GRAPHIC CALCULATOR INSTRUCTIONAL APPROACH AND STUDENTS’ PROBABILITY PERFORMANCES

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Abstract. Previous studies found that the graphic calculator (GC) has the potential to influence the way mathematics is taught and learned in which positive effects in the mathematics education are reported. This study aims to examine the effects of the GC instructional approach on students’ Probability performance, particularly students of different ability levels. A sample of 63 students at a private higher learning institution in Malaysia involved in the study and they were grouped into two groups (GC group and non-GC group (NGC)). In the teaching and learning of Probability, GC group adopted the GC instructional approach while NGC group used the conventional teaching approach. Probability Achievement Test (PAT) was employed to collect qualitative data. The study found favourable findings, i.e. students from different ability levels particularly the low-performing students gained benefits when the GC instructional approach was used in Probability learning.

JEL Classifications:
Keywords: Probability Learning, Graphic Calculator Instructional Approach, Mathematics Performance

INTRODUCTION

Studies found that most students perceive mathematics as a difficult subject that involves many tricks and rules to memorise in order to solve problems, and it involves many tedious, complex and boring calculations (Waits & Demana, 1999). As such, teaching and learning mathematics become complex tasks and thus researchers and educators are continuously searching ways to improve the effectiveness of teaching, particularly teaching to different ability levels of students. The adoption of a teaching approach, particularly those involve information and communication technology (ICT), greatly influences students’ learning because it makes mathematics richer and more experimental where students study new content of mathematics and pay greater attention to processes that are not feasible without ICT (Heugl, 2004; Mkomange, Chukwuekezie, Zergani, & Ajagbe, 2013). Many researches adopted and incorporated such educational technologies as LEGO, websites, Mathcad, and simulation software into the teaching of mathematics with the aim to improve and enhance students’ understanding on those difficult and complex concepts of mathematics. This includes the adoption and integration of G Cs. Research evidence supporting the integration of the GC to enhance mathematics performance appears to be growing. Favourable effects of the integration of the GC into the mathematics curriculum, particularly the improved performance in topics/subjects such as trigonometry, functions, graphs, algebra, geometry and calculus (Auitin, 2001; Muhundan, 2005; Nor’ain, Rohani, Wan Zah, & Mohd. Majid, 2011; Ocak, 2008; Spinato, 2011; Steele, Levin, Blecksmith, & Shahverdian, 2008) were reported. However, it was found that most researches on G Cs were carried out in developed countries, but it appears that there is limited research in developing countries like Malaysia, particularly which focuses on the effects of GCs in Probability curriculum at the higher leaning institutions. This may due to its adoption into the Malaysian curriculum and classrooms were found limited and at the infant stage in which it is a relatively new educational technology in Malaysia (Nor’ain et al., 2011). In addition, studies on examining its effects on students of different ability levels in Malaysia were found limited too.

Therefore, this study was conducted to overcome the deficiency of previous research. It was to examine the effects of the adoption of the GC instructional approach on students’ Probability performance, particularly students of different ability levels. The study could be significant to researchers, educators and policy-makers in improving the quality of Probability education with the adoption of the GC instructional approach. The research hypotheses of this research are:

H1: There are significant differences between the low-performing students (LP) in GC group and NGC group in the students’ performance for random variable (RV), poisson distribution (PD), binomial distribution (BD) and normal distribution (ND).

H2: There are significant differences between the average-performing students (AP) in GC group and NGC group in the students’ performance for RV, PD, BD and ND.
H3: There are significant differences between the high performing students (HP) in GC group and NGC group in the students’ performance for RV, PD, BD and ND.

LITERATURE REVIEW

The main issue of unsatisfactory achievements in mathematics was evident in some countries such as in United States, students’ mathematics performance was below average (Fields, 2005); in Idaho, the overall mathematics achievement that was identified in the annual results of the Iowa Test of Basic Skills (ITBS) was much lower than it should be (Strickland, 2005); in Hong Kong, most students were found weak in plotting and reading graphs (Leong, 2006) and in Chile, the mathematics achievement in TIMSS1999 was very low (Ramirez, 2005). This issue also happened in Malaysia. Malaysia’s ranking in mathematics in TIMSS 2011 (TIMSS 2011 International Results in Mathematics, 2013) dropped from 20th in 2007 to 26th in 2011 and the average score fell from 474 in 2007 to 440 in 2011.

