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The Effect of Using Interactive Spreadsheet as a Demonstrative Tool in the Teaching and Learning of Mathematics Concepts

Douglas D. Agyei

University of Cape Coast, Faculty of Education,
Department of Science and Mathematics Education
Cape Coast, Ghana.
Email:ddagyei@yahoo.com

Abstract

This investigation studied pre-service teachers' development of reform oriented teaching through the use of interactive spreadsheet a demonstrative teaching tool in the learning of secondary school mathematics concepts. A qualitative analysis of various data sources (written lesson plans and reflections, observations, and interviews) for 8 participants working in teams of two was conducted. Findings showed the participants' growth in understanding and implementing interactive spreadsheet as a teaching tool in the development of mathematics lessons; their pedagogies and classroom management were enhanced. Furthermore, the study showed that adoption of the spreadsheet application as a tool for instruction and learning was key in enhancing students' higher–order thinking and mathematics concepts formation. Implications of these findings are discussed.

Introduction

Teaching and Learning mathematics place a lot of challenges to teachers and has increasingly become an important concern to stakeholders in education: government, parents and schools. Many countries are currently experiencing a gradual dropdown on students' participation and performance in mathematics (Beauchamp & Parkinson, 2008). Ottevanger, van den Akker and de Feiter (2007) attribute such failure to teachers' lack of important teaching competencies and lack of students' motivation in the subject. Koehler and Mishra (2009) also refer to this problem as stemming from both teaching approaches and the way students learn. This seems to suggest that effective teaching approaches have high potential to impact on students' learning.

Technology use in education has been identified as an important tool in promoting effective teaching and learning in recent times. Many studies (eg. Tilya, 2008; Voogt, 2003) have demonstrated advantages that technology uses in education seem to have on teachers and students' learning. According to various studies (Collis & Moonen, 2005; Nieveen, Handelzalts, van den Akker & Homminga, 2005), the use of technology in teaching, presents a paradigm shift from a teacher centered to a learner-centered, from individual learning to collaborative learning, and from a teacher as a source of knowledge to a learner as source of knowledge. So and Kim (2009) indicated that technology can play a critical role in representing a certain subject matter to be more comprehensible and concrete, helping students correct their misconceptions on certain topics, providing cognitive and metacognitive scaffoldings, and ultimately improving learning outcomes. Several other studies address the importance of incorporating technology in mathematics teaching to improve the way mathematics is taught and enhance students' understanding of basic concepts (Keong, Horani & Daniel 2005), as well as enhance motivation and improve the performance of students (Beauchamp & Parkinson, 2008). Voogt (2003) indicated that technology use easily support constructivist pedagogical approach where students explore and reach an understanding of mathematical concepts by concentrating on problems solving process rather than on calculations related to the problems as a result. While it is encouraging to see that several previous studies have demonstrated positive effects of technology integrated lessons on students' outcomes, a search of literature shows that many of these studies have not focussed on interactive spreadsheet applications. In spite of its potential to support higher-order thinking skills, spreadsheet use is limited or even non-existent in most mathematics classrooms primarily because teachers have not been prepared to integrate them as teaching and learning tools; few teachers have used spreadsheets as tools for learning mathematics, leaving many of them unprepared to guide students in learning mathematics with spreadsheets (Niess, 2005). In this study, a professional development arrangement was enhanced to provide opportunities and support for pre-service teachers to design and use spreadsheet–supported lesson teaching materials in their instruction. The effect of the arrangement on the teachers' teaching practices and students' learning was examined.

