The effect of graphing software on students' conceptual understanding of quadratic functions

P. H. Armah[2], & W. Osafo-Apeanti[3]

Abstract

This study investigated the effects of graphing software in teaching mathematics at senior secondary level in Ghana. The purpose was to determine the extent to which the effective use of graphing software as an instructional technology could improve the performance of students in mathematics. It also examined the effect of gender on these outcomes. An action research design with quantitative data was used. The sample consisted of 43 Form 2 students of Adiembra Senior High School, 13 males and 30 females. The sample was taught the concept of quadratic functions in accordance with the Senior High School core mathematics teaching syllabus for two weeks using the graphing software. The students were pretested and posttested. A t-test analysis revealed a significantly high performance in the posttest than the pretest. Thus, the use of technology improved academic performance in Mathematics. However, there was no significant difference between the performance of males and females. The study has therefore provided some empirical evidence about the effectiveness of graphing software in the cognitive gains of students in Mathematics. Research with larger samples is hereby recommended before any major implementation of the intervention.

Introduction

In today's world we can easily see around us range of technologies, especially computers, are being widely used in all walks of life. The educational field is not an exception. Not only is the number of computers at school quickly growing, but also the recognition about the use of technology in education is rapidly increasing. As a result, many research studies (e.g. Forgasz & Prince, 2004; Fitzallen, 2007) have revealed that integrating technology in mathematics instruction has the potential to make learning effective and interesting towards improving students learning outcome. Other studies (e.g. Kumar, 2008; Gill & Dalgarno, 2008) also depict technology as a tool that provides opportunities for students to develop their skills and knowledge that will empower them in this modern society. So, the influence of technology in education is getting more and more interesting. Besides, the rapid development of technology in quantity and quality seems to force curriculum developers to pay particular attention to the use of technology in the mathematics classroom.

Incidentally, the foundation for integration of technology is an evolving process of investigation in many developing countries. However, it is encouraging to note that Ghana is embarking on programmes and policy aimed at tapping the potentials of technology as part of her medium and long term vision. For instance , country's educational system is expected to be modernised by the use of technology to, inter

[2] Prince Hamidu Armah is a mathematics educator at St. John's SHS, Sekondi, Ghana. Email: pkarmah@yahoo.co.uk.

[3] Osafo Apeanti Wilson is a lecturer at the Department of ICT Education, University of Education, Winneba, Ghana. Email: osafoapeanti@googlemail.com

alia, improve the quality of education and training as well as make the educational system responsive to the aspirations of the country (Republic of Ghana, 2003). As a result, specific references are made in the teaching syllabus for core mathematics at the senior high school level about the use of technology in drawing graphs, calculating means, modes, medians and standard deviations of mathematical data (Ministry of Education, Science & Sports, 2007).

Yet, many students are still taught Mathematics using 'traditional' pedagogical practices which essentially promote instrumental understanding and relegate relational understanding to the background. There is substantial anecdotal evidence to suggest that, mathematics teachers are looking for more concrete proof for the positive impact of technology integration in mathematics education so that they will not waste their limited time allocation. In fact Emin (2005) strongly contends that the teachers of mathematics have been persistently inundated with extensive amount of suggestions on how to teach mathematics with technology rendering them very confused about the effect of technology integration in mathematics education.

It is in the light of promoting the use of technology that this study builds upon earlier study by Elliott and Hudson (2000) using similar concepts and software tools for improving students' conceptual understanding of quadratic functions. This approach is also in pursuance of Ghana's anticipated goal to promote technology initiatives that will transform the culture and practices of traditional memory based learning to education that stimulates thinking and creativity (Republic of Ghana, 2006). In line with this goal, the study provides adequate ways where technology can enable students to develop a greater understanding of the relationship between the quadratic functions and its graphs. It indicates how numerous functions and graphs can be demonstrated by a teacher in an effective manner that would not be possible with a whiteboard and marker.