Okello (2010) noted that students perceive mathematics as the most difficult subject to learn, particularly Probability, and involved complex formulae that they find difficult, which consequently entails poor performance in mathematics. Students’ inability to relate mathematics knowledge with real life situations resulted in students not understanding the usefulness and importance of mathematics in life. Moreover, students view learning mathematics is difficult as they are unable to “visualise” those abstract concepts and mathematical symbols that represents the real world. Consequently, they tend to memorise formulae and facts, and hence entails with difficulties in applying the knowledge in solving unfamiliar problems.

Research evident that the use of GCs in mathematics lessons yield positive results such as students showed better understanding of mathematical concepts and improved performance (Michelle, 2013; C. K. Tan, 2012). More specifically, students developed better understanding and appreciation on the concepts of functions and graphs, algebra, equations, statistic, significant digits, applied calculus and calculus (Autin, 2001; Muhundan, 2005; Nor’ain et al., 2011; Ocak, 2008; Spinato, 2011; Steele et al., 2008). The GC provided opportunities to students for active communication, discussion and involvement in classrooms, and consequently fostered better interactions and communication between students and teachers (Nik Rafidah, Zarita, & Safian, 2008; C. K. Tan, Madhubala, & Lau, 2011a; Choo-Kim Tan, Tan, Siti Fatimah, & Lew, 2013). It also made students’ learning easy and fun particularly save the ‘trouble’ of memorising formulae and computational time in performing and solving complex mathematical tasks as well as removed complicated and manipulative procedures (Daire, 2010; C. K. Tan, Madhubala, & Lau, 2011b). Consequently, it resulted in giving students accurate answers in few seconds and students used the saved time to explore more problems. This has helped students develop better understanding of mathematical concepts.

Previous studies found that GC’s functions helped students focus on the concept which cannot be done with the traditional way, and therefore it is more effective in explaining concepts to students (Brooks-Young, 2009; Ong, 2004). With the use of the GC, students were able to apply more sophisticated strategies to solve these mathematics problems that cannot be solved using normal algebraic methods or normal calculator easily, hence deepen students’ mathematics understanding and thinking skills (Sundram, 2008) as well as their decision making ability (Nor’ain et al., 2011). Students’ perception had also changed from ‘mathematics is difficult’ to “mathematics is enjoyable”. Therefore, with GCs, students were motivated to achieve their learning goal which was relevant to their needs with attempting more other questions, liked to answer questions that require long and complicated calculation, and asked more questions which they did not understand more frequently (Ha, 2008; Nik Rafidah et al., 2008).

Students of various ability levels too gained benefits from the GC instructional approach particularly the low-performing students had achieved the higher achievements (Harskamp, Suhre, & Van Streun, 2000; Van Streun, Harskamp, & Suhre, 2000). Acelajado’s (2004a, 2004b) studies reported an obvious significant difference in the mean scores between the pre- and post-test in the achievements of the different ability groups, i.e. the improved achievement within each of the high, average and low ability groups. Moreover, GCs also helped students with disabilities in mathematics learning. Bouck (2009) reported that while students without disabilities performed significantly better in the post-test, positive outcomes was also seen among students with disabilities (health impairment and emotional impairment). Students with disabilities made gains from the pre-test to post-test. Nor’ain et al. (2011) too found that the adoption of the GC approach increased the performance of average and low ability mathematics students and induced better levels of their meta-cognitive awareness with less mental effort invested during learning and test. The average mathematics ability students greatly gained benefits from the GC approach because it decreased the mental effort by double amount than the low mathematics ability students.
METHODOLOGY

Participants and Instructional Approach

The participants were the students who were pursuing their foundation programme at a university in Malaysia. The syllabi in the foundation programme are equivalent to Form 6 or A-levels. A quasi-experimental study with non-equivalent control group design with pre-test and post-test design was adopted as the reshuffling is not possible in which the existing groups of students have been formed during the students’ enrolment into the university, i.e. the university’ administrative constraints. The sample was divided into two groups, i.e. 32 students in the GC group and 33 students in NGC group. Their age ranged between 17 to 21 years old. Both groups were taught with the same syllabi of Probability on RV, BD, PD and ND.

To verify that students in both groups were homogeneous in their mathematics achievement, the independent samples t-test was conducted on students’ mathematics marks that they scored in the previous final examination. It was found that the mean score of GC group (73.12) was not significantly different from that of NGC group (73.06); the standard deviations were 19.874 and 19.733 respectively, with p value of 0.989 (> 0.05).