Potential of spreadsheets for mathematics education

Spreadsheets have been around since the early 1980s and, although not designed as an educational tool, have been used in mathematics classrooms since they first became available (Jones, 2005). According to Niess (2005), spreadsheets offer dynamic modeling capabilities that lead toward their use as a mathematical problem solving tool with the capacity for engaging students in higher-order thinking skills that supports them in exploring beyond initial solutions. She indicated that spreadsheets offer a technology readily available among classroom technologies with the potential for supporting students' higher-order concepts development in the mathematics curricula. Niess, Sadri and Lee (2007) recognized advantages of using spreadsheets for solving complicated problems, motivating students, and providing opportunities for students to extend problems to additional hypothetical situations. Their study reported that teachers who are able to design and enact spreadsheet lessons engage their students in critical thinking to explore mathematical concepts and processes for accurate analysis. Jones (2005) indicated that one way to help learners move from a non-algebraic to an algebraic approach is through work with spreadsheets. He explained that in using such a tool, compared to using paper and pencil, learners appear to be able to learn more readily to express general mathematical relationships using the symbolic language in the spreadsheet environment. Dettori, Garuti and Lemut (2001) suggested that while using spreadsheet may lead learners to solve problems using “trial and improvement”, under the guidance of the teacher they can come to understand what it means to solve an equation, even before being able to handle equations. Liang and Martin (2008) illustrated how to use interactive spreadsheet to enhance students’ understanding in difficult and important calculus-based mathematical principles. Their study showed that spreadsheet can greatly simplify the interpretations of pure calculus principles and can substantially reduce students’ misunderstanding in applying calculus principles in solving quantitative business problems. Oldknow and Taylor (2003) indicated that interactive spreadsheet allows learners to deform shapes dynamically and observe which of their properties change and which stay the same. Further, they reiterated that the vivid and dynamic images produced when modeling with spreadsheet help learners to form mental images on which to base their understanding of concepts. Such concepts include parallelism. Kissane (2007) explained that spreadsheet has the ability and capacity to support the teaching and learning of algebra and statistics. He furthered reiterated that interactive spreadsheet offers an environment in which early ideas can be developed regarding topics as functions and equations.

The potential of spreadsheet as an instructional tool does not seem to impact on students learning only, but pre service teachers as well; enhancing and extending their knowledge of their subject matter and influencing their pedagogies and classroom management (cf. Author, 2012). Niess et al. (2007) indicated that teachers who are able to design and enact spreadsheet lessons experience elementary concepts of mathematical modeling, expand their own conceptions of teaching mathematics with spreadsheets, investigate and expand their knowledge of instructional strategies for integrating spreadsheet learning activities, develop their own knowledge and skills of spreadsheets as tools for exploring and learning mathematics, and explore curricular materials that support learning with and about spreadsheets over an extended period of time. This redirection exposes the importance of teachers’ strategic thinking and actions with respect to integrating technologies as learning tools in mathematics instruction. Niess, van Zee and Gillow-Wilise (2010-11) also indicated that spreadsheets contain features for modelling and analyzing change, providing teachers with tools that support mathematics concepts and processes for accurate analysis. In this study, spreadsheet has been used as a tool for teaching and learning mathematics, to provide pre-service teachers the opportunities to develop their personal knowledge and skills for teaching with technology and also promote student in-depth mathematical concept formation and learning.

The Professional Arrangement

Eight weeks professional development arrangement was organized for the pre-service teachers in the study. The arrangement consisted of three stages: an introductory workshop, the design stage and implementation stage. The workshop lasted for two weeks and was aimed at preparing the pre-service teachers by giving them practical basic skills necessary for spreadsheet integration. The topics included: introduction to spreadsheet, entering and correcting data in excel, naming of cells in Microsoft excel, creating or changing cell reference, naming or defining of cells, basic mathematical operators, working with mathematical functions creating and deleting formulas, creating charts and graphs etc. Since these pre-service teachers were novices in the use of technology, they were also introduced to word processing application and presentation applications. During the design stage (4 weeks), the pre-service teachers were challenged to select mathematics topics suitable for teaching with spreadsheets, and to make use of the affordances of the technology to design learning activities that foster higher order thinking in mathematics. They were to carefully choose instructional strategies they felt will be useful in supporting their lessons. The teachers worked in teams of two to develop and model their own spreadsheet-supported lessons by the end of the sixth week and implemented them in different senior high school classrooms during the two-week implementation period. T**he topics they designed and taught were polynomial functions, linear equations, trigonometric functions and enlargement.** Each lesson comprised of a plan for lesson implementation and a student worksheet which promoted hands-on activities during lesson implementation. All lessons were taught in a classroom with a computer and a LCD projector available to the teacher. The researcher's role was purely demonstrative and consultative at various stages of the study.