Statement of the problem

The concept of function is a fundamental unifying idea in Mathematics. As result, it is greatly emphasized in the senior secondary school mathematics curricular (Ministry of Education, Science and Sports, 2007). The mathematics teaching syllabus of senior high schools requires function to be taught from first year to the third year. Specific references are made to the linear functions and quadratic equations as prerequisites for quadratic functions. In the traditional method of instruction, the quadratic functions are introduced by writing its standard form, $y = ax^2 + bx + c$. The students are then given a quadratic function (in standard form) for which they are required to complete the table of values and subsequently plot the graph using the table. The students' are not engaged in any activities to enable them investigate the properties of the quadratic functions. Yet they are then required to solve problems using the graph. This includes symmetry, maximum and minimum value and value for which they occur, the roots of the given equation and so on.

Students' difficulties in dealing with a function given in graphical form or connecting functions with their graph are as a result of this traditional instructional method (Leinhardt, Zaslavsky & Stein, 1990). In such instruction method, learning mathematics involves the whole class instruction, rote memorization and individual seat work. The lesson does not allow for experiences where students are able to discover, invent or apply mathematics to problems that are meaningful to them (Cangelosi, 1996). This approach, therefore, does not provide a thorough understanding of mathematical concepts as more classroom time is spent on routine computation skills than on understanding mathematical concepts. It does not take much account of differences between students in a particular class with respect to their speed of learning or their previous knowledge background.

Consequently, academic performance in core mathematics, in Ghana, is still deplorably low in the West Africa Senior Secondary School Certificate Examinations. However, a comprehensive review of studies on technology integration in mathematics instruction indicates that there is an improved student conceptual understanding when they use graphing software with curriculum specifically designed to take advantage of the technology (Tarmizi, Ayub, Abu Bakar &Yunus, 2008). Graphing software refers to any computer software that is used to draw graphs. It is also the collective name for software that produces a graph given some type of input (usually a list of numbers or an equation). Graphing software can vary based on different abilities. Some examples are Microsoft Excel and Math Tool.

Purpose of the study

According to Mereku (2001), the mathematics classroom of today stresses on the use of technology in the development of mathematics concepts. He argues further that mathematics teaching has moved from the talk- to-chalk method to an emphasis on problem solving where students are expected to construct their own knowledge for lifelong learning whilst the teacher plays the role of a facilitator. In the teaching of mathematics, many teachers still rely on the chalk and talk approach or more commonly known as the traditional method. In the traditional method, learning mathematics involves the rote memorization and individual seat work. The lesson does not allow for experiences for students to discover, invent or apply mathematics to problems meaningfully. Visualization is minimal if at all. Drawings of graphs if done are sketches which are static, not according to scale and very too often distorted. The use of visualization tools like the Microsoft Math Tool in this study would, therefore, present an alternative instructional dimension to overcome these instructional inadequacies in traditional methods.

Research questions

Based on the purpose of the study, the following questions were answered:

i. To extent can the use graphing software improve students' performance in quadratic functions?

ii. To what extent will the performances of females and males be differently affected by the use of the graphing software?

Review of literature

Effect of graphing software on learning functions

Various studies have been conducted on the potency of technology integration in mathematics instruction which has been summarized by BECTA (2003). Firstly technology promotes greater collaboration among students and encourages communication and the sharing of knowledge. Secondly, technology gives rapid and accurate feedbacks to students and this contributes towards positive motivation. Finally, the use of technology in mathematics classroom also allows students to focus on strategies and interpretations of answers rather than spend time on tedious computational calculations.

Specifically, the relationship between a function and its graph is considered to be difficult for students to delineate. However, the use of technology provides multiple visual representations, allowing students' hands-operation to enable them to experience different forms of relationships through real-world examples (Laughbaum, 2002). Consequently, many studies (e.g. Doerr & Zangor, 2000; Noraini *et. al*., (2003), have shown a positive impact on using graphing software in the mathematics classroom. Dyke (2003) in a study revealed that students resort to complicated algebraic expressions rather than read information from graphs. In order to place greater emphasis on graphs, she suggested introducing concept of function by the use of graphs through the graphing software. This suggestion concurs with the result of Dunham's (1994) study. In review of research reports, Dunham (1994) indicated that many students who use graphing technology:

1. are better able to relate graphs to their equations;
2. can better read and interpret graphical information;
3. obtain more information from graphs;
4. have a greater overall performance on graphing items;
5. are better at symbolizing, that is, finding an algebraic representation for a graph;
6. better understand global features of functions;
7. increase their example base for functions by examining a greater variety of representations; and
8. better understand connections among graphical, numerical and algebraic representations.

In addition to these earlier studies, Ye (2009) in a study identified the following as some of the effect of graphing software in teaching and learning functions:

i. Using graphing software in middle school mathematics helps in the understanding of mathematics concepts, qualities etc.
ii. It promotes changes for the passive, old learning approach to diverse learning through self learning, cooperation, and exploration.

iii. The use of graphing calculators in secondary mathematics teaching is conductive to the reform of evaluation systems, especially in the way exams are constructed.
iv. Graphing software promotes the modernization of mathematics textbooks, and is conducive to the information, visualization, diversification, and popularization of the contents of teaching materials

These conclusions are in conformity with Streun, Harskamp, and Suhre (2000) assertion that the use of graphing software reduces the burden on students, so that students spend more time on understanding, reasoning, and the applications of mathematics, which can stimulate their enthusiasm for learning. In general, the graphing software has not only provided strong support for the teaching of mathematics, at the secondary school level, but also have become good tools for independent exploration and experiments (Shore & Shore, 2003).

Method

Research design

The study is an action research design with quantitative data. An action research is a process by which practitioners examine their problems systematically and carefully, using the techniques of research in order to guide, correct, and evaluate their decisions and actions (Kemmis & McTaggart, 1990b). In this respect, the study employed an action research design to undertake a systematic enquiry into the research problem in a collective, collaborative, self-reflective, and critical manner. The rationale for this research design was to identify a practical problem in the classroom and to attempt to seek and implement solutions in that class.

Population and Sampling Procedure

The population for this study was all form 2 students from the Adiembra Senior High School (ADISEC) in Sekondi, a capital town of the western region of Ghana. The participants for the study were 43 purposively sampled form 2 home economics students from ADISEC, out of which 30 were females and the rest, were males with their ages ranging from 14 to 18 years.

Data Collection

The pre-test and the post-test were administered and scored in a consistent manner. The pretest was administered before the intervention stage whilst the post test was done after the intervention stage. Both tests were designed in such a way that the questions, the scoring procedures and interpretations were administered and scored in a standard manner so that they were valid and relevant. The researchers developed both tests by carefully selecting standard theory questions from past WASSCE examination papers. It contains five theory items, which tested knowledge of simple concept, applications and reasoning in quadratic functions.

Analysis of Data

The paired and independent sample t-tests were used to analysis and answer research question 1 and 2 respectively. Both tests were conducted at a significance level (α) of 0.05. The content validity of the two tests (pre and post tests) was evaluated by making sure that the test items matched the specific instructional objectives proposed in the senior secondary school mathematics syllabus. The Internal consistency of the pre and post tests were high as the questions were taken from WASSCE past papers which means that they were set by experienced mathematics examiners, pretested, and approved by WAEC.

Instructional Methods and Materials (Intervention)

The intervention was implemented by the first author within two weeks. Students were assessed at every stage of the implementation. As indicated earlier, the respondents are form two home economics students. In form one; these students were exposed to linear equations. Thus the respondents are able to find solution sets for linear equations in one variable and graph linear equations. Before, the problem was identified, the respondent were able to solve quadratic equations by factorization.

Investigating quadratic functions

This lesson also took place in the ICT lab with students seated mostly in pairs at a computer, but sometimes individually. The resource materials for the lesson consisted of a worksheet devised by the first author which called for use of the graphing software, *Microsoft Math Tool*, a simple to use, computer software. *Microsoft Math Tool* allows the user to input a mathematical equation, and if desired to choose the scale. The program then plots the graph of the equation and the user can zoom in or out to focus on particular points on the curve, and to determine their precise co-ordinates. The lesson agenda followed the sequence of worksheet tasks. The first task was to use the graphing software to draw quadratics graphs. The second task was to explore the effect of altering particular coefficients of a quadratic function (transformational effects) on the shape and location of the resulting curve, with a set of three function specified in relation to each coefficient (such as $f(x) = x^2 + x - 3$, $f(x) = x^2 + 2x - 3$, $f(x) = x^2 - 3x - 3$) (see figure. 1).

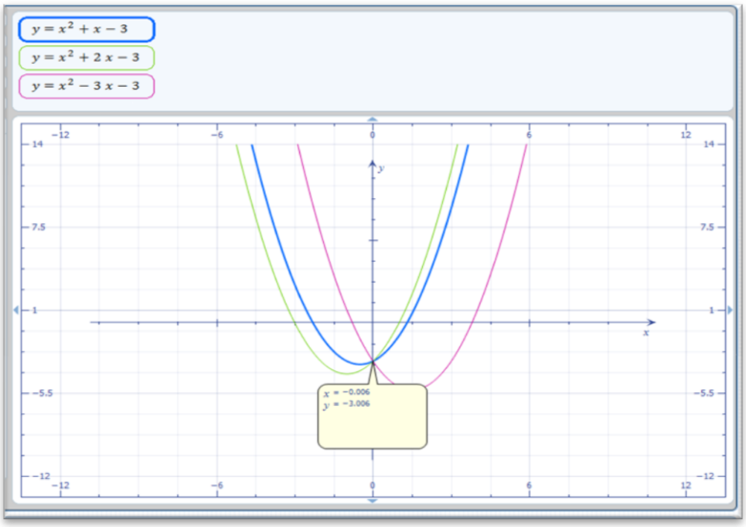

Figure 1: The transformational effect of *f*

More broadly, the researchers wanted students to develop habits in which use of the graphing software was accompanied by more analytic processes of prediction and reflection, so as to make them more critical users. The researchers wanted them to start to think about what a graph looks like before they actually click 'graph' using the software. This will enable them to know what a graph look like before they actually draw it thereby forming a mental image of the graph. In this way, students will have some idea of what they are expecting and spot their own mistakes in the future when drawing graphs, thus, achieving the purpose of the study.

In terms of activity format and structure, the lesson started with around 15 minutes of whole-class, teacher-led exposition and questioning, reviewing prerequisite material and previewing the tasks. They then followed about 45 minutes of student work, individually or in pairs, with the first researcher circulating to provide guidance and support. The lesson concluded with around 15 minutes of plenary review and elaboration of strategies and solutions, through whole-class, teacher-led exposition and questioning.

Minimum and maximum values and points of quadratic graphs & Line of symmetry

This part of the interventions was an aggregate one sixty minute's lesson (i.e. four periods) divided into two sessions. Each session composed of eighty minutes (2 periods). The objectives were to use the graphing software to :

- guide students to find the maximum and minimum values from graphs and state the coordinates of the points where these occurs ;
- assist students to establish that the quadratic graph is symmetrical about a vertical line and write its equation as $x = k$, where k is a real number.

Session 1: Investigating quadratic functions (minimum and maximum values/points)

This was another 80 munities lesson (2 periods) involving the respondents. Once again, it took place at the computer lab with students seated individually at a machine and a projectable computer available. The resource materials for the lesson consisted of two investigation and discussion exercises involving use of graphing software. The class was already familiar with the software, having used it several times in the previous lesson, but in the opening review the teacher reminded students where to find the function button in case some of had forgotten where that is.

The lesson agenda consisted of a quick opening review of transformational effect of varying the constants **a**, **b**, and **c** of the quadratic functions as exhibited in the previous lesson, followed by work on the structured investigations. The teacher first started by asking respondents to plot quadratic functions of any form of their choice and note their maximum and minimum values and points using the trace bottom of the software (see example in figure 2).

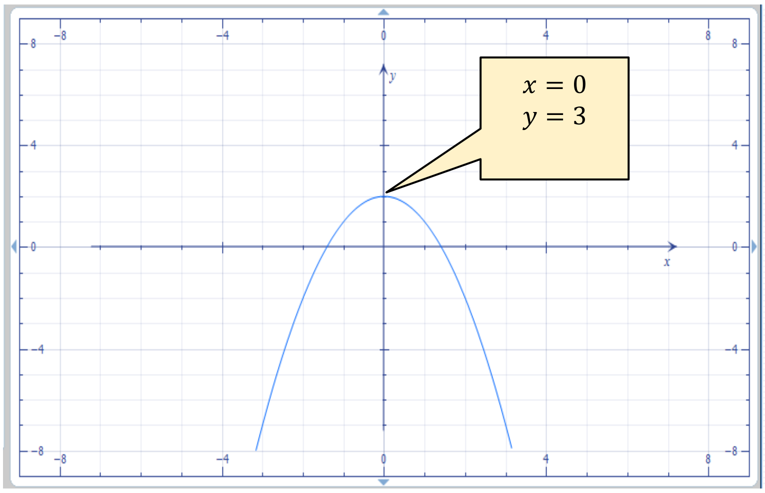

Figure 2 The quadratic graph with maximum point

The second investigation specified four groups of quadratic functions (such as $y = x^2$, $y = x^2 + 2$, $y = x^2 - 2$, $y = (x + 2)^2$, $y = (x - 2)^2$) and suggested examining cuts on the axes, extreme values, and lines of symmetry, to explore what the graphs in each group had in common(see figure 3). The activity format within the lesson alternated between periods of up to 10 minutes of whole-class, teacher-led exposition and questioning to prefigure, elaborate or review an investigation task, and periods of individual student work on these tasks with the teacher moving across the class to provide guidance and support. This lesson was more of them investigating, exploring, almost on their own.

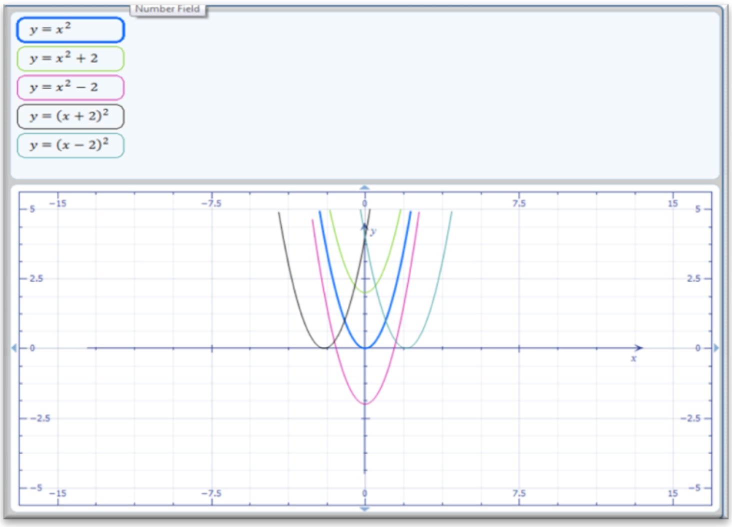

Figure 3The transformational effect of

Session 2: More investigation of quadratic functions (line of symmetry)

This lesson took 80 munities (2 periods). The resource system for the lesson consisted of a teacher-devised sequence of worksheets involving use of graphing software. The lesson agenda followed the sequence of worksheet tasks. Each task involved using the software to generate specified members of a family of graphs, recording these graphs on the worksheet, then completing a statement or answering a question designed to highlight their generic characteristics the line of symmetries (see figure. 4).