The categorisation of students into different mathematics achievement levels was based on students’ mathematics scores in the previous final examination. Students who obtained grades A+, A or A- were categorised as HP, the AP were those who obtained B+, B or B-, and the LP were those who obtained C+, C and F. Table 1 displays the frequencies of each category in GC group and NGC group.

<table>
<thead>
<tr>
<th>Mathematics Performance Level</th>
<th>GC Group</th>
<th>NGC Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>AP</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>HP</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>33</td>
</tr>
</tbody>
</table>

The GC instructional approach, also known as handheld technology instructional approach, was employed in the teaching and learning of Probability in GC group. It is a teaching and learning approach using the GC as a teaching and learning tool and GC instructional worksheets as modular lessons. The GC instructional worksheets were designed for the four chosen topics as per the probability syllabus. On the other hand, NGC group employed the conventional teaching approach with a textbook as a teaching and learning tool. Students used scientific calculator, statistical tables and paper-and-pencil in solving Probability problems. The same instructor and same syllabus were used for this study in order to ensure consistency. The instructor was the only lecturer who taught Probability to the sample of this study and was not the project member for this study.

Instrument

To measure students’ achievement in Probability before and after the study, a self-designed test called the Probability Achievement Test (PAT) was designed. PAT consists of four problem solving questions on the four chosen topics. It is particularly to measure students’ knowledge and problem solving ability on RV, BD, PD and ND. Each question carried 20 marks which contributed to a maximum total score of 80 marks. A group of panels with five experts in the field of Probability with 15 years of teaching experience at the university validated PAT for its relevance and concordance with the syllabus. The acceptable reliability of Cronbach’s coefficients of 0.93 and 0.72 were obtained from the pilot study and the filed study for PAT, respectively. In order to attain the comparative data, a test-retest approach was employed in this study.

Procedure

The research was conducted during the 14-week trimester. For the period of the first three weeks, administration of pre-PAT and the GCs workshops were conducted. The pre-PAT were administered to both GC group and NGC group at the beginning of the study (Week 1). The GCs workshops were conducted to GC group only with the aim to provide students opportunity to learn and master the important key features of the GCs that are essential for the four chosen topics for this study.

The GC intervention period was from week 4 to week 12. During this period, students in GC group were taught with the GC instructional approach, while students in NGC group were taught with the conventional
teaching approach. For the teaching of Probability lessons, each lesson for both groups began with the discussion on the theories and examples for about 15 minutes, followed by GC aided instructional activities to GC group and paper-and-pencil problems solving activities to the CG for about 100 minutes, and finally the lesson ended with the 5 minutes conclusion. The instructor as a facilitator guided and facilitated students throughout all the lessons particularly during the problem solving. In addition, if necessary, encouragement for active interaction, discussion and ideas exchange was given by the instructor during the problem solving. Journals were kept by students in both groups at the end of the lesson for the purpose of recording their experiences of learning Probability.

After the GC intervention period, both groups were again given the PAT, which was the post-PAT. By using SPSS, data produced from both the pre- and post-PAT were analysed for descriptive statistics, graphs and t-test at 5% significance level. Students’ comments in journals were analysed with the help of a group of three experienced lecturers who have 15 years of teaching experiences in Probability at the university.

**FINDINGS**

An overall picture for pre-PAT and post-PAT are presented first, followed by the results of each topic.

The pre-PAT’s t-value can only be generated for RV as all the values of average and standard deviation for BD, PD and ND were zeros for GC group and NGC groups. t-value of -1.678 and p-value of .099 for RV indicate that there is no statistical significant difference in achievement between the two groups. That is, NGC group’s mean score of 2.95 (SD = 2.63) is not significantly higher than that of NGC group (M = 1.99, SD = 1.95).

**FIGURE 1. MEAN VALUES OF POST PAT**

![Graph showing mean values of post-PAT](image)

Figure 1 shows that the mean values of all topics in post-PAT for GC group are higher than the mean values for NGC group. GC group recorded the highest mean score in PD, followed by ND, BD and RV, while NGC group has the highest mean score in RV, followed by PD, BD and ND. The t-test results confirmed that GC group performed better than NGC group in all topics, i.e. GC group’s mean values in RV (SD = 1.94), PD (standard deviation (SD) = 1.90), BD (SD = 1.24) and ND (SD = 1.62) are significantly higher than that of NGC group (SD for RV, PD, BD and ND are 3.74, 7.57, 6.93 and 8.11, respectively), p < 0.001. The mean difference in ND between the two groups is the greatest (10.33) while the mean differences for the other three topics, in decreasing order, are 9.82 for BD, 7.64 for PD and 5.73 for RV. Furthermore, with 95% confidence level, the interval estimation for the mean difference (MD) between the two groups, i.e. using GC instructional approach and conventional approach, produced the results that the mean difference in ND recorded the widest interval (5.843), or it can be said that the mean values in ND for the GC instructional approach to be anywhere from 7.405 points less than to 13.248 points more than the mean scores for the conventional approach. This followed by PD (5.511), BD (4.974) and RV (2.964), i.e. it is estimated that the mean scores in PD, BD and RV for the GC instructional approach to be anywhere from 4.885 points less than to 10.396 points more than the mean scores, from 7.336 less than to 12.310 points more than the mean scores, and from 4.249 points less than to 7.213 points more than the mean scores, respectively for the conventional approach.
The findings for the research hypotheses will be presented below.

Findings for H1

FIGURE 2. BOX PLOT OF RV FOR LP

FIGURE 3. BOX PLOT OF PD FOR LP
Comparisons of box plots between the LP of GC group and NGC group in the topics of RV, PD, BD and ND after the study are displayed in Figures 2, 3, 4 and 5. The LP in GC group have achieved highly in RV, PD, BD and ND when compared with the LP in NGC group. The lower quartiles are higher than the NGC group medians for all topics. The minimum values in PD and ND for LP in GC group (17 and 14, respectively) are even higher than the maximum values for LP in group B (15 and 3, respectively). The LP in GC group scored maximum marks in all topics.

Figure 6 shows that the mean values of all topics after the study for the LP in GC group are higher than the mean values for the LP in NGC group. GC group has the highest mean value in PD, followed by BD, ND and RV, while NGC group recorded the highest mean score in RV, followed by PD, BD and ND. t-test results confirmed that there are significant differences in achievement for all topics between the LP in both groups. The LP of GC
group scored significantly higher mean values in RV, PD, BD and ND in post-PAT (SD for RV, PD, BD and ND are 2.66, 1.03, 1.94 and 2.14, respectively) compared to their counterparts in NGC group (SD for RV, PD, BD and ND are 5.18, 5.42, 5.94 and 1.44, respectively). The greatest mean difference between the LP of two groups was recorded for ND, followed by BD, PD and RV (Table 2). That is, among the four topics, the LP in GC group performed significantly better than their counterparts particularly in ND, followed by BD, PD and RV.

**FIGURE 6. MEAN VALUES OF POST PAT FOR LP**

**TABLE 2. MEAN DIFFERENCE BETWEEN GROUPS FOR EACH TOPIC**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Mean Difference</th>
<th>LP</th>
<th>AP</th>
<th>HP</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV</td>
<td>6.43</td>
<td>7.11</td>
<td>4.69</td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>12.21</td>
<td>10.22</td>
<td>4.13</td>
<td></td>
</tr>
<tr>
<td>BD</td>
<td>13.90</td>
<td>13.28</td>
<td>5.88</td>
<td></td>
</tr>
<tr>
<td>ND</td>
<td>16.31</td>
<td>13.55</td>
<td>5.76</td>
<td></td>
</tr>
</tbody>
</table>

Findings for H2
FIGURE 7. BOX PLOT OF RV FOR AP

FIGURE 8. BOX PLOT OF PD FOR AP
FIGURE 9. BOX PLOT OF BD FOR AP

FIGURE 10. BOX PLOT OF ND FOR AP
Figures 7, 8, 9 and 10 show the comparisons of box plots between the AP of GC group and NGC group in the topics of RV, PD, PD and ND after the study. The AP in GC group scored highly in RV, PD, BD and ND as compared to their counterparts in NGC group. Their lower quartiles are higher than the medians of NGC group for all topics. NGC groups’ minimum values in PD, BD and ND for AP are all zeros. The AP in GC group scored maximum marks in all topics.

Figure 11 shows that the mean values of all topics after the study for the AP in GC group are higher than the mean values for the AP in NGC group. The AP in GC group scored the highest mean in ND, followed by BD, PD and RV. In contrast, NGC group scored the highest mean in RV, followed by PD, ND and BD. It was also found that there are significant differences in mean scores for all topics between the AP in both groups. GC group ($SD = 1.86, 3.05, .95$ and $1.25$ for RV, PD, BD and ND, respectively) performed significantly better than NGC group ($SD = 3.01, 8.95, 7.24$ and $7.75$, for RV, PD, BD and ND, respectively) in all the four topics after the study, $p < .05$. In addition, same with the LP, the greatest mean difference between the AP of two groups was found in ND, followed by BD, PD and RV (Table 2). In other words, among the four topics, the AP in GC group performed significantly better than their counterparts particularly in ND, followed by BD, PD and RV when the GC instructional approach was employed.

**FIGURE 11. MEAN VALUES OF POST PAT FOR AP**
Findings for H3

FIGURE 12. BOX PLOT OF RV FOR HP

FIGURE 13. BOX PLOT OF PD FOR HP
FIGURE 14. BOX PLOT OF BD FOR HP

FIGURE 15. BOX PLOT OF ND FOR HP
Comparisons of box plots between GC group and NGC group in all the topics after the study are also made for the HP (Figures 12, 13, 14 and 15). Similar to the LP and AP, the HP in GC group scored highly in all the four topics when compared with the HP in NGC group. Their lower quartiles are higher than the medians of their counterparts in NGC group for all topics too. They also scored maximum marks in all topics. However, the minimum value of zero in PD was scored by the HP in NGC group.

The mean values of RV, PD, BD and ND for the HP in both groups after the study are displayed in Figure 16. The HP in GC group scored almost maximum marks for the mean values in all topics except BD. Their highest mean value was recorded in PD ($SD = 0.49$), then followed by ND ($SD = 0.48$), RV ($SD = 0.90$) and BD ($SD = 0.90$). In contrast, NGC group achieved the highest mean score in PD ($SD = 5.43$), then followed by RV ($SD = 2.35$), ND ($SD = 6.23$) and BD ($SD = 4.65$). In addition, the HP in GC group obtained higher mean values than NGC group. This was confirmed from $t$-test results that they performed significantly better than NGC group in all the four topics, $p < .05$. The mean differences between the HP in both groups in all the four topics (Table 2) are not as large as those for the LP and AP, i.e. in the range of 4.13 to 5.88. The greatest mean difference was found in BD, and then followed by ND, RV and PD.

**FIGURE 16. MEAN VALUES OF POST PAT FOR HP**
In sum, $t$-test results show that, for all the research hypotheses, there are significant differences between the LP (AP and HP) in GC group and NGC group in the students’ performance for all the four topics, RV, PD, BD and ND. Furthermore, all the three levels, LP, AP and HP, obtained the largest mean differences in BD and ND, i.e. greater than 5 for both topics for the HP, greater than 13 for both topics for the AP, and greater than 13 and 16, respectively for the LP. That is, the mean difference gets smaller by levels, i.e. from LP to HP.

**Qualitative Findings**

A clearer picture on students’ views with the GC instructional approach and the conventional approach is discussed below. The comments are cited in the discussion and pseudonyms are used to cite the students’ comments.

**GC Group’s Comments**

It was found that the GC instructional approach has facilitated students’ learning particularly in solving problems that require the use of statistical tables. It helped to increase students’ understanding in which students could use the built-in functions of GC such as `binomcdf` and `binompdf` to solve distributions problems without referring to the statistical tables. Mutu cited that “… I use many functions of GC to solve problems. My understanding in Probability improves as it helps me to understand the concept…” Siti too stated that “… I found that the GC functions that I used to solve Poisson distribution problems same as using statistical tables to solve them. I am able to solve the problems with GC and statistical tables. Now, I understand the concept and know how to solve the problems using the statistical tables.” Moreover, students could tabulate the data and draw the graphs in the GC using ‘LIST’ function and graph function. The graphical representation enabled students to observe and visualize the pattern of distributions particularly for the normal distribution. As such, students found their understandings improved. Mei Lin noted that “… shaded area was displayed in normal curve on the screen, and now I understood that it is the probability…”

Students also found that GCs simplified the tedious and complex calculations during problem solving. They used the saved time to carry out many tasks. For instance, Chin responded that “… solving probability problems with the GC involves entering only a few data into it and it does all the calculations for me. Therefore, I could practise more exercises. It gets rid of the complicated calculations that I scared of” and Cindy commented that “I can get the solution in few seconds, it is quite interesting. Now, I am confident to solve difficult questions.” As such, the GC helped students to build their confidence particularly in solving difficult questions and perform complicated tasks in which it provided them an easier way to understand the concepts, and saved the tedious manual calculations and time.

Students enjoy learning Probability with the GC instructional approach. They found learning Probability with GCs is fun. They recorded in their journals that they have active interaction with GCs, peers and lecturer. They actively participated and discussed the methods of using GC’s multi-functions, ideas and steps of getting
answers, hence, their understanding improved. Low-performing students found that they become independent learners now after using GC. After scaffolded by their peers, they are not only improved in their understanding, but they are confident to solve the problems independently and to teach others as well. Swee stated that “Learning probability with GCs is fun and I enjoy it very much”, Henry cited that “… after discussed with my friends and lecturer and using GCs, I found that I like this subject. I also happy to know more friends by interacting with them” and Minah, who was a low-performing student, responded that “I could grasp the Probability concepts and solve the problems independently. I am glad to use the GC as I am now able to teach my friend when she could not get the solution.”

**NGC Group’s Comments**

Comments by NGC group showed that the conventional approach was boring and the manual calculations were complex and tedious. Majority of the students showed less interest towards learning Probability particularly the LP felt bored in class. Keng cited that “I didn’t like to solve the problem due to long calculations. It is very boring too.” This resulted in the adoption of ‘wait and see’ approach among the LP, i.e. to wait for the answers from peers or lecturer. In addition, another reason given by students that they prefer to wait for the answers is that the long and tedious calculations resulted in them getting the wrong answers most of the time. Students also felt that much time was spent in solving Probability problems when the paper-and-pencil method in the conventional approach was used. As such, they could not explore and practise more exercises in a day particularly to solve more difficult questions. This could be seen in Joe’s journal that “Too much time was used to solve the questions. Moreover, the subject involves many formulas which are difficult to memorise, sometimes I am lazy to solve the problems till I give up to solve them” and Jojo too recorded that “We spent a lot of time to write the formula and substitute the figures in the formula. A lot of time was also spent on reading the probability values from the statistical tables. Thus, we cannot solve many problems.” There was less interaction among students especially the LP. They seemed passive in the class. For instance, Susan, a LP, commented that “We have less discussion and interaction because I could not solve the problems and I did not discuss with my friends who also could not solve the questions completely. Most of the time, I wait for my lecturers to provide the solutions and answers.”

**DISCUSSIONS AND IMPLICATIONS**

Findings from this study are consistent with previous research findings such as Ha (2008), Michelle (2013) and C.-K. Tan (2012) that the GC helped students to improve mathematical understanding and perform better in mathematics. Students’ understanding has been enhanced with the GC instructional approach. Furthermore, this study showed that the GC was a useful educational technology device that not only helped students’ learning in functions and graphs, algebra, equations, statistic, significant digits, applied calculus and calculus (Autin, 2001; Muhundan, 2005; Nor’ain et al., 2011; Ocak, 2008; Spinato, 2011; Steele et al., 2008), but also Probability learning, particularly RV, PD, BD and ND. The LP, AP and HP showed improved performance in Probability which is in line with previous studies (Acelajado, 2004a, 2004b; Bouck, 2009; Nor’ain et al., 2011) that students with different mathematics ability levels gained benefits from the GC instructional approach. Moreover, findings of this study showed the great mean differences between the LP in GC group and NGC group, particularly for BD and ND, and the minimum scores of the LP in GC group in PD and ND are greater than the maximum scores for the LP in NGC group are in line with Harskamp, Suhre and Van Streun (2000) and Van Streun, Harskamp and Suhre’s (2000) studies.

Students were also provided opportunities for communication and active involvement in classrooms, and better interactions and communication between students and teachers were fostered, which consistent with previous studies (Nik Rafidah et al., 2008; C.-K. Tan et al., 2011a; Choo-Kim Tan et al., 2013). The GC instructional approach appeared to be an effective approach that enabled students to actively communicate and interact with GC, peers and instructor as well as willingly to help each other to deliberate the steps on how to solve the Probability problems, exchange ideas on the solution, and compare the answers from GCs, which help to increase their understandings. Hence, students showed significant improvement in Probability. During the GC hand-on activity sessions, students displayed more interest in using the GC. They felt that the Probability learning became less stressful. They enjoyed Probability learning with the GC instructional approach. Furthermore, the GC approach made students especially those LP become independent learners. They were found to be not only able to solve the problems without the help of the competent peers and instructors, but they were able to help others especially their counterparts who are taught with the conventional approach. In contrast, students who are taught with the conventional approach were passive and had little interaction despite of encouragement was provided. They were dependent learners in which they adopted ‘wait and see’ approach, i.e. wait for the instructors or
Findings of this study provide evidence that the GC instructional approach eased students’ learning. It saved the ‘trouble’ of memorising formulae, computational time, and complicated and manipulative procedures, which are also consistent with the findings of previous studies (Daire, 2010; C.-K. Tan et al., 2011b). This allowed students to have more time to explore more problems which in turn enhance students’ understanding of mathematical concepts. The multi-functions of GCs provide students opportunity to explore various strategies for problem-solving and various levels of differentiated instructions in studying mathematical concepts. The functions such as binompdf and binomcdf allowed students to solve binomial problems without referring to the statistical tables or writing the formulae with paper-and-pencil method which is time consuming. Hence, students are able to obtain answers that cannot be solved using normal calculator easily. The GC is particularly very useful for solving the PD, BD and ND problems that require more parameters in the formulae. With its graphing function, GC appeared to be a useful and user-friendly educational technology device that enabled students particularly the LP to visualize the graph, especially the Normal curves, and this had improved their problem solving skills. Therefore, this is in line with previous research (Brooks-Young, 2009; Ha, 2008) that the GC enabled students to understand mathematics problems in various ways and hence improve their performance.

Based on the findings, there are significant implications for adopting the GC approach. The GC instructional approach seemed to be an effective approach to be adopted as it benefits all students regardless of their previous mathematics ability levels. Findings of this study showed that the LP who were taught using the conventional approach did not perform significantly better in Probability topics particularly in BD and ND than their counterparts who were taught with the GC instructional approach. Evidently, the GC instructional approach appears to enable the LP to obtain higher achievement in these two topics. Thus, this approach can be an alternative innovative and effective instructional approach to improve Probability performance in higher learning institutions and the GC should be widely adopted particularly in Malaysia mathematics education, in higher learning institutions and in Probability. It is also recommended to instructors who teach Binomial Distribution and Normal Distribution especially to the LP to adopt this approach.

Efforts to improve unsatisfactory achievement in mathematics and probability among Malaysian students should be taken by Ministry of Education (MOE). One of such efforts is to encourage the use of GC in all higher learning institutions. All mathematics and science instructors must also be encouraged to create interactive learning environment by adopting the GC instructional approach. For the teaching to students with different ability levels, particularly to the LP, Probability instructors could be more creative and innovative in designing the lecture plans, the GC instructional activities and the teaching and learning strategies with GC. The setting of the examinations questions can be improved by incorporating the GC so that students could be tested to formulate the mathematical models and to interpret the answers from the GC.

CONCLUSION

Given the advancement of GCs and the increasing use of GCs in developed countries, a better understanding in the implementation of GCs will certainly enhance the use and educational value of such an educational technology in Malaysia. In this study, it is clearly seen that the GC instructional approach and the GC is a tool worth considering since there are promising outcomes such as increased performance and understanding, and meaningful learning.

Findings of this study showed that the GC approach is superior to conventional approach and the GC is a powerful and influential device in solving complicated mathematical problems. With the GC instructional approach, the complex procedures and tasks in mathematics are simplified; consequently students changed their perception to “learning mathematics is easy and fun now”. In addition, the GC instructional approach is beneficial in improving Probability achievement among all ability levels of students particularly the low-performing students.

In concluding, it was obviously seen that the GC saved tedious computational process, freeing up students to explore more problems, helped students think about probability spatially by visualizing density curves and provided students more opportunities for interaction, communication and collaboration, which in turn boost students’ interest in mathematics and increase their performance in mathematics. It is therefore recommended that the GC instructional approach is adopted in mathematics and probability teaching-learning process so that an interactive and meaningful environment could be provided with the instructor and GC act as facilitators and scaffolders, while students as competent peers working in partnership with each others to develop new knowledge and enhance mathematics concepts. Last but not least, it is recommended that the benefits of strengthening this approach may extend to other subject domains and scopes.

REFERENCES


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