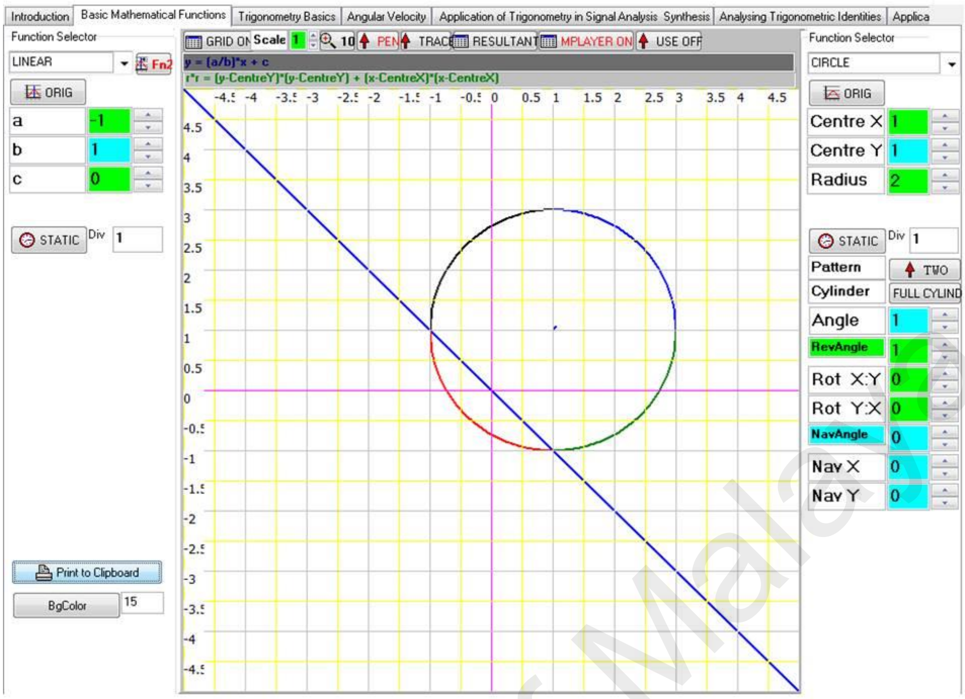

Figure 4.6 Linear and Circle functions shown with all the control buttons

1. Generate Function1 as y1 = (a/b)x + c = - x + 0

   where a = -1, b = 1 and c = 0.

2. Select Function 2 as Circle with radius 2 centered at 1,1.

   Thus a = 1, b = 1, c = 2.

3. Solve the equations by substituting linear equation into the circle equation (the normal substitution method).

   y = -x,

$$r^2 = (y - CenterY)^2 + (x - CentreX)^2, \quad where\ CentreY = 1, CentreX = 1$$

   The answers should be x = -1, y = 1 and x = 1, y = -1.

4. On checking the point of intersections on the plots, the same answers are given.

4.4.1.3 Differentiation and Integration of a Linear Function.

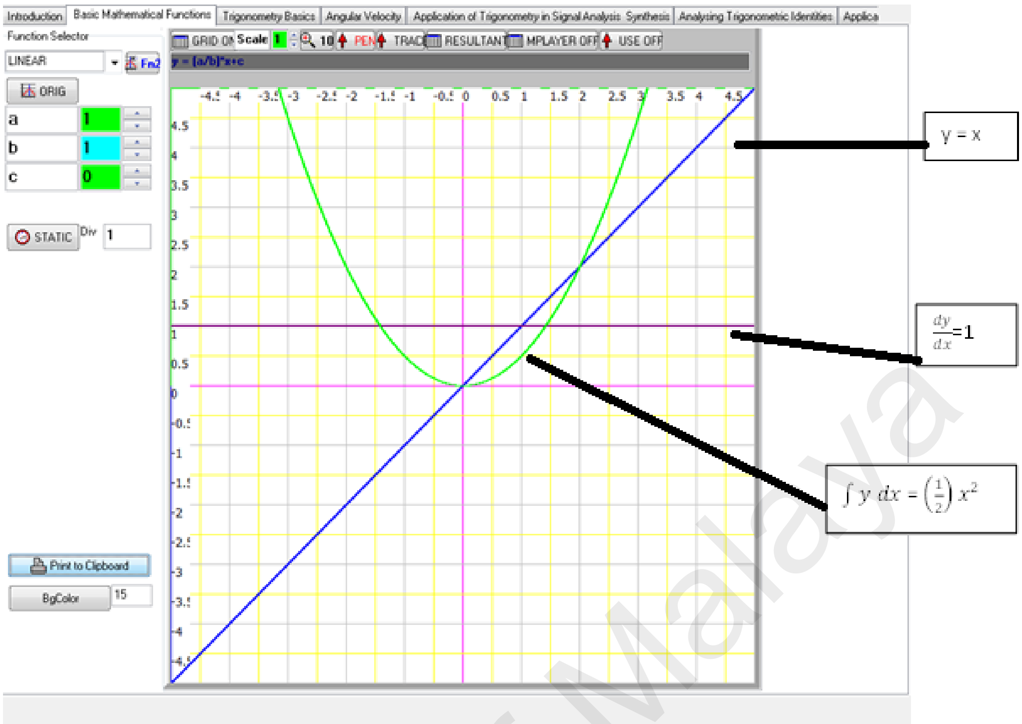

Figure 4.7 showing a linear function y = x, plotted with its derivative and integral.

4.4.1.4 Formation of Graphic by 2 Cosine(2piX) functions

This formation is obtained when two Cosine (2piX) functions are combined together to form a "COSINE (2piX) +" with the formula given as

y = a*Cos (2*pi*(0.5*b*x + 0.05*c)) + a*Cos (2*pi*(0.1*b*x + 0.05*c)) + d.

If this formula is plotted as Function 1 with

a = 5, b = 1, c = -5 and d = 0,

and for Function 2 with a = 5, b = 1, c = 0 and d = 0,

with scale set to 3 and 10 settings, the plot will look like Figure 4.8. The blue plot is Function 1 and the brown plot is Function 2 while the green plot is the vector of the two functions.

A vector plot is the plot of the values of Function 1 and Function 2 for the same values of x. The values for Function 1 takes the X axis and that of Function 2 takes the Y axis. So as x changes the vector plot shows the formation of locus of coordinates of Function1 and Function2 values. If a values for b for both functions are changed to b = 91 the plots shall be as at Figure 4.9. If plots for Function1 and Function2 are removed leaving the Vector plot alone, Figure 4.10 is shown with PEN size switched to 1. If the scale is changed more beautiful vector graphics can be derived.

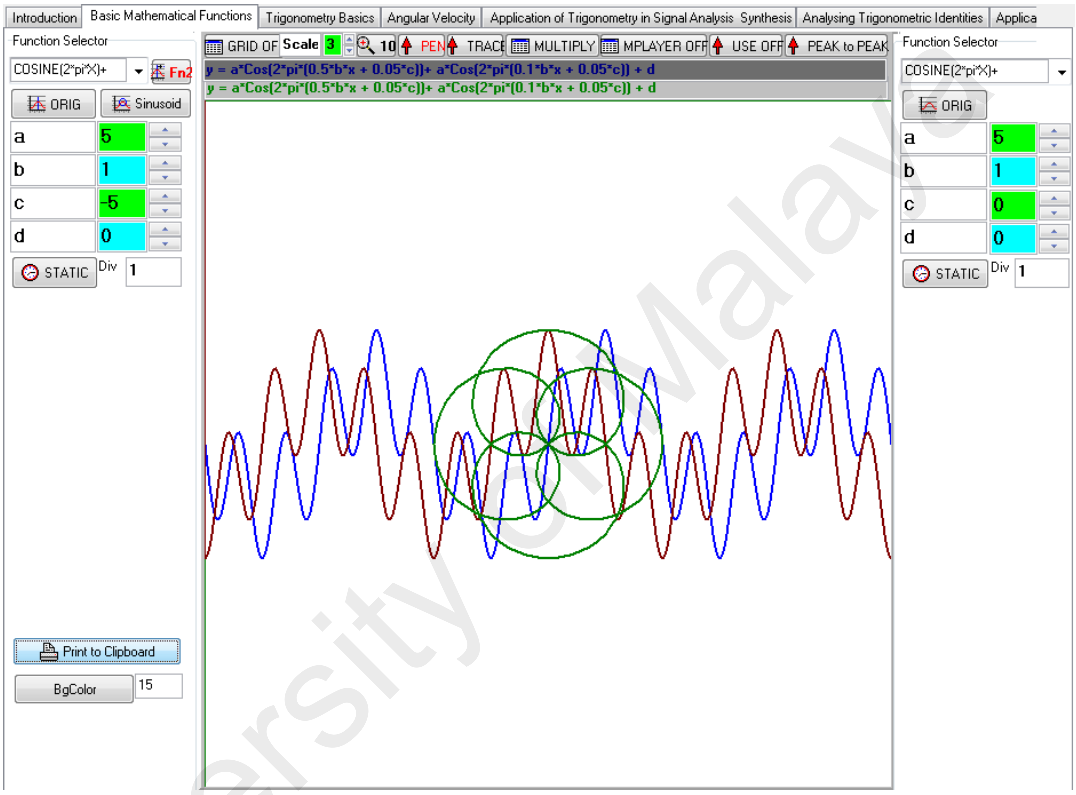

Figure 4.8 plot of 2 ‘COSINE(2piX)+’ functions showing when b = 1

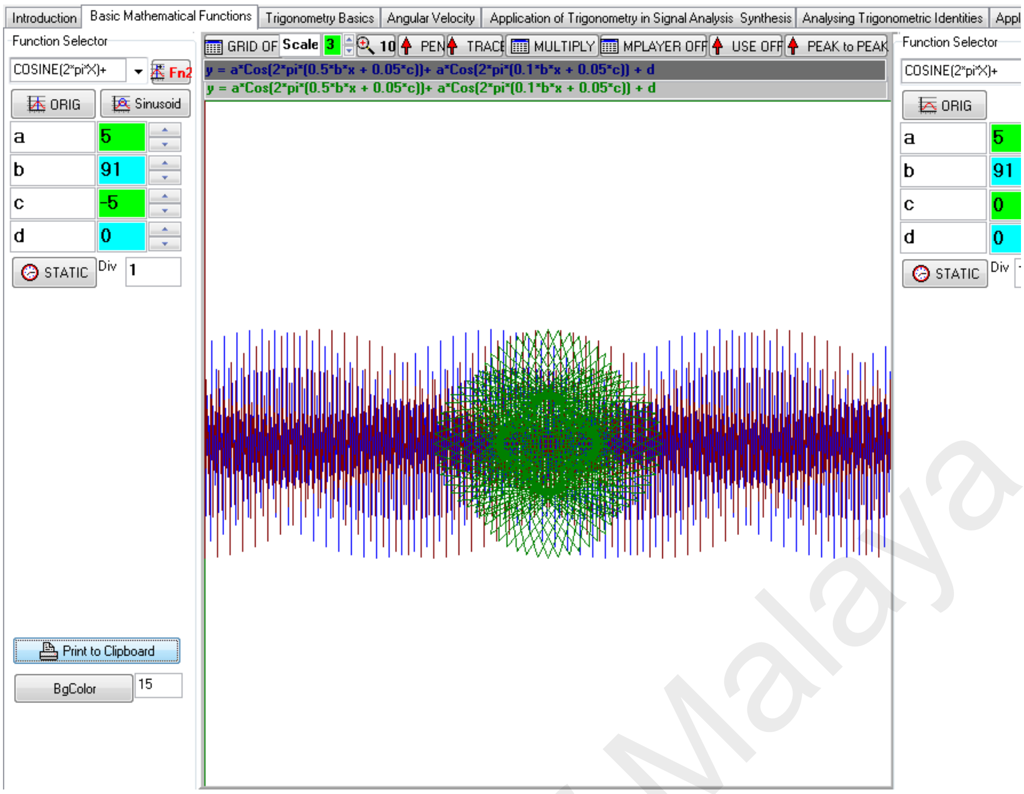

Figure 4.9 plot of 2 'COSINE(2piX)+' functions showing when b = 91

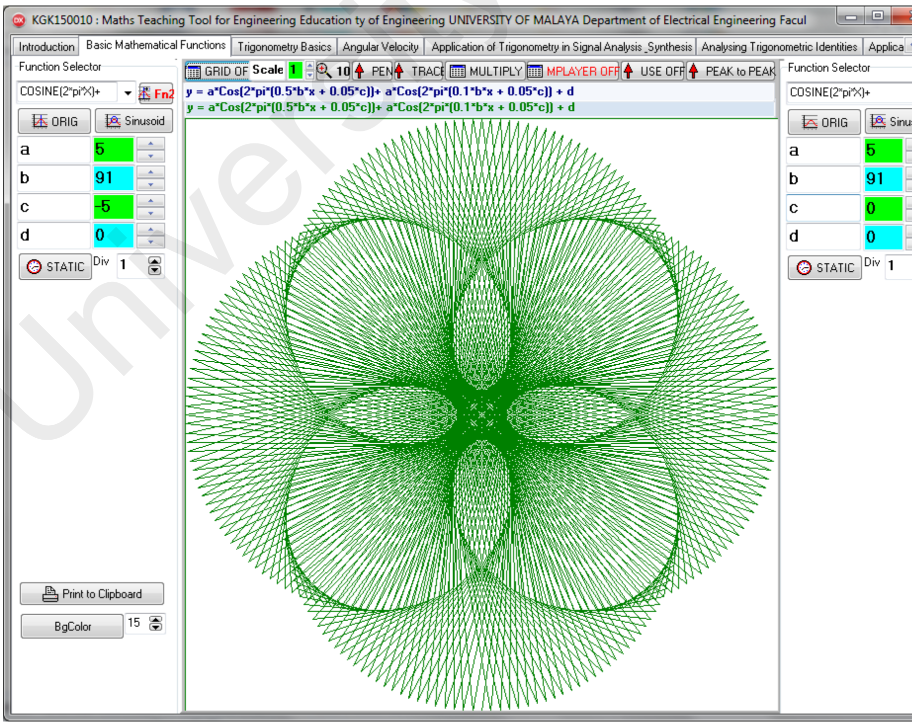

Figure 4.10 The locus of resultant vector of 2 'COSINE(2piX)+' functions forming beautiful graphic