Research questions and research design

The study examined the impact of interactive spreadsheet-enhanced lesson use on pre-service teachers' classroom practices, and their students' learning of mathematical concepts. The main research question that guided the study was: What are the effects of using interactive spreadsheet on pre-service teachers' classroom practices and their students learning of mathematical concepts? The following sub research questions guided the study: (1) how did the pre-service teachers implement the interactive spreadsheet-enhanced lesson materials in their teaching practices; and (2) how was the learning of their students' mathematical concepts enhanced? A case study of 8 pre-service teachers was applied (Yin, 1993). The study focused on an in-depth investigation of the effect of spreadsheet on pre-service teachers' development of knowledge and skill of instructional strategies for integrating spreadsheet learning activities and student learning of mathematical concepts. The study employed an embedded design using multiple sources of qualitative method evidence. Consequently the units of analyses were the pre-service teachers and their lesson artifacts as well as their students from the Senior High Schools (SHSs). The case was the effect of the interactive spreadsheet application learned and applied during the professional development arrangement which was organized within the context of the mathematics teacher education programme at the University of Cape Coast (UCC).

Methods

Participants

Eight (5 males and 3 females) pre-service mathematics (selected on purpose) and 135 senior high school students (who were taught by the pre-service teachers) participated in the study. The pre-service teachers were in their final year of the teacher education (B.Ed Mathematics) programme at UCC. The B.Ed (Mathematics) is a 4-year programme which allows graduates to teach at Junior and senior high schools after their training. The pre-service teachers have not had any experience in technology-supported lesson; neither as part of their training nor in their pre-university education. The average age was nearly 26 years. The SHS students (94 males and 41 females) were in years 2 and 3 from 4 SHSs that were selected at random from the Cape Coast municipality in Ghana. Their average age was approximately 16 years.

Instruments

Three types of data from the respondents (self-reported, product evaluation and classroom observation) were collected. In Table 1 an overview of the data collection instruments measuring the effect of interactive spreadsheet on pre-service teachers' classroom practices and students' conceptual learning of mathematics lessons are presented. The instruments were used at various stages of the professional development arrangement.

Table 1: Effect of interactive spreadsheet use on teachers' classroom practices and student learning of mathematics concepts

Instrument	Construct	Measurement Type	Source	Type	Stage of Adminstration
Lesson Plan (Rubric)	Teachers' demonstration of mathematical concept	Performance assessment	Team	Artefact	Lesson implementation
Lesson Observation	Students learning of mathematical concepts	Performance assessment	Team	observable	Lesson implementation
Semi-Structured Interview	Students learning of mathematical concepts	Survey	Team	Self-report	After lesson implementation
Student Worksheet	Students learning of mathematical concepts	Performance assessment	Student Groups	Artefact	Lesson implementation

Logbook was used by researcher at different stages of the study

Lesson Observation

A direct semi-structured observation was done during the lesson implementation. The observation focussed on events as they happened in a classroom, for example, how teachers use spreadsheet applications to deliver lessons, communicate concepts, introduce the lessons, engage students in activities and enhance student learning manage their classrooms. Two raters (the researcher and another expert) were responsible for data collection and analysis of the data. The interrater reliability (Cohen's κ) was $\kappa = 0.92$.

Lesson Artefacts

Analyses of written documents including lesson plans and student worksheets were done. The documents were coded and assessed. Emergent themes included skills about use of spreadsheet, roles of teachers/students, pedagogy/instructional strategies. Two raters (the researcher and another expert) were responsible for analysis of the data. The interrater reliability (Cohen's κ) was $\kappa = 0.92$.

Teacher Interviews

Interview data was collected after each teaching session. This interview focused on teachers' experiences and opinions of interactive spreadsheet supported lessons; reflecting their views from the planning and preparation stage to the actual implementation of lessons as well as a post- review of the teaching. All interviews were audio-taped and transcribed using pattern coding techniques (Miles and Huberman, 1994).

Researcher's Logbook

A researchers' log book was used to maintain record of activities and events occurring during the design and enactment of the spreadsheet supported lessons. The logbook entries complemented findings from the other data collection instruments. Information recorded in the logbook was analyzed qualitatively using data reduction techniques in which major themes (classroom management; teachers' role; pedagogies used, concept communication, concept learning and challenges in enacting the spreadsheet supported lessons) were identified and clustered (Miles & Huberman, 1994).

Results

Pre-service teachers' classroom practice

During the lesson implementation, the pre-service teachers applied their knowledge and skills in enacting activity-based lesson by employing a mix of direct instruction and hands-on activity to guide students through activities with spreadsheets. The pre-service teachers used their lesson plans to guide class instructions and by changing parameters in cells, they used the spreadsheet in an "interactive demonstrative" lecture stimulating students' discussions with worksheets to help students explore mathematics concepts and perform authentic tasks. The pre-service teachers were able to demonstrate a wide range of examples of graphs by changing variables in cells

without having to draw them physically. As a result learners were able to explore many graphs in a shorter time, giving them greater opportunity to consider general rules and test and reformulate hypotheses. For instance during the trigonometry function lesson, the pre-service teachers used the spreadsheet to allow for investigating the nature of graphs of trigonometric function graphically providing a visual link between graphs of trigonometric functions and their solution sets . This made it relatively easier for students to match graphs of trigonometric functions and their solutions on their worksheets. In the lessons on linear equations and quadratic functions, the pre-service teachers used spreadsheet to guide their students to explore patterns, (see how changes in parameters affect graphs) to assist them in making generalizations from the observed patterns. Visual representations of algebraic functions allowed for immediate feedback, which allowed learners to concentrate more on mathematical relationships rather than on the mechanics of construction. Furthermore, graphic representations from the use of the spreadsheet made it relatively easy for the teachers to guide their students in identifying properties of families of functions. In all the lessons, activities were carried out in groups (2-3 students) on the worksheets and this promoted healthy interactions among students and also between students and the teacher. The pre-service teachers used the spreadsheet environment to generate active interactions among students and to engage them in different learning activities to support their learning. For instance in all the lessons, the students view presentations, collected data, explored patterns and made predictions. In the lessons on trigonometry functions and quadratic functions, students collaborated in teams to explore relationships/properties of functions and their graphs, making generalization through discussions. In the lesson on enlargement, students viewed presentation, collaborated to collect data (on coordinates of an object) and made predictions of the image location when the object was rotated by a vector. In the lesson on linear graphs, students worked in teams to explore the properties of linear equations and presented their work to their peers in teams for peer assessment.
It was apparent from the lesson observations that the use of the interactive spreadsheet impacted on pre-service teachers' classroom practices and this was reiterated in the interview data. For example, one of the pre-service teachers indicated in an interview that, it would have been a struggle to teach the concept of negative angles in trigonometry functions to his student without the aid of the spreadsheet application. He indicated:

> *I was thinking of ways of representing and communicating this concept for students to understand the way we did without the graphs, but the spreadsheet demonstrations told it all.*

Inpsite of the positive impact on their teaching practices, the pre-service teachers indicated some challenges regarding designing spreadsheet supported lessons. They mentioned that generating authentic activities and ill-structured problems for their chosen topics was one of the challenges. They also mentioned experiencing difficulties in finding and integrating appropriate spreadsheet applications for the learning activities they designed. These frustrations were observed in their interviews.

For example in one of the teams, a member indicated:

> *In designing the learning activities for our students' worksheet, we had to go through so many iterations. The challenge had to do with designing a task that will promote active learning and at the same time help student form the needed concept.*

The second member of the same team also indicated:

> *We had to strike a balance between making the activities suitable for team learning and at the same time meeting the learning objectives*

Other teachers' indicated the following:

> *Designing innovative and creative activities having in mind the objectives of the lesson took us a long time in accomplishing this task.*
>
> *Deciding on what concepts that needed the incorporation of spreadsheet application was a struggle in our case…*
>
> *It was difficult to think of appropriate spreadsheet applications that tied in with the topic (Trigonometric functions) we taught…*

Students' understanding of some mathematical concepts

Trigonometric functions in the form of $y = asin^2x + bsinx + k$

Of the 4 teams of pre-service teachers who were observed, team 1 (t11) taught a lesson on trigonometry functions. They used spreadsheet to prepare a graph of trigonometric function in the form $y = a\sin^2 x + b\sin x + k$ on the interval $0^0 \leq x \leq 360^0$. By using cell references they labelled the parameter *a*, *b* and *k* in cells *B24*, *B25* and *B26*.The values of *x* range from 0^0 to 360^0 while the *y* values were calculated using a formula that includes cell references for the parameters *a*, *b* and *k* represented in cells *C24*, *C25* and *C26* respectively. By observing how changes in the parameters had immediate feedback on the graph, the learners got first-hand information on the role played by each part of the equation. For example in demonstrating the effect of *a* on the graph of $y = a\sin^2 x + b\sin x + k$, the pre-service teachers in the lesson first set the values of $b = 0$, $k = 0$ whiles $a = 1$ and kept altering the value of *a* while the students observed and recorded the changes in the graph on their worksheet.

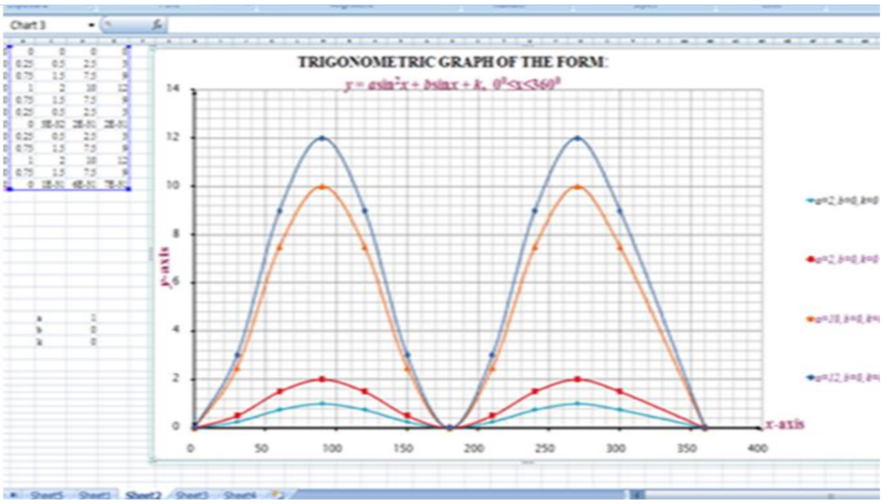


Figure 1: Snapshot of trigonometric graph in the form of $y = a\sin^2 x + b\sin x + k$ (Investigating a)

The demonstrations helped the students to understand that when $|a|$ of any trigonometry function of the form y $= a\sin 2x + b\sin x +$ k increases the peak of its graph increases and when $|a|$ decreases the peak of the graph decreases. This was a difficult concept for students prior to the lesson. Similarly students were able to identify that when *a* is positive (+) the graph is located above the x-axis and below x-axis when *a* is negative (-). Another discovery the students made was the effect changes of the parameter *b* had on the graph. They noted that the graph opens downwards on the interval $0^0 \leq x \leq 180^0$ when *b* is (+) opens downwards on the interval $180^0 \leq x \leq 360^0$ when *b* is (-). Exploring the effect of *k* on the graph y $= a\sin 2x + b\sin x + k$, students visualised that when the value of *k* increases, the graph moves upwards, and downwards when the value of *k* decreases. While communicating such a concept could have been a challenge, the interactive spreadsheet demonstrations helped the teachers a great deal by avoiding word-only description in assisting students achieve such a concept.

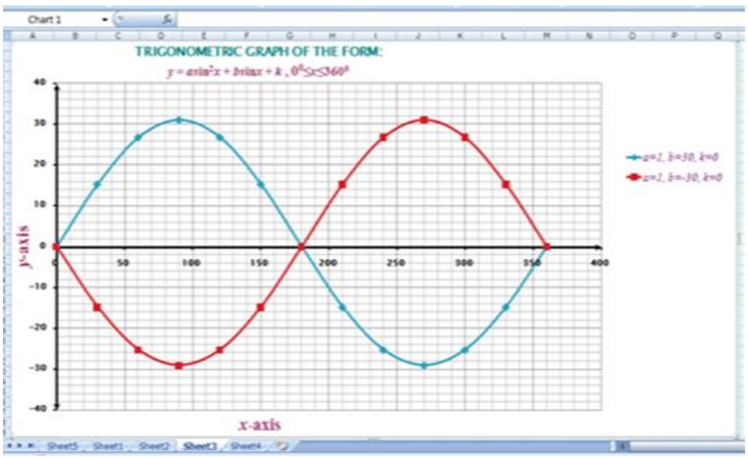


Figure 2: Snapshot of Trigonometric graph in the form of $y = a\sin^2 x + b\sin x + k$ (Investigating k)

The pre-service teachers of the lesson generated a wide range of examples of graphs by changing the values of the parameters without having to draw them physically on the board. This helped the learners to explore many examples through observations and generalization of patterns regarding the effect of the parameters on the trigonometric functions conceptualising their mathematical knowledge.

Nature of the graph of quadratic function: $y = ax^2 + bx + k$

Among the objectives team 2 (t22) wanted their student to achieve, was how changes in the parameters of a quadratic function in the polynomial form affect its graph. The teachers of the lesson guided their students to discover from the visual representation of the algebraic functions, mysterious behaviours of the quadratic function when the parameters a, b and k were altered. For instance beginning with simulations of the graph $y = ax^2 + bx + k$ when b=0 and c=0, students discovered that the basic second-degree curve $y = ax^2 + bx +$ gives a thinner parabola if $|a|$ is increasing and a flatter parabola if $|a|$ is decreasing (See figures 3 and 4). Thus the coefficient a was identified to control the increase/decrease of the quadratic function from the vertex.

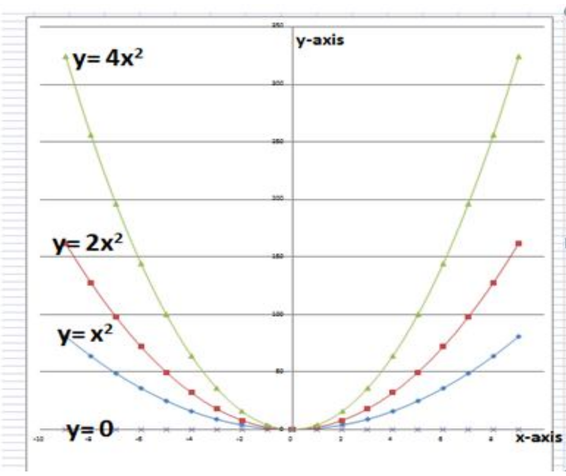


Figure3: Snapshot of graphs of $y = ax^2$, $a > 0$

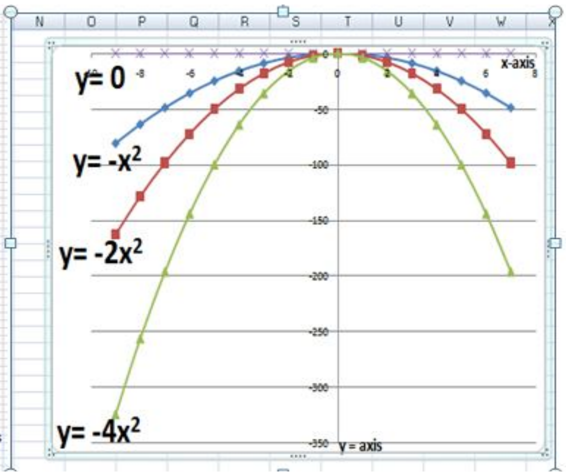


Figure 4: Snapshot of graphs of $y = ax^2$, $a < 0$

The students also visualised that the parabola $y = ax^2$ opens upward when $a > 0$ (See figure 3) and opens downwards when $a < 0$ (See figure 4). The axis of symmetry was identified to be $x = 0$, symmetrical about the y-axis passing through the minimum point (0, 0). Another interesting observation the students made during the lesson was the effect of k on the parabola. They identified that k moves the parabola vertically upwards or downward (see figure 5).

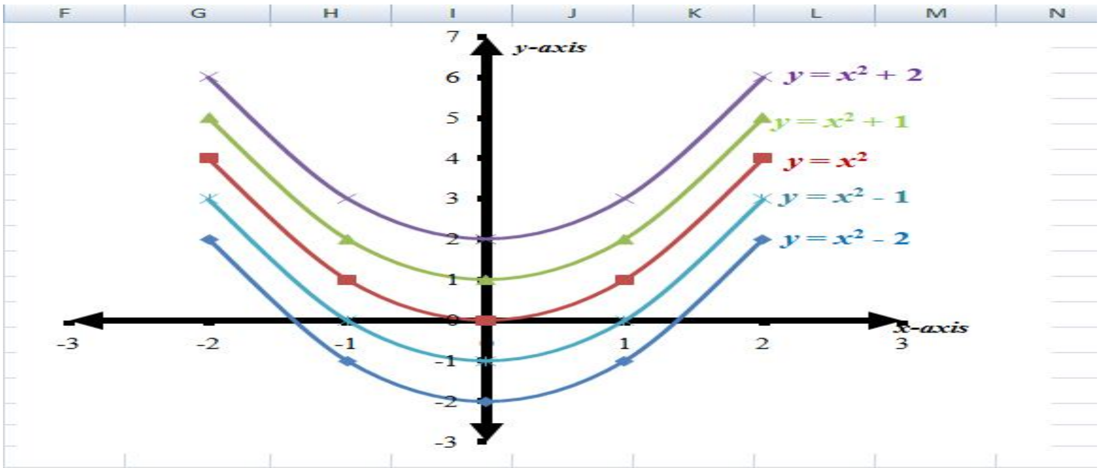
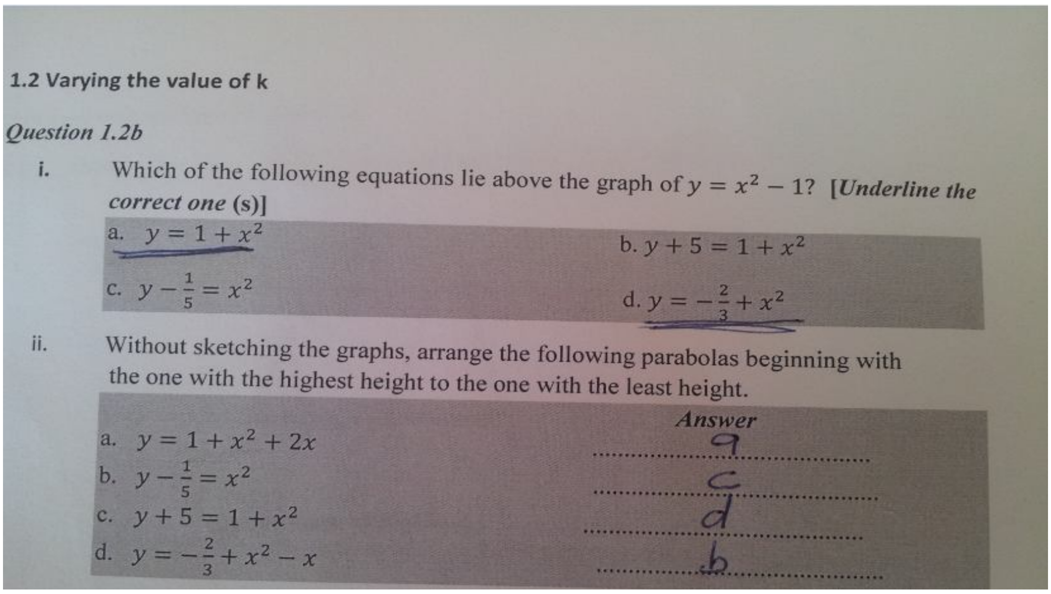


Figure5*:* Snapshot of graphs of: $y = ax^2 + bx + k$; b=0, altering k

The students also understood that k controls the height of the parabola and it is the value that moves the parabola vertically upwards or downwards. They demonstrated this understanding by providing right solutions to activities that were given to them. For example about 89% of the student groups in the class answered all questions on activity 1.2b correctly where as 11% had only question (i) correctly. Figure 6 shows a snapshot of the solution provided by one of the groups indicating correct answers for both questions.



1.2 Varying the value of k

Question 1.2b

i. Which of the following equations lie above the graph of $y = x^2 - 1$? [*Underline the correct one* (s)]

a. $y = 1 + x^2$ b. $y + 5 = 1 + x^2$

c. $y - \frac{1}{5} = x^2$ d. $y = -\frac{2}{3} + x^2$

ii. Without sketching the graphs, arrange the following parabolas beginning with the one with the highest height to the one with the least height.

	Answer
a. $y = 1 + x^2 + 2x$	a
b. $y - \frac{1}{5} = x^2$	c
c. $y + 5 = 1 + x^2$	d
d. $y = -\frac{2}{3} + x^2 - x$	b

Figure 6: A snapshot of students' solution to some activities from their worksheet

Such similar deductions of concepts were identified by the students throughout the lesson. Thus through such investigations, students were able to observe the changes in numerical data and their graphical representation concentrating more on mathematical relationships rather than a mechanic of construction or mere solutions. This helped them to make connections between different quadratic function types.

Enlargement

Pre-service teachers of team 3 (T33) conducted their lesson on enlargement focusing on how changes in the scale factor k affect the behavior of the graph of a given object. They had begun the lesson by asking students do some exercises on their worksheet since the students had prior knowledge of the topic from the junior high school. The same exercise was repeated by the students after developing the lesson. During the lesson delivery, the teachers guided student to discover several concepts.

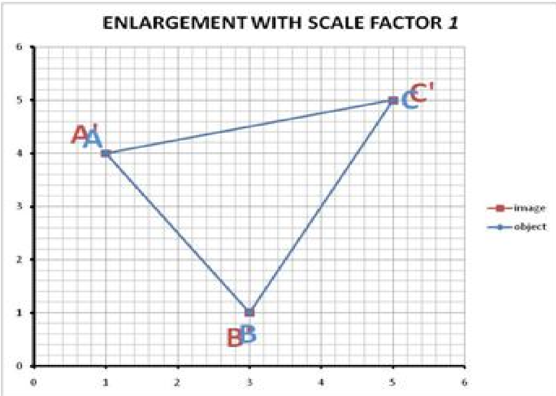


Figure7*:* Enlargement with: $k = 1$

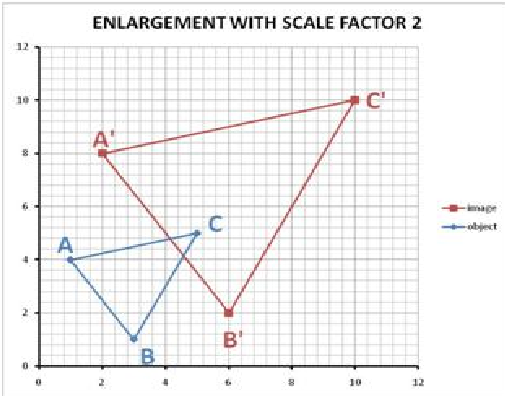


Figure 8*:* Enlargement with: $|k| > 1$

For instance student were able to discover that the size of an image is the same as its object when k =1 (figure 7) but the image becomes larger than its object when |k|, the scale factor of enlargement increases (figure 8). When |k| decreases the image becomes smaller than its object (See figure 9).

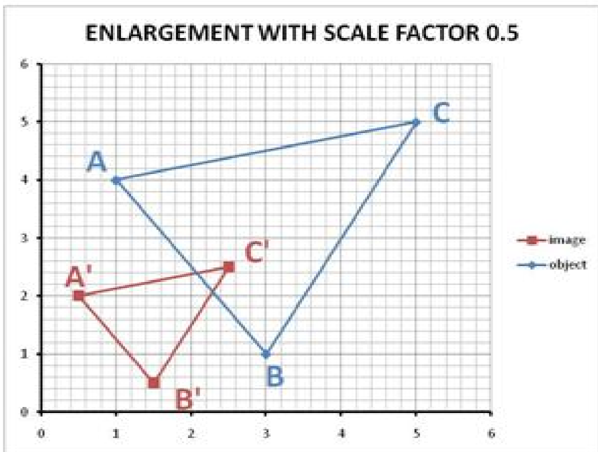


Figure 9*:* Enlargement with: $k < 1$

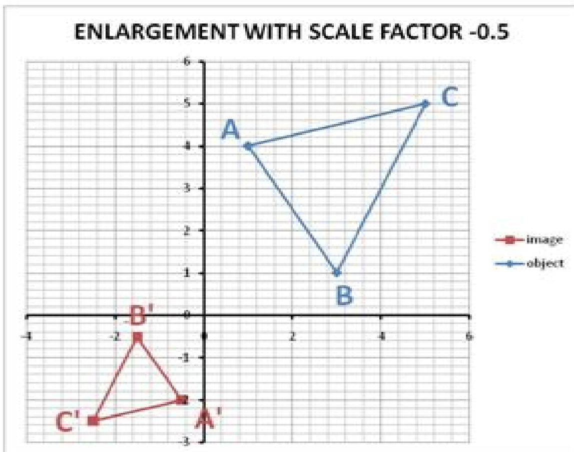


Figure10*:* Enlargement with: $k < 0$

Another observation the student made was that an image becomes invertible at the opposite side of the object when k is negative (See figