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The Use of Graphics Calculator in a Matriculation Statistics Classroom: A Malaysian Perspective

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Authors
Krishnan, Saras
Idris, Noraini

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1. INTRODUCTION

Use of technologies in mathematics classrooms triggered a paradigm shift in statistics classrooms from giving importance to routine computations and procedural knowledge to the development of students' conceptual knowledge. The global advances in technologies created more opportunities to change the pedagogy, the methods and the materials used in teaching mathematical subjects (Rowell, 2004). Students need not trouble themselves with tedious and often repetitive calculations that may diminish their joy for learning mathematics. Instead, integrating technologies into the teaching and learning of mathematics enables students to direct their attention to other aspects of mathematics learning such as exploration, decision making, reflection, reasoning and problem solving (Idris, 2004). Although rapid technological development has greatly influenced the pedagogy of mathematics, Collins and Mittag (2005) opine that there has been little research resulting in few publications on the usage of graphics calculators in statistics classrooms. We also find that most publications highlight the advantages of using the graphics calculator in the teaching of mathematics and statistics but do not elaborate on the problems faced by the teachers and students when this technology is introduced. To achieve successful teaching and learning of statistics using technology, we must also consider both the advantages and the difficulties encountered and find ways for continual improvement.

In view of that, in this paper we communicate the challenges faced by teachers using graphics calculator in teaching statistics in Malaysian. The students in this study are in an external matriculation program in a private higher learning institution in Malaysia. Although the use of graphics calculator in the teaching and learning of mathematics in Malaysia is not made compulsory yet, educators and researchers have been showing increasing interest in investigating the use of graphics calculator in teaching various topics in mathematics and statistics. Studies involving pre-university and tertiary students are scarce, probably because the use of any technological tools in their learning, other than the scientific calculator, is governed by the requirements of the courses the students undertake. In this paper, we share our experiences and observations from conducting statistics lessons with the aid of a graphics calculator. It is hoped that the reflections shared will give some insights to other teachers of statistics to reflect on their own classroom teaching and find strategies to incorporate the use of graphics calculator more effectively. We also hope to receive ideas and suggestions from teachers in the more developed countries on ways to better integrate graphics calculator into classroom teaching in a developing country such as Malaysia.

2. GRAPHICS CALCULATOR IN MALAYSIAN EDUCATION SCENARIO

The rapid advancement of technology in the developed countries and the increasing availability to access these technologies in the developing countries had positive consequences on the use of technology as a teaching and learning tool in statistics classrooms. The use of hand-held technologies, most commonly the graphics calculators has gained ubiquitous acknowledgement as a powerful pedagogical tool to promote better learning among students (Tajudin, Tarmizi, Ali & Konting, 2011). Graphics calculators are equipped with functions to plot graphs, give numerical solutions to equations, and perform statistical calculations, operations on matrices and more advanced mathematical functions such as algebra, geometry and advanced statistics (Kor & Lim, 2004). The graphics calculator empowers students in solving mathematical problems by actively engaging them in doing the mathematics (Idris, Nor, Chew, Lim & White, 2010). Students form better understanding of the mathematics involved and are motivated to confront more complex problems (Idris, Tay, Goh, Mahfud, Ding, Aris & Bakar, 2003). According to Idris (2004), the use of graphics calculators improves spatial visualization skills, critical thinking ability and understanding of connections among graphical, tabular, numerical and algebraic representations.

In Malaysia, the use of graphics calculators is still at the initial stage compared to the developed nations (Idris, 2004). Graphics calculators were first introduced at secondary schools in year 2003 when the Ministry of Education together with Texas Instruments, a U.S. calculator manufacturing company, provided training to 500 mathematics and science teachers from 250 schools nationwide on the usage of the TI-83 Plus graphing calculator. Between 2004 and 2007 another 120 secondary schools in Malaysia were equipped with the TI-84 Plus model graphing calculator. Starting in 2006, examples involving the use of graphics calculators have been included in the Grade 11 Mathematics and Additional Mathematics textbooks (Idris & Chew, 2011). More importantly, Malaysian Integrated Curriculum for Secondary Schools Mathematics places a lot of emphasis on the use of technology in the teaching and learning of mathematics. Although the secondary school level public examinations allow the use of scientific calculators, the use of graphics calculators on these exams is not allowed. This may be a factor that contributes to the reluctance of those who make decisions within the Malaysian educational system to incorporate and increase the use of graphics calculators in the mathematics classrooms at school levels. Thus far, however, the use of graphics calculators in the mathematics and statistics classrooms in Malaysia has been well received and successful as shown by past studies.

A study conducted by Idris et al. (2003) investigated school teachers' perceptions on the use of graphics calculator. The study involved 11 teachers and 712 students from both rural and urban schools in various states in West Malaysia. The teachers were given four days of training on the usage of TI-83 Plus graphics calculator including the use of the TI-83 Plus to plot graphs, manipulate symbolic expressions, and perform matrix calculations. Four aspects of the teachers' perceptions of the use of graphics calculators were investigated: mathematics content, the students' behavior, the teachers' personal attitude towards graphics calculator and the usefulness of TI-83 Plus in the mathematics classrooms. One of the two mathematics content areas involved in this study was statistics. It was found that the teachers responded positively towards the use of graphics calculators in their teaching of statistics. The study reported that more than 90% of the

teachers found it was easier to teach statistics with the graphics calculator whereas 73% said it was easier to get the students' attention and co-operation in the classroom lessons.

Idris (2004) investigated the use of TI-83 Plus graphics calculator as a tool to improve students' achievement and to develop their self-confidence. This study involved both the quantitative and qualitative data collected from Grade 11 students from two secondary schools in Malaysia. She found that students in the experimental group who learned mathematics using the graphics calculator for five weeks showed significantly greater improvement on their mathematics achievement than students in the control group who learned mathematics without the calculators. More importantly, a high percentage of the students from the experimental group affirmed that they enjoyed mathematics more and that they were able to better perceive the relationships between the mathematical concepts. The results of this investigation agree with earlier researchers in Malaysia (Idris et al., 2003) who found that graphics calculators aid students' visualization of mathematical concepts and improve students' problem solving skills.

Kor and Lim (2003, 2004) explored students' views on the use of graphics calculators in the learning of statistics and the impact graphics calculators had on their understanding of statistics. In particular, they wanted to find out if any relationship existed between students' attitudes and confidence level, and their learning of statistics when the graphics calculator is used as an intervention. Students were found to have an improved understanding of statistics, possibly because the graphics calculator helped the students to visualize the statistical concepts and to explore and experiment with different values in learning various statistical concepts. The students indirectly built their confidence when they found the lessons more exciting and enjoyable, and their negative perceptions about statistics changed. In contrast, among the difficulties conveyed by the students are that they found the instructions for using the graphics calculator complicated. Therefore, some of the students still preferred the paper-and-pencil method of performing their statistical calculations. However, the researchers concluded that the advantages of using the graphics calculator as a teaching tool to promote conceptual understanding outweigh its disadvantages.

Kamaruddin and Amin's (2007) study concerned the teachers' feedback on the use of graphics calculator in the teaching and learning of mathematics. The research sample consisted of teachers from the secondary and primary schools who participated in a graphics calculator course conducted by one of the universities in Malaysia. Research findings showed that the teachers had a high level of acceptance of the usage of the graphics calculator and that the school management provided the teachers with information and encouragement they needed to implement teaching with graphics calculators. They also showed, however, that limitations in teachers' skill and knowledge and low levels of confidence were a hindrance to using the graphics calculator in class. In view of these findings, the researcher feels that it is important to provide training for the teachers and to monitor the implementation process. The study by Nordin, Zakaria, Mohamed and Embi (2010) involved secondary school teachers' opinions on the pedagogical usability of the Geometer's Sketchpad (GSP) in the teaching of mathematics. This study provided positive feedback and found benefits of using this tool in the teaching and learning of mathematics but did not explore in depth the teachers' perception and the difficulties in incorporating this tool in their teaching.

According to Stacey (2004), the main objective in incorporating technology into mathematics and statistics classrooms is to increase students' understanding of

mathematical concepts and their abilities to deal with more realistic problems. On the whole, research has shown that the use of graphics calculator in mathematics and statistics classrooms in Malaysia has many benefits such as improving students' performance (e.g., Idris, 2004; Tajudin et al., 2011) and helping students to develop more positive attitudes towards the learning of mathematics and statistics (e.g., Kor & Lim, 2004). However, a major drawback is that students may neglect the basic and underlying mathematical concepts by being too dependent on the graphics calculator in their problem solving (Haili, 2004). Moreover, for a developing country such as Malaysia, the availability of the technological tools and the accessibility to the teaching resources are some of the challenges faced particularly in the more remote areas. In addition, the teachers may not be skilled enough to be able to transform their way of teaching.

In the context of Malaysian education system, although the use of graphics calculator is at the initial stage, at present 500 out of 1500 secondary schools in the country have already adopted use of graphics calculator in their classrooms. Following the revision of the Malaysian secondary school curriculum to include the use of graphics calculator in the mathematics and statistics classrooms, the Ministry of Education (MOE), and particularly the Curriculum Division Centre, provides extensive training to mathematics and statistics teachers by working together with Texas Instruments and the computer analytics company, Statworks (http://www.statwks.com/index.php). They also organize an annual conference on graphics calculators during which selected school teachers are given opportunity to attend trainings in Australia. Also, the Ministry of Higher Education (MOHE) makes available research grants to universities in the country to carry out research on designing instructional activities using the graphics calculators. Moreover, most public universities in Malaysia offer elective courses on the use of technology in mathematics and statistics for teachers and postgraduate students. Finally, statistics instructors in private universities and colleges are exposed to using the graphics calculator when teaching external programs such as the one mentioned in the next section.

3. THE USE OF GRAPHICS CALCUALTOR IN A MATRICULATION STATISTICS CLASSROOM

Figure 1 shows the structure of the Malaysian education system from the primary school level to the higher education level (International Bureau of Education, 2012). The primary education is for a period of six years followed by the secondary education for a period of five years. The primary education is mandatory for all children, but the secondary education is not. The secondary education is divided into three years of lower secondary and two years of upper secondary. A common public examination is held at the end of the primary, lower secondary and upper secondary education levels. After that, the students either continue for another two years in the schools or proceed to pre-university programs, in either public or private higher learning institutions. Those students who did not obtain their primary education at a national language school must take an additional year prior to the first year in the lower secondary education. These are known as remove classes as depicted in Figure 1. The post school academic progression follows three paths, classified as technical, academic and vocational. The matriculation program discussed here is in the higher education academic category. The government in Malaysia provides 60% of the tertiary-level education and the private sector provides the remaining 40%

(eTawau, 2012). It is evident then that the private education in Malaysia has a substantial importance in propelling the direction of Malaysian education.

At present, there are an increasing number of students, especially those from the well-off families, who opt for private education because it makes them more saleable in the global employment market. In light of that, Malaysia has initiated many approaches in order to

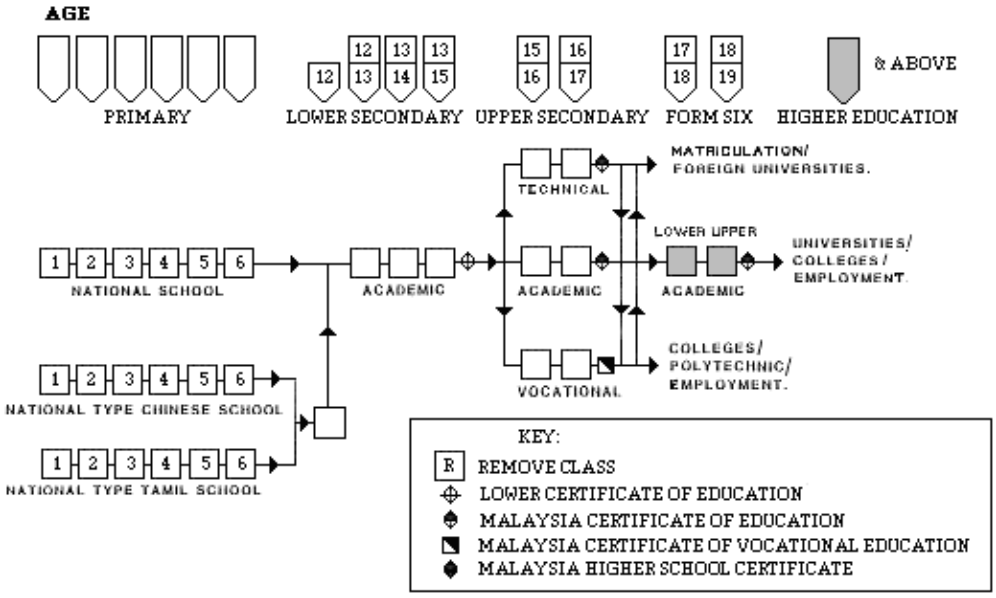

Figure 1. Structure of the Malaysian education system

keep up with the current needs of the changing world. Amongst others, in the 9th Malaysian Plan from 2006 to 2010, a total of RM40.3 billion which is about 21% of the total national budget allocation was set aside for the expenditure of education and training development. Besides that, the National Higher Education Strategic Plan is responsible in shaping Malaysia to be an international center of educational excellence by year 2020 which means it is important to build on the strength and opportunities provided by the private education sectors as a way for the country to grow in all aspects particularly in engaging and empowering its citizens with technological knowledge and skills.

The students discussed in this paper are in an external matriculation course at a private higher learning institution in Malaysia. Students enroll into this program after having completed their Grade 12 education. A majority of these students have limited exposure in using the graphics calculator in learning statistics and solving statistical problems. The graphics calculator used in this matriculation course at this particular private institution is the Hewlett Packard HP39gs graphics calculator, which is said to be an ideal classroom graphing tool especially for students from high-school through college. It has large adjustable contrast split screen that renders greater readability. The symbolic, numeric and graphing views provide greater teaching and learning opportunities while the intuitive algebraic data entry allows students to solve problems as if working on paper. Also, it allows students to create and store custom applets with 256KB memory (Hewlett Packard, n.d.).

The picture on the left of Figure 2 shows the graphics calculator HP39gs. Meanwhile, on the right is what appears on the screen of the computer used by the teachers. This is an effective way of teaching students to use the graphics calculator because instead of attending to the students one at a time, the teacher can show the instructions on a projected screen and the entire class can follow the steps easily and clearly. It also helps to control the speed of teaching because the teacher and students work together at a more manageable speed when the teacher is actually performing the calculations on the screen instead of just providing the students with instructions, leaving them behind and the teachers being oblivious to it. Statistics are covered in two out of the ten chapters in the matriculation mathematics course. The HP39gs calculators are used to calculate the mean and standard deviation of data sets and probability distributions, and to find the probability values involving normal and binomial distributions. The instructions to perform the statistical computations using HP39gs in this course are provided in the appendix.

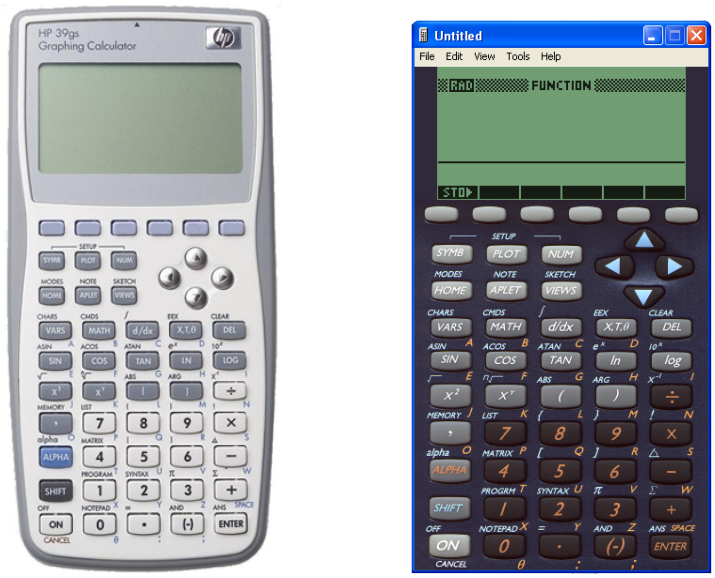

Figure 2. The graphics calculator HP39gs

The challenges that the teachers face in using HP39gs in teaching statistics in this matriculation course are primarily the time factor, teaching pedagogy and issues concerning assessments. The mathematics syllabus for this course contains ten chapters, which are taught over ten months for students who enroll in January and seven months for students who enroll in March of an academic year. Both cohorts of students take their public examination in the month of November of the same year. Statistics is taught in the second semester of the two-semester course and is contained in the seventh and eight chapters of the textbook. In addition to statistics, the mathematics syllabus covers algebra, calculus and matrices. Time is a crucial factor because the teachers not only have to complete the ten chapters comprising of different areas of mathematics, they also have to teach and guide students in answering questions which are of a different nature than their secondary school mathematics, such as requiring students to reason their answers and to form conjectures. Thus, teachers are not able to maximize the use of HP39gs in their teaching and are not able to provide the students with enough opportunities to

explore and discover the advantageous of using HP39gs to help them construct their understanding more successfully.

The graphics calculator, therefore, tends to be used as a calculating tool similar to the scientific calculator. In other words, students regretfully use the HP39gs in a methodical manner but are not able to extend their understanding of statistics to more real-life and complex problem situations. This could also be due to the fact that the assessments do not actually take into account students' ability and resourcefulness in using the graphics calculator. On the contrary, the statistics questions on the tests and examinations are designed in such a way that there is minimal use of HP39gs other than to calculate the mean and the standard deviation or to find the probability. In these instances, the capability of the graphics calculator is greatly compromised and reduced to those of a scientific calculator. If students have a choice not to use the graphics calculator in their assessment, they probably will not be as keen to learn to use this technology. Therefore, as put forward by Idris et al. (2010), in designing assessment tasks to integrate the graphics calculator, the most important decision to be made is whether to allow graphics calculator or to require the graphics calculator to be used in that tasks.

4. PEDAGOGICAL CONSIDERATIONS

If teachers in Malaysia are going to play a pivotal role in incorporating the use of graphics calculator into education systems effectively and successfully, they must change their pedagogy of teaching. Conventional methods of delivering knowledge cannot go hand-in-hand with using graphics calculator to teach statistics. Instead, teachers must be able to synergize teaching statistics with the implementation of graphics calculator so that students can appreciate the use of graphics calculator in learning statistics and not regard it as a mere tool that speeds up calculations. Teachers must help students explore and investigate the mathematical problems while encouraging students to learn on their own (Hasan, Azizan & Kassim, 2005). In other words, teachers should solve mathematical problems in classroom *with* students and not *for* students. The teachers also need to be creative enough to incorporate the use of technology into their lessons plans for maximum benefits to be gained by both parties. Ideally, classroom teaching needs to be set in a more constructive environment where students are given ample scope and opportunity to discover, explore, question and work with statistical problems in an explorative and innovative way to enhance learning. Teachers also need to be equally excited and motivated to learn and continuously seek new knowledge so that besides making learning more exciting for students, the teachers are well-equipped to deal with students' queries and curiosities in using the tool.

We find that many students do not understand how the HP39gs calculators can be used to their maximum benefit because the students have limited exposure to the different capabilities of this technology. It is a demanding and time-consuming task for the teachers to revise their lesson plans to allow time for teaching students the use of the HP39gs calculator and for both performing calculations and developing understanding of statistical concepts. Moreover, since this is an external program, we have no liberty to make changes to the mathematics curriculum. For instance, the HP39gs can be used as an excellent tool in teaching the inferential topics hypothesis testing and confidence interval. It has the capability to generate the critical regions for an hypothesis test and can also

produce the endpoints of a confidence interval. If these capabilities are utilized, then the students learning can be concentrated on the interpretation of these values in the context of the inferential problem. However, the questions in the assessments are designed in a step-by-step manner and so students must be taught to manually execute the steps. While instructors might use the calculator to develop their students' conceptual understanding in class, because students know they cannot use the inference applet on tests and examinations they would rather focus on the mathematical procedures.

If students are required to learn differently, assessment must be done differently because assessment is the factor that drives pedagogy. Idris et al. (2010) too agree that if graphics calculator were to be integrated into the statistics curriculum, then we must strive to reduce the gap between classroom conditions and assessment conditions. When assessments involve minimal or unintelligent use of graphics calculator, we would inadvertently fail to create "judicious users of technology" as mentioned by Stacey (2004). Although teachers have no control over the external examination, they have room to be more imaginative with their assessments at the school level. Ali, Seth, Zainuddin, Kassim, Sulaiman & Haili (2002) suggested letting students do projects that are designed to foster their understanding and critical thinking of statistics whereby the students consolidate their statistical concepts and principles by applying the methods and techniques learned in the process of working on their projects. Often teachers tend to "play it safe" by giving tasks that emulate the previous assessments and expect specific answers from students instead of giving assessments that let students provide different perspectives on the same statistical problem. The issue of concern however is whether and to what extent teachers are in favour of the use of graphics calculator in their assessments because it raises the problem of how to set questions that are both equitable and still test the required knowledge (Idris et al., 2010).

Another aspect to be considered in transforming statistics pedagogy is teachers' attitudes toward technology because teachers' attitudes influence their thoughts and behaviors towards students (Idris, 2006). A teacher who is enthusiastic about using the graphics calculator in the classrooms and believes that the use of graphics calculator can help to develop better understanding among the students will inspire the students to be equally motivated and excited about their own learning. More specifically, Malaysian teachers must take upon themselves the responsibility of continuously developing their technological knowledge and skills besides improving their pedagogical skills. The internet, for instance, is a wonderful source of ideas and information as there are a number of websites and videos on teaching pedagogy, interesting ways of teaching certain topics and assessment materials. The internet can be used as an ideal platform for teachers from all over the world to exchange ideas on teaching statistics more effectively and interestingly using the graphics calculator as a learning tool. This will be especially useful for teachers in the developing countries because they can adopt different kind of strategies and be exposed to newer methods and technologies from their developed counterparts.

Among the factors that determine students' engagement in their work is curiosity and originality (Idris, 2006). It is up to the teachers then to invoke the curiosity in their students' mind and to provide the students with authentic data for statistical analysis so that the work is more meaningful for the students. Idris (2004) also advocates the teachers to form working relationships with their students and break traditional barriers to allow students to be creative and exercise their higher order thinking. At present, students in

this matriculation statistics course by and large use the graphics calculator in an unthinking and button pushing manner which defeats the entire purpose of integrating graphics calculator into the mathematics curriculum.

4. REFLECTIONS

Technologies such as the graphics calculators offer mathematics teachers with both opportunities and responsibilities (Idris et al., 2004). Graphics calculators are a useful tool and teaching aid for introductory statistics courses mainly due to its accessibility and affordability (Collins & Mittag, 2005). Idris et al. (2010) had mentioned a number of past studies that found students and teachers in Malaysia were in favour of the use of the graphics calculator in their classroom teaching. However, the difficulties a teacher can have in incorporating the graphics calculator into their lessons especially when the students have had little exposure to using any such technology in their earlier schooling periods and the teachers themselves have limited experience in it must also be looked into. Some of these difficulties can be overcome by changing the design of the curriculum of mathematics and statistics to specifically allocate more time for teachers to create a self-motivated learning environment for the students and to design assessments that incorporate the use of graphics calculator in a more viable and useful manner instead of requiring students to use it as a mere calculation tool.

Students in the matriculation statistics course discussed here view the graphics calculator as just another calculation object due to two factors. First, they have low level of appreciation for such technology because Malaysian mathematics curriculum has not developed to a stage where technology plays a major role in the teaching and learning of mathematics. Second, many of the students in this course are in transition to a degree program and are unlikely to use a graphics calculator again. As such, they feel no obligation to give importance to the graphics calculator as a tool that helps them to understand statistics better. Both in the matriculation course discussed here and in Malaysian schools mathematics curriculum, statistics is regarded as a component of mathematics whereas statistics have been holding its own forth for a long time now. Of course, there is very little that can be done with respect to changing the curriculum of the matriculation mathematics course. Since statistics plays an important role in everyday life, however, Malaysia can consider changing its present school mathematics curriculum to have separate curriculums for mathematics and statistics.

The curriculum designers should also consider revising the school assessments and perhaps allow the use of graphics calculator in the public examinations. Then, the integration of graphic calculator into the mathematics curriculum becomes more meaningful and has more impact on the students. This year the school based assessment has been introduced into the secondary school curriculum. It opens the door to administrators and teachers in the schools to change the nature of their assessments so that the efforts taken to bring the graphics calculator into the mathematics classrooms in Malaysia are not wasted. In comparison to the developed nations that are employing the very latest technologies and gadgets in their statistics classrooms, Malaysia is far behind at the moment. Figure 3 shows the mathematics curriculum development in Malaysia and in America. In America, technology development began during the New Mathematics period but in Malaysia, technology was only included in the mathematics curriculum in

the Smart Curriculum program which took place much later than the New Mathematics in America. As such, when statistics curriculum in the developed nations are already including the more advanced computer programs, developing countries like Malaysia have only achieved success with graphics calculator. At the pace technologies are evolving we cannot be satisfied with only using the graphics calculator but have to seriously consider incorporating other technologies into the statistics classrooms.

Malaysian policy makers are aware of the development in the mathematics and statistics curricula around the world and continuously strive to bring Malaysian mathematics curriculum to the next level. In fact, the present mathematics curriculum outlines the application of technology as one of the objectives of teaching and learning of mathematics that is "…employ the latest technology to help students understand mathematical concepts in depth, meaningfully and precisely and enable them to explore mathematical ideas". However, other factors such as socio-economic conditions can determine how well and how fast we are able to keep up with the other countries. Now that the use of graphics calculator has been successful as a teaching tool in the Malaysian mathematics curriculum, other and especially more advanced tools can be considered in future.

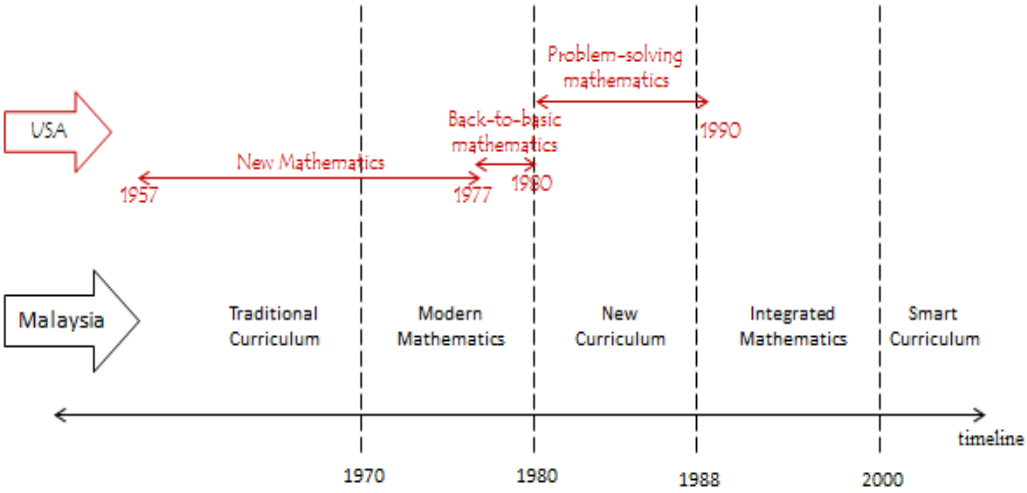

Figure 3. Development of mathematics curriculum in Malaysia and America

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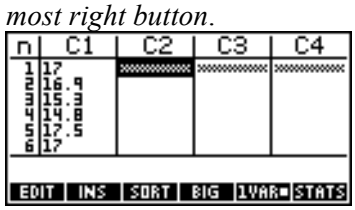
APPENDIX

Computing mean and standard deviation for a sample.

Step 1: Click on APLET Statistics.

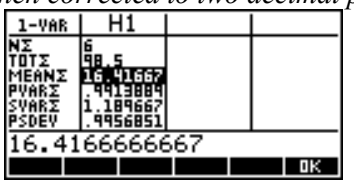
Step 2: Key in the data. *Here, we show the example for 6 data*.

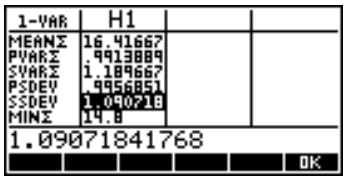
Step 3: Press 'STATS'. *It is the most right button*.



Step 4: Read the sample mean and sample standard deviation values.

For this example the sample mean is 16.42 and the sample standard deviation is 1.09 when corrected to two decimal places.



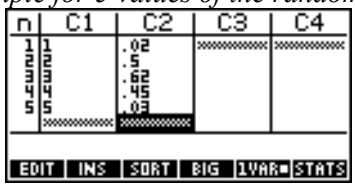


Computing mean and standard deviation for a probability distribution.

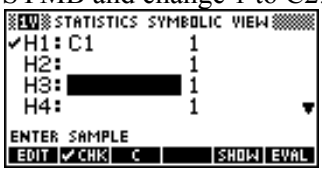
Step 1: Click on APLET Statistics.

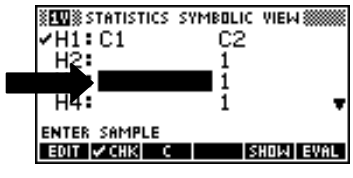
Step 2: Key in the values of random variable (commonly designated as x) in C1 and the corresponding values of probabilities (commonly designated as $P(x)$) in C2.

Here, we show the example for 5 values of the random variable.



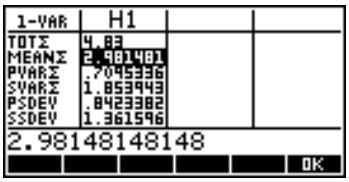
Step 3: Click on SYMB and change 1 to C2.





Step 4: Read the mean and standard deviation as before.

For this example the sample mean is 2.98 and the sample standard deviation is 1.36 when corrected to two decimal places.



These procedure is followed for large sets of data as well. Students will key-in the data in APLET Statistics and proceed to find the mean and standard deviation values in the same manner.

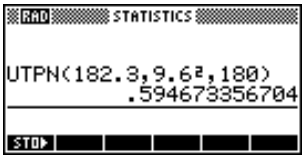
Finding the probability values for a normal distribution.

On the HOME view, type

UTPN(μ,σ2,X)

where this instruction generates the probability of getting more than X for a normal probability distribution. However, to activate this instruction we need the APLET StatPack39 which is not in-built but can be obtained from the calculator's homepage.

For instance, the probability of Pr(X>*180)* for a normal probability distribution with mean 182.3 and standard deviation 9.6 is 0.595 (correct to three significant figures) as shown below.



Finding the probability values for a binomial distribution.

On the HOME view, type

BPDF(n,p,X)

to find the probability of getting X

or BCDFn,p,X

to find the probability of getting less than or equals to X for a binomial probability distribution.

For instance, to find the probability of P(X = 2) for a binomial probability distribution with n=*25* and p = 0.05, students will type

BPDF(25,0.05,2)

whereas to find the probability of P(X ≤ 2) students will type

BCDF(25,0.05,2)

for the same binomial probability distribution. The results obtained using HP39gs are shown below.