4.4.1.5 Plots of 4 Stroke Mechanical Engines.

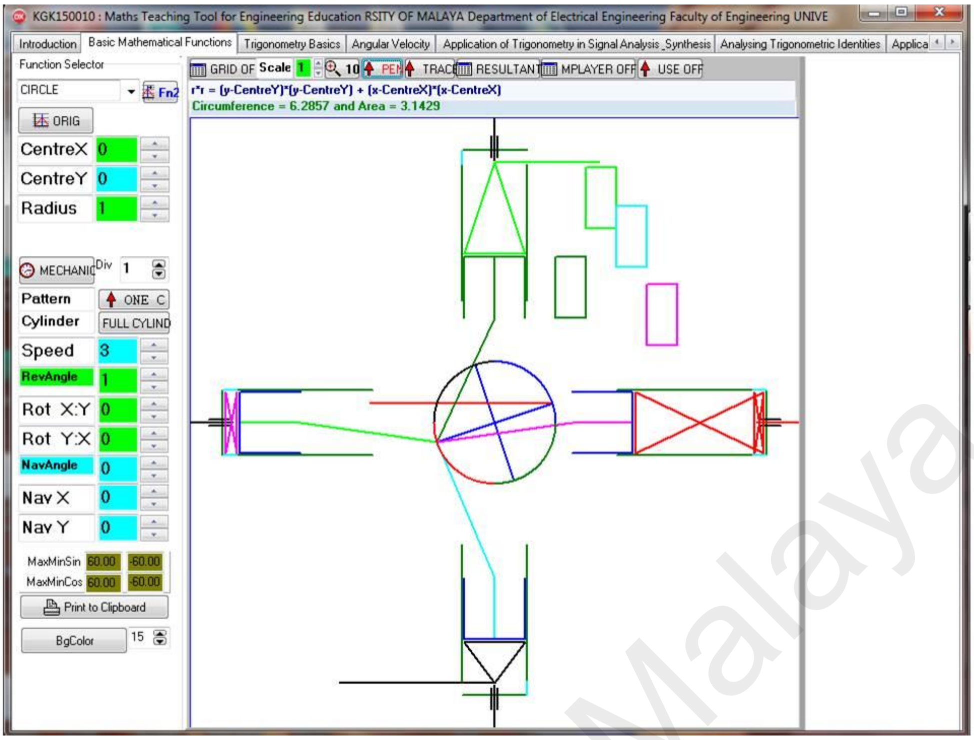

Figure 4.11 Animated Basic 4 Cylinder Straw (shaft and piston arms) Rubber Band (circle) Mechanical Engine

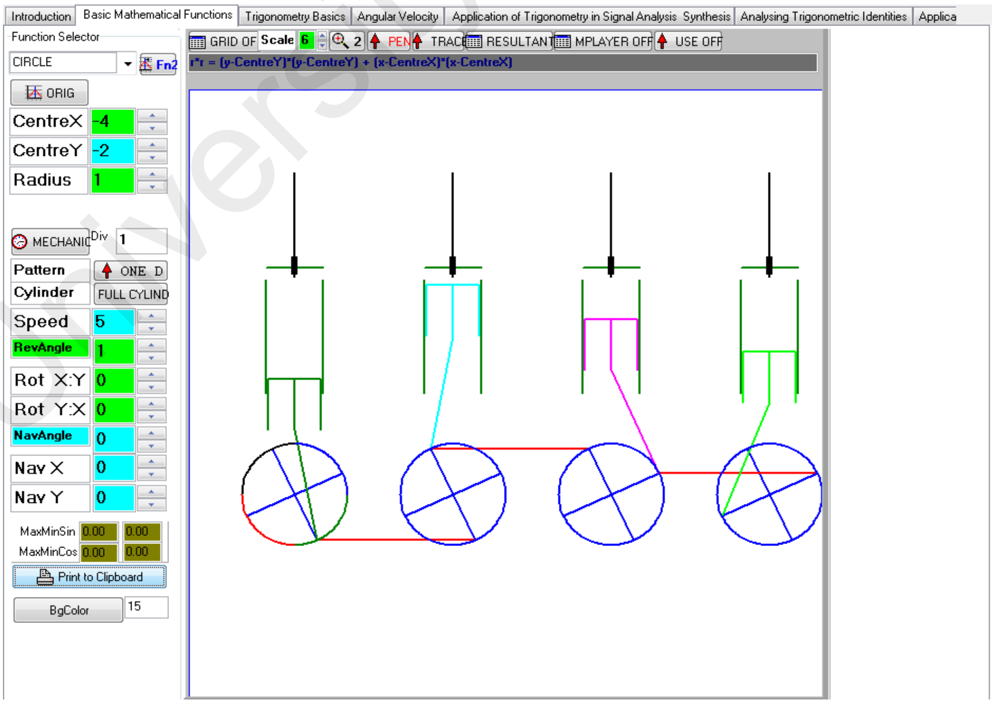

Figure 4.12 Animated Basic 4 Cylinder StrawRubberBand Mechanical Engine

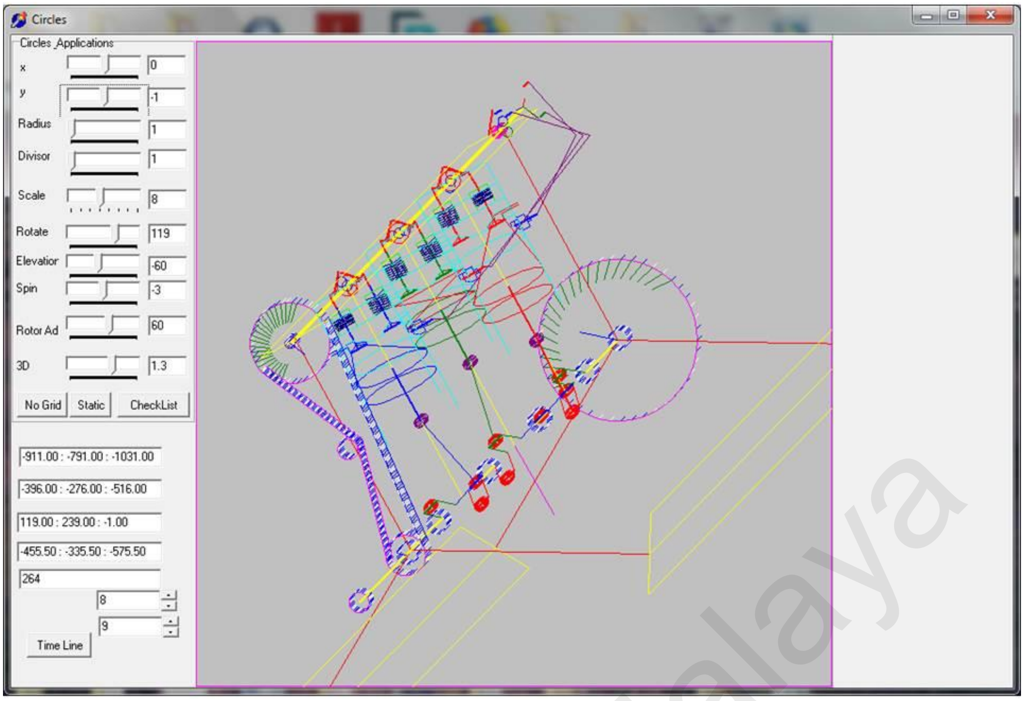

Figure 4.13 Animated Complex 3 Cylinder StrawRubber Band Mechanical Engine

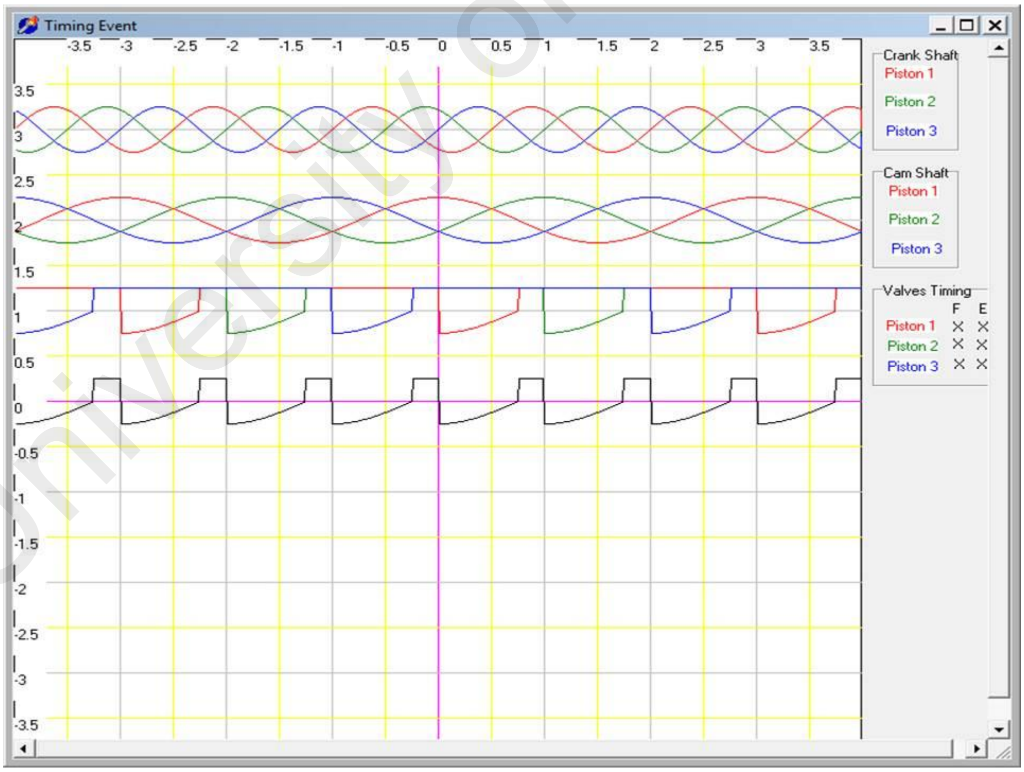

Figure 4.14 Event Timing of 3 Cylinder StrawRubberBand Complex Mechanical Engine

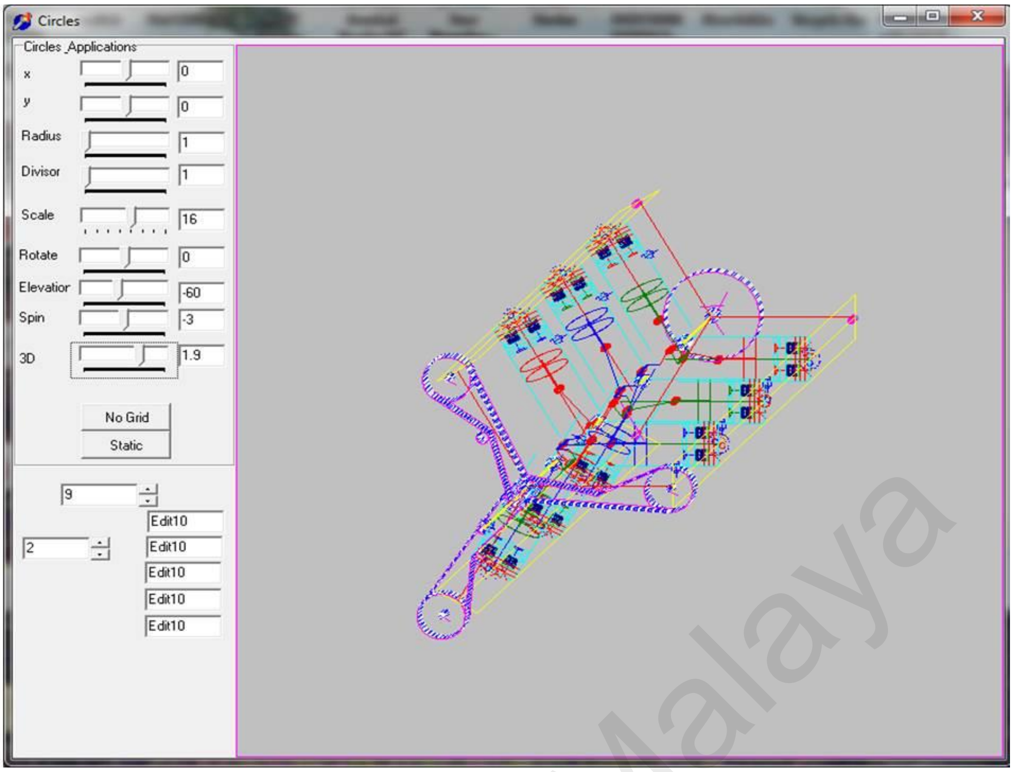

Figure 4.15: Animated Complex 9 Cylinder StrawRubberBand 3 Sector Mechanical Engine

Figures 4.11 and Figure 4.12 show animated simple StrawRubberBand 4 stroke engines that depict 4 pistons engine arrangement. Figure 4.13 shows animated a bit of complex StrawRubberBand 3 pistons 4 stroke engine with Figure 4.14 shows the timing events for each piston, valves and flywheel positions at every instance of 4 stroke cycle. Figure 4.15 shows a more complex 3 sectors 9 pistons 4 stroke engine working in harmony with the help of knowledge of circle, trigonometry and other applicable math in mechanical engineering. These examples show how circle and trigonometry are being used in a highly sophisticated mechanical engineering practice. With animation capability it may be an attraction for the student to explore mechanical in their future engineering study.

In order to code the software to demonstrate the 4 stroke engine cycles in this project as shown in Figures 4.11, 4.12, and 4.13 above, the author adopted the knowledge in mechanical engineering specifically on automotive technology by reading an excellent textbook with a title of Automotive Technology a Systems Approach 2nd Edition (Erjavec & Thompson, 1996). Chapter 6 of the book, starting from page 105 to page 108 provides an excellent treatment on engine classification and descriptions of 4 stroke gasoline engine cycles of intake, compression, power and exhaust strokes. In order to reduce engine rocking, as described in Chapter 6 page 113 and Chapter 21 page 506, cylinder firing order for 4 cylinder engines are recommended to be either 1-3-4-2 or 1-2-4-3. However in order to simplify the demonstration of dynamic of the 4 stroke engine cycles for a 4 cylinder engine, the software written for this research project is coded to show firing order of 1-2-3-4 for 4 cylinder engine and 1-2-3 firing order for 3 cylinder engine. Chapter 10 starting from page 223 explains typical Camshaft/Crankshaft and valves timings within the 4 stroke engine cycles.

4.5 Trigonometry Basics Page.

This page is a revision of Pythagoras Theorem and introduction to basic trigonometry relation of sine, cosine and tangent.

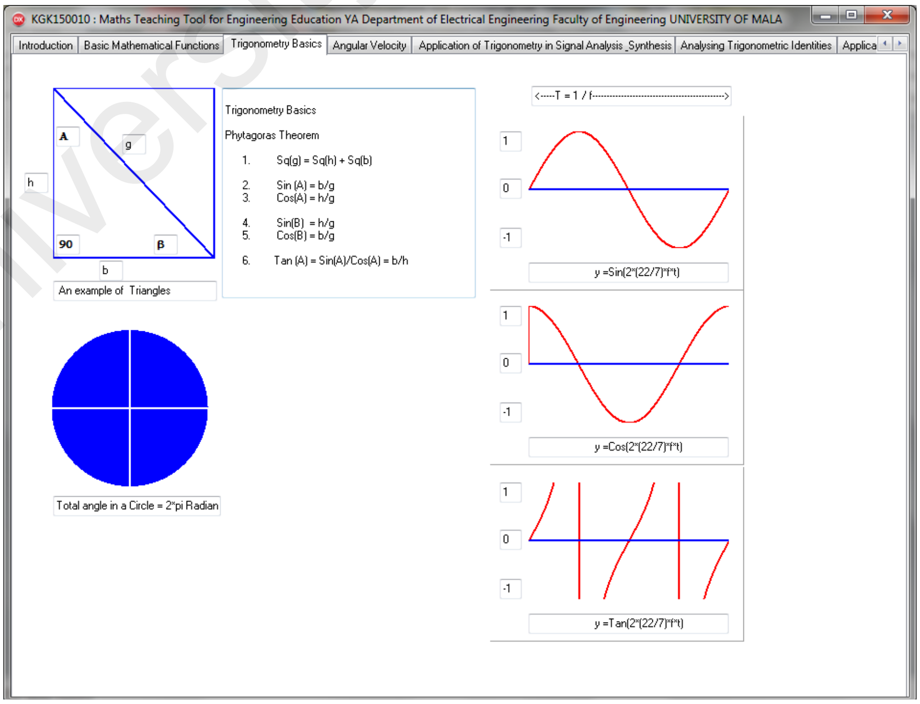

Figure 4.16 Trigonometry Basic

4.6 Angular Velocity Page

This page is an introduction to basic angular velociy and plot of sine, cosine and tangent in relation to two bars rotated with total anlge of 360 degrees.

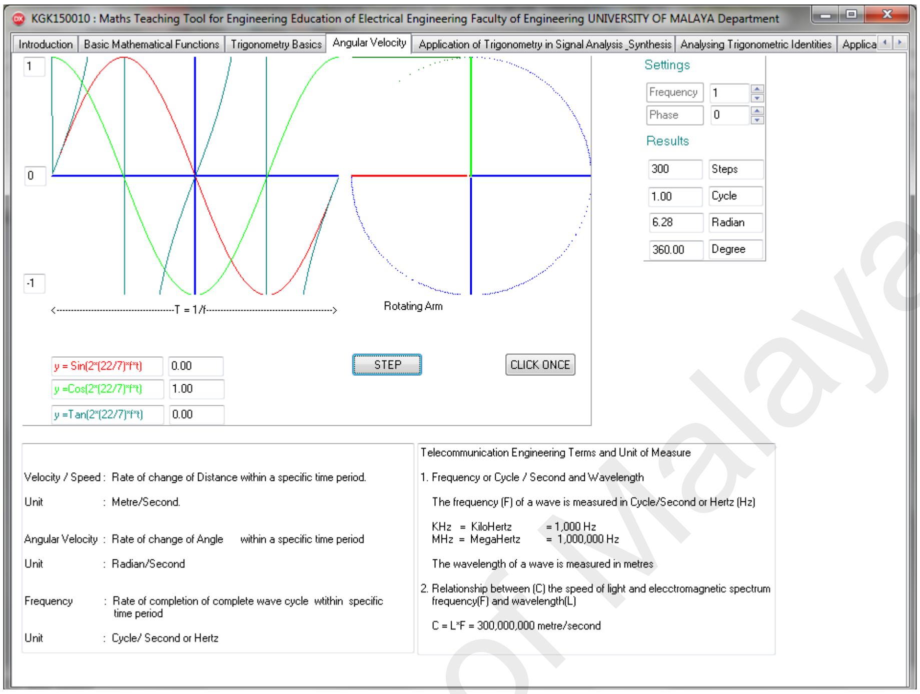

Figure 4.17 Angular Velocity

4.7 Introduction to Signal Analysis and Synthesis Page

This is an information page introducing signal analysis and synthesis on trigonometrical signal of sine and cosine.

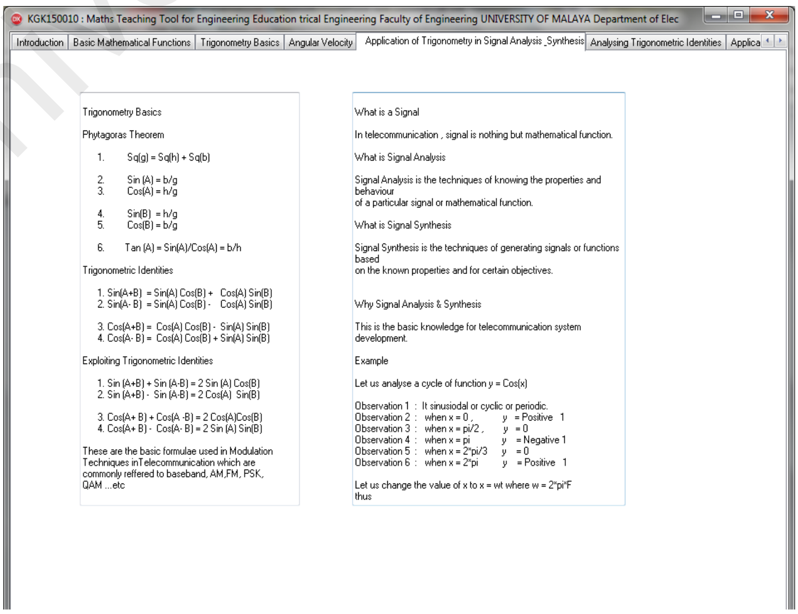

Figure 4.18 Signal Analysis and Synthesis

4.8 Analysing Trigonometric Identities Page

This page is an interactive page where trigonometric identities are inspected to see both functions at the top and bottom plots are equal at all instances.

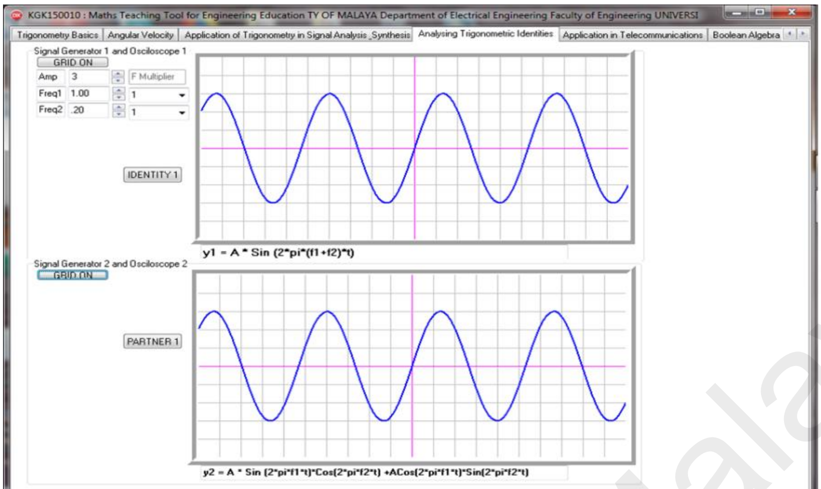

Figure 4.19 Trigonometric Identity

4.9 Application in Telecommunication Page

The following figures show typical instances of periodic pulse signal derived from trigonometric function is used in digital modulation techniques in telecommunications. This software now functions as Virtual Telecoms Mini Laboratoty. Analog modulated signal such as AM, DBSC, SSB and FM generation and detection can also be demonstrated with this telco minlab where the details operation is described in Appendix C.

To enable coding of the software for the modulation systems and techniques, the author made reference to two traditionally popular old textbooks on communication systems and electrical engineering respectively. Very detail materials on the subject can be referred to an excellent book published in 1971 (Taub & Schilling, 1971). A brief but sufficient treatment can be referred to another 1966 book (Morton, 1966).

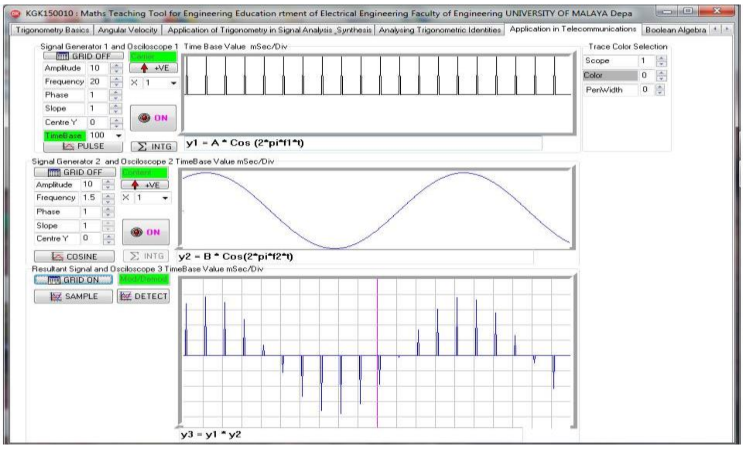

Figure 4.20 PCM signal sampling.

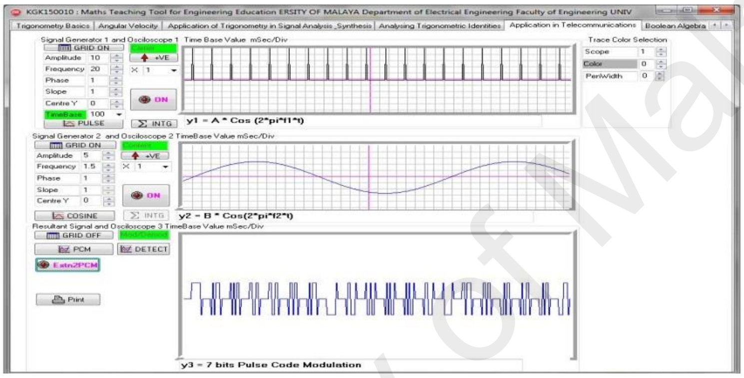

Figure 4.21 PCM signal Analog to Digital Conversion.

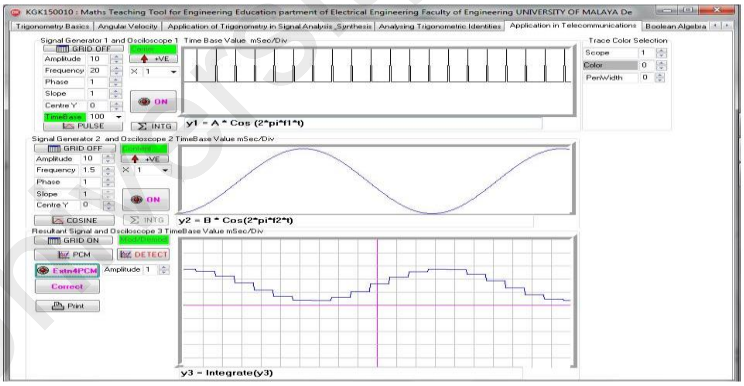

Figure 4.22 PCM signal Digial to Analog Conversion

Figures 4.20 shows how Pulse Code Modulation or PCM is done in telecommunications systems. It shows the telecoms laboratory where pulse signal is shown on top, sampling the baseband signal at the middle and giving pulses of different high corresponding to the levels of the original signal. Figures 4.21 shows how the analog pulses of various levels are converted to digital signal by using 7 bits binary codes with return to zero signaling. Figures 4.22 shows how the 7 bits digital binary signals are converted back to analog signal resembling the inverted original analog signal. The virtual mini lab is also capable to show how basic trigonometry identities are exploited in analog modulation communication systems. The lab also able to show example of Phase or FM Modulation where angle of the carrier signal is changed according to a modulating math functions or signals.

4.10 Boolean Algebra Page.

This page allows Truth Tables for basic logic functions of NOT, OR, AND, EX OR are tested with attractive game like background sound effects.

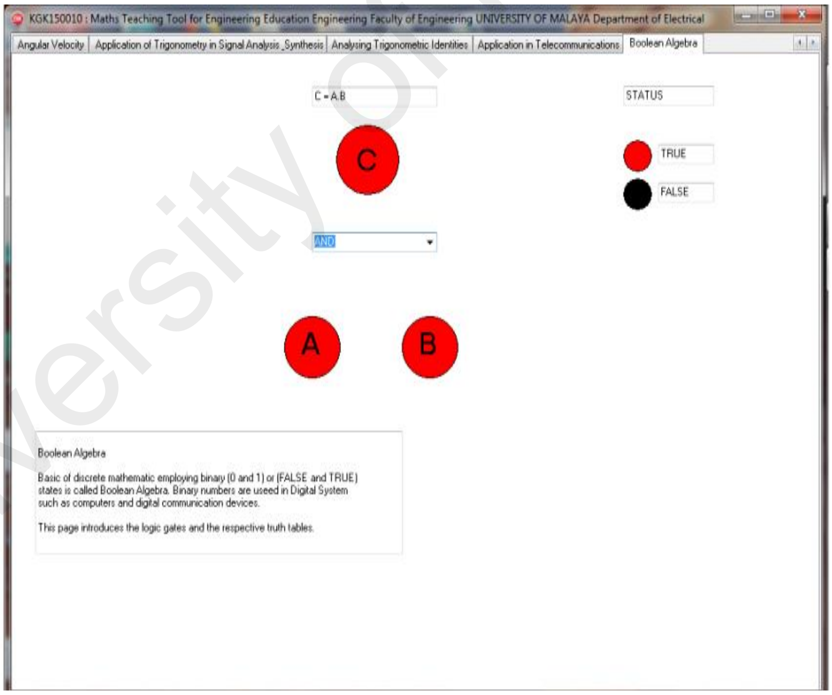

Figure 4.23 AND Gate practice page

4.11 Field Test

In order to gauge the acceptability and usability of the software among the secondary school students, two(2) workshops on using the software were carried out at one tuition center in Pekan Pahang and one Science Secondary School in Gua Musang Kelantan on 19th and 20th May 2019 respectively. The number of 15 students attended in Pekan consisting of 7 form 3, 2 form 4 and 6 form 5. Gua Musang session were attended by 18 form 3 students. Each student was equipped with a computer with the software installed and a handy user manual during the workshop session.

The workshop was initiated with a hands on session such as, launching the software, trying the control buttons for function selections and changing the functions parameters to see changes to graphical plots as an orientation. Subsequently once the students are familiar with the control buttons the workshop went on according to the programmed module and students feedback were obtained by filling up the survey forms with rangking scale of of 0-4 (0-**U**seless, 1-**P**oor, 2-**S**atisfactory, 3-**G**ood and 4-**E**xcellent). Students are asked to grade their experience of using the software through out the workshop session over 25 programmed topics. Appendix A compiles the survey data and results which are listed as follows;

Form A1 : Results of 25 Topics Evaluated by 33 Students.

Form A2 : Results of 15 Student Evaluation from Pusat Tuisyen Galaksi Ilmu.

Form A3 : Results of 18 Student Evaluation from Sekolah Menengah Sains Gua Musang.

Raw Survey Forms collected from 33 students.

4.12 Results and Analysis

The results of this work have produced a laboratory stage software that has been tested on the field. Table 4.4 gives test results summary.

Table 4.4 Field Test Results

Test Site	No of Student				Survey Results(Average)									
	F3	F4	F5	Tot	25 Topics Rating Distribution					Student Rating Distribution (derived from 25 Topics Voting)				
					U	P	S	G	E	U	P	S	G	E
PTGI	7	2	6	15	3.9	1.9	4.1	11.1	4.1	2.3	1.1	2.5	6.6	2.4
SMS GM	18	0	0	18	1.4	0.4	5.1	9.7	8.3	1.0	0.3	3.7	7	6
Total Students	25	2	6	33	2.5	1.1	4.7	10.3	6.4	3.3	1.4	6.2	13.6	8.4

F3 = Form F3, F4 = Form 4 and F5 =Form5

Looking at Table 4.4 the following observations can be recorded;

4.12.1 Sampling at Pusat Tuisyen Galaksi Ilmu (PTGI)

a) 25 Topics Ranking.

15 students of PTGI indicate that among the 25 topics covered with them, 4 (3.9) topics are **U**seless, 2 (1.9) are **P**oor, 4 (4.1) are **S**atisfactory, 11 (11.1) are **G**ood and 4 (4.1) are **E**xcellent.

b) 15 Votes Distribution.

On average the distribution of their votes to the software are as follows: 2 (2.3) students rated it as **U**seless, 1 (1.1) **P**oor, 3 (2.5) **S**atisfactory, 7 (6.6) **G**ood, and 2 (2.4) students gave it as **E**xcellent.

4.12.2 Sampling at Sekolah Menengah Sains Gua Musang (SMSGM)

a) 25 Topics Ranking

18 students of SMSGM indicated that out of 25 topics covered with them, 1 (1.4) topic is **U**seless, 0 (0.4) is **P**oor, 5 (5.1) are **S**atisfactory, 10 (9.7) are **G**ood and 8 (8.3) are **E**xcellent.

b) 18 Votes Distribution

On average the distribution of their votes to the software are as follows; 1 (1.0) student rated it as **U**seless, 0 (0.3) **P**oor, 4 (3.7) **S**atisfactory, 7 (7.0) **G**ood and 6 (6.0) students gave it as **E**xcellent.

4.12.3 Combining numbers of students from the two test sites

a) <u>25 Topics Ranking</u>

33 students indicated that among the 25 topics covered with them, 3 (2.5) topics are **U**seless, 1 (1.1) is **P**oor, 5 (4.7) are **S**atisfactory, 10 (10.3) are **G**ood and 6 (6.4) are **E**xcellent.

b) <u>33 Votes Distribution</u>

On average the distribution of their 33 votes to the software are as follows; 3 (3.3) students rated it as **U**seless, 1 (1.4) **P**oor, 6 (6.2.) **S**atisfactory, 14 (13.6) **G**ood and 8 (8.4) students gave it as **E**xcellent.

Table 4.5 Comparing Table 4.4 with students' specific voting on "Oveall Rating " item.

Test Site	Survey Results (Average)														
	25 Topics Rating Distribution					33 Student Rating Distribution (Derived from 25 Topics Voting)					33 Students Specific Votes On " Overall Rating"				
	U	P	S	G	E	U	P	S	G	E	U	P	S	G	E
PTGI	3.9	1.9	4.1	11.1	4.1	2.3	1.1	2.5	6.6	2.4	3	0	5	7	0
SMS GM	1.4	0.4	5.1	9.7	8.3	1.0	0.3	3.7	7	6	1	0	4	9	4
Total Votes	2.5	1.1	4.7	10.3	6.4	3.3	1.4	6.2	13.6	8.4	4	0	9	16	4

4.12.4 Comparing findings in paragraph 4.12.3(b) with students' specific individual vote on "Oveall Ranking" item.

Table 4.5 combines the findings elaborated in paragraph 4.12.3 (b) with what each student voted on the survey form on one item called "Overall Ranking". It is found that the rating distribution on "Overall Ranking" by 33 students are; 4 students rated as **U**seless, no or 0 student voted for **P**oor, 9 went to **S**atisfactory, 16 went to **G**ood and 4 students gave it as **E**xcellent. Averaging 33 "Overall Ranking" data with the corresponding data derived from 33 votes on 25 topics evaluated in the workshop, the averaged results are shown in Table 4.6. The average of 33 students ranking derived from the two sets of data now are 3.7 for **U**seless, 0.7 **P**oor, 7.6 **S**atisfactory, 14.8 **G**ood and 6.2 for **E**xcellent.

Beside looking at the averaged overall distribution of 33 votes for the software, Table 4.5 also exhibits data on the rankings of the 25 topics derived from the software. If we regroup these two sets of data into new groups of three as shown in Table 4.6, the following conclusion can be made. Firstly from the persepective of 25 topics about 16 (64 %) topics are graded as good to excellent and about 21 out of 33 students voted the software is between good to excellent. Thus from the persepectives of content and usage provided by the software, both are graded as 64% to be between good to excellent. The percentage ratios for the two perspectives of topics and usage are 16:20:64 and 12:24:64 respectively for Useless and Poor : Satisfactory : Good and Excellent.

Table 4.6 Averaged Overall Rating results with two evaluation perspectives of topics and usage by students.

Perspectives	**U**seless and **P**oor	**S**atisfactory	**G**ood to **E**xcellent
Out of 25 Topics	4 (16%)	5 (20%)	16 (64%) Note*
Out of 33 Students	4 (12.%)	8 (24.%)	21 (64%)

Note* 16.7 is rounded to 16 to keep 4+5+16 = 25

4.12.5 Students' Positive and Negative comments.

Rating No 8 on the survey form asks 2 last questions. Firstly is about student's posibility of attending the workshop again and secondly the possibility of recommending to their friends to attend. Answers are tabulated in Form A4 in Appendix A. Table 4.7 summarises the findings to those questions.

Table 4.7 Summary of answers to two questions for RATING NO 8

Do you wish to attend this kind of workshop again ?		Would recommend your colleagues to attend this workshop ?	
Answers	Comments	Answers	Comments
Y (Yes)	+Ve Comment	Y(Yes)	+Ve Comment
26	15	21	14
N (No)	-Ve Comment	N (No)	-Ve Comment
7	4	12	0
	No Comment		No Comment
	14		19

Data in Table 4.7 clearly indicate that, 26 show interest to attend the workshop again while the remainder 7 are not interested. Comments data to this question shows that 15 of are positive while 4 are negative and 14 offered no comment. While attending to the second question, 21 students are willing to recommend to their friends to attend the workshop but the other 12 are not keen to do that. There are 14 positive, 0 negative and 19 gave no comment. Averaging the answer data gives the results in Table 4.8.

Table 4.8 Averaging RATING NO 8 data Note*

Q 1		Q 2		Average of (Q1+Q2)
Answers	Comments	Answers	Comments	Answer
Y (Yes)	+Ve Comment	Y(Yes)	+Ve Comment	Y(Yes)
26	15	21	14	23.5(71.2%)
N (No)	-Ve Comment	N (No)	-Ve Comment	N (No)-
7	4	12	0	9.5(28.8%)
	No Comment		No Comment	
	14		19	

Note* Only answers are averaged and comments are left intact.

Based on the results shown in Table 4.8, about 23 (70%) students out of 33 are keen to follow the workshop again and willing to suggest to their friends to participate as well, while 10 of them are not interested to join again and will not encourage their friends.

Table 4.9 lists parts of the comments picked up from Table A4 in Appendix A.

Table 4.9 Samples of Positive and Negative Comments recorded by students.

No	Positive Comments	Negative Comments
1	*"Its not boring bcos interactive"*	*"I am not interest with this field"*
2	*"Its exciting"*	*"I don't understand about this, not my level"*
3	*"Interesting and Challenging"*	*"much don't study with KGK150010MTEE"* **note***
4	*"because I learn new things that are not in textbook "*	*"I don't understand"*
5	*"Like Boolean Algebra"*	

note* KGK150010MTEE is the name given to the software by the author. Please refer to User Guide in Appendix C

CHAPTER 5: CONCLUSION AND RECOMMENDATION

A laboratory stage interactive math teaching tool for engineering education software is developed with the capacity to offer more than 25 basics math functions. Some parts of the software has undergone field tests carried out by two interactive math for engineering workshops at a tuition center and a science secondary school with total participation of 33 students from forms 3, 4 and 5. The objectives of the test is to evaluate the ability of the software to attract students studying mathematics interactively by doing hands on reviewing and exercises on functions known to them as well as introduction of certain functions that are not known to them but with immediate use in daily life to inculcate interest in studying mathematics and engineering. Test results indicated that out of 33 students participated in the workshop, 21 (64 %) of them rated the software as good to excellent, 8 (24%) graded it to be satisfactory and 4 (12%) indicated that it is useless. Correspondingly, out of 25 topics covered with the students, 16 (64%) are good to excellent, 5 (20%) are graded as satisfactory and lastly 4 (16%) falls under the category of useless and poor.

Immediate examples of showing secondary math applications of circle and trigonometry in major parts of 4 stroke external combustion engine cycle has been demonstrated with animation capability via simple StrawRubberBand engine and a bit complex 3 piston 4 stroke external combustion engine.

In addition to its application in mechanical engineering, trigonometry also demonstrates how it is applied in telecommunications system with a set of mini virtual laboratory equipment having signal generators, oscilloscopes and vector scope. This mini lab can be a handy tool to students studying basic modulation system in telecommunication engineering to have a feel on their laptop what DBSC, SSB, AM, FM and PCM are all about without having to go to actual lab.

With the demonstration it is hope that the students who are exposed to this software will realize that circle and trigonometry is just not about finding area, circumference and angles but also almost everywhere in the dynamic of engineering.

It is an interesting piece of work as interactive software itself is recursive in nature. This is evident by the fact that the author aims at producing only up to 25 basic math functions in the planning stage. However as the software shows capability of exploring to generate other math functions by employing mathematical operation of addition, subtraction, multiplication and division it offers more functions to be created by reusing that modules that were gradually developed.

Another important findings of the work is beautiful graphics are able to be generated especially when two sinusoidal functions are put together and tested. Beauties of math like fractals are easily generated with this basic math teaching tool.

Hopefully this bit peace of work should be able to kill the paranoid about math among school children and at the same time can use it to explore math for engineering education. It would be inspirational to the author to have an opportunity to test the software with students who are obscured to the truth of mathematics.

There a few suggestion for future works. It would be a remarkable contribution to the math illiterate society if an attractive, easy to use, not taxing to remember the sophisticated formula for them to study math, is made available for them to download freely as readily available open source math software. Since this software is already available and to certain extend usable, it would be interesting to improve it so that the faculty has a math product to be offered to students and teachers who want to have an alternative math teaching tool for them to use not only for teaching and learning but also exploring for engineering education..

Future postgraduate students who are willing to explore this project for improvement can opt to develop further the virtual laboratory part to enable laptop computer be used as real test equipment when doing electronic and communication fieldwork.

The software developed out of this research work is of no basis to compare with established product like GeoGebra and Geometer SketchPad but this work can be treated as a basic building block for further enhancement.

Lastly it would be fair to note that this research project to certain extend has arrived at its two objectives of developing an interactive math teaching tool in the form of software for engineering education with immediate examples of engineering application. The intention of inculcating students' interest to maths for engineering education is also met as more than 60% as graded by the students after going through the workshop. The tool also is equipped to demonstrate examples of applications of basic math studied at secondary levels, not only hidden in mechanical and telecommunications engineering but everywhere within the area of engineering.

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