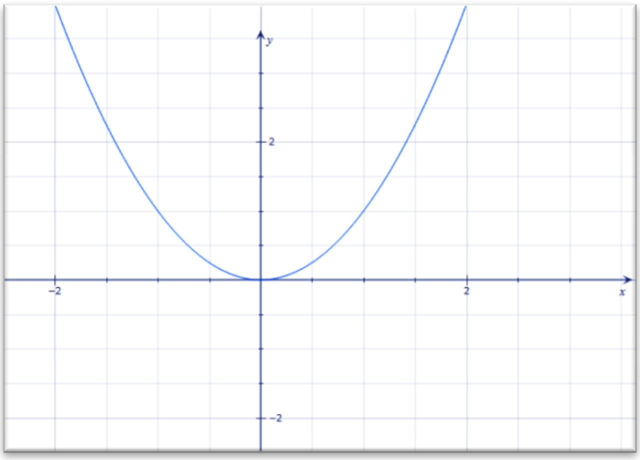

Figure 4 **The line of symmetry of the graph of** $(f) = x^2$

0) During most of the lesson, the activity format alternated between short bursts of whole-class, teacher led exposition and questioning to quickly prefigure or review a worksheet task, and more extended periods of individual student's work on these tasks with the teacher circulating to provide guidance and support.

This formed an activity cycle covering each task in turn. The lesson concluded with 15-minute plenary, reviewing and elaborating findings through teacher-led presentation and questioning. In preparing the lesson, a prime concern of the researchers has been to secure the active engagement of students. The interactive character of work with a computer and the requirement to record results on the worksheet were both intended to help achieve this.

Evaluations and limitation

A set of varied quadratic functions were given to students to find and state the maximum/minimum points and values of graphs they draw and also find the line of symmetry from a quadratic graph and write its equation after the intervention. The present study had several limitations, which may affect the internal as well as external validity of the result. Primarily, this is an action research, which involved students from one school only. The study lasted only three weeks and with topics from only quadratic functions. Only 43 Form 2 students participated in the study. The restriction to Form 2 class is based on the fact that they had difficulties in quadratic equation.

The study consisted with only this group of students and aimed to determine the effect of the graphing software. For better external validity and generalizability, the Solomon four-group design would have been better as the effect treatment would be replicated in four different fashions. This design would enable the researcher to determine both the main effect of the graphing software, and the interaction of testing and treatment, and combined effect of maturation and history. The generalization of the findings from this study to the entire population of senior secondary school students in Ghana must be approached with caution. For example, students of government schools and private schools may not show exactly the same performance; students of rural areas and urban areas may not show exactly the same performance; the achievement and motivation pattern of Form 3 students may not necessarily be like that of the Form 2 students.

Results

Question 1 *To extent can the use graphing software improve students' performance in quadratic functions?*

Both the pre test and post test were scored over 50 marks with 25 marks as the pass mark. When comparing the pre test and post test scores for all the participants (n=43), the average score of the pre test was 16.07 (SD=3.34) whilst that of the post test was 39.95 (SD=4.79), yielding a difference of 23.88 in the average class score. A t-test was conducted and it was found to be significant at 0.05 significance level (t = -36.472, p = 0.00; (i.e. p< 0 .01)), meaning that for the whole class the difference between the pre-test average score and the post-test average score was statistically significant(see Table 1). Hence the graphing software could significantly improved students' performance in quadratic functions.

Table 1 Pretest & post test scores of participants and t-test results

Test	N	Mean	SD	t	df	p –value
Pretest	43	16.07	3.341	-36.472	42	0.000
Posttest	43	39.95	4.791			

Question 2 To what extent will the performances of females and males be differently affected by the use of the graphing software?

In answering this research question, the post-test scores of both the male and female participants were taken and compared. From Table 2 the means score of males was 41.23 (SD=4.49) whilst that of the females was 39.40 (SD=4.88). This shows that the male participants performed slightly better that the female participants. An independent sample t-test was then conducted to determine whether or not this slightly better performance of male against the female was significant.

Table 2 The means score of the male and female participants

Sex	N	Mean	SD	t	df	p -value
Male	13	41.23	4.494	1.155	41	0.255
Female	30	39.40	4.882			

Table 2 indicates that the difference in the male and female participants' performance was statistically not significant (t = 1.155, p = 0.255; (i.e. p>0.05)). That is, female and male students performed equally well in the post test. Thus, the performance of male and female participants was not differently affected by the use of the graphing software.

Discussion

With regard to researcher question 1 the paired sample t-test was applied. The paired sample t-test was chosen because it assesses whether the mean (average) score of the pre test and post test was statistically different from each other. Therefore, by comparing the means of the pre test and post-test scores, this study found that participants performed better in the post-test than in the pre test and this deference is statistically significant. By implication, this finding depicts that the use of computer (Microsoft Math Tool) improved student's performance in quadratic functions.

This finding is consistent with findings of several other researches in the western world. In a review of studies, the CEO Forum (2001) concluded that technology can have the greatest impact when integrated into the curriculum to achieve clear, measurable educational objectives. Furthermore, a study of a comprehensive effort to integrate technology into schools shows an increase in test scores related to the use of technology. In West Virginia, Mann, Shakeshaft, Becker and Kottkamp (1999) found that when curriculum objectives for basic skills development in mathematics were integrated with instructional software, gains in student test scores on the SAT-9 (for 950 fifth graders in 18 schools) were attributable to the alignment of the targeted curriculum objectives with the software, teacher instruction and the tests.

In respect of answering the research question 2, the post-test scores of both the male and female participants were taken and compared. The findings in research question 2 implied that the male participants performed slightly better than the female participants, albeit not statistically significant. The implication is that the use of the computer (Microsoft Math Tool) did not give the male participants an advantage over their female counterpart and vice versa, at least statistically. Thus, the result of this study shows no gender differences in participants' performance after the intervention.

In general, the present analyses suggest that the observed positive effect of the intervention benefitted both male and female participants equally, in contrast with the general result of several studies in which males usually outperformed females (e.g.

Fox, Brody & Tobin, 1980). The implication is that the gap between male and female can be minimized or removed by the use of this intervention. These results concurred well with those of Sapienza (2008) who found that that boys are not innately better at mathematics than girls, and any difference in test scores is due to nurture rather than nature. According to Sapienza (2008) the 'gender gap' in mathematics, long perceived to exist between girls and boys, disappears in societies that treat both sexes equally. When girls have equal access to education and other opportunities they do just as well as boys in mathematics tests. In the context of this study, when boys and girls are taught mathematics with graphing software, their performance could be the same.

Conclusion, recommendation and implication

The results of this study revealed that integrating graphing software in the mathematics classroom is very effective. The effect of the graphing software on gender indicates that the graphing software benefited both male and female participants equally. This finding is of particular importance and interest of a developing country like Ghana where gender biases is still very pervasive. There is the need to increase female enrolment in the physical sciences and engineering for which success in mathematics is fundamental. The result of this study is consistent with findings of several other researches in the western world (e.g. CEO Forum, 2001; Mann, Shakeshaft, Becker & Kottkamp, 1999).

Primarily, irrespective of how good a programme or policy may be, its success depends substantially on the commitment and competence of those who implement it; in this case the teachers. A major implication of technology integration in the mathematics classroom is the need to equip mathematics teachers with the requisite skills and knowledge to be able to use technology as an instructional tool. Failure to do so, mathematics teachers might find it extremely difficult to weave technology attributes with the curriculum needs, classroom management and other instructional skills.

Therefore teacher training programmes of the 40 public teacher training institutions (two Universities and 38 Colleges of Educations) in Ghana must be supported so as to equip new mathematics teachers with the required professional competence and academic proficiency to integrate technology in the mathematics classroom effectively. Additionally, in-service training programmes need to be organized for practicing teachers. It is worthwhile to state however that the adoption of technology integration in the teaching of mathematics demand a change in the assessment procedure. This is because the technology integration, assessment should be an integral part of the learning object.

Finally, this study contributes to literature in two ways. First, it provides evidence that the use of graphing software in teaching mathematics could have a significant improvement on students' performance. Second, it has provided an idea of a pedagogical model for constructivist and situated learning approaches in conjunction with the effective use of computer technology.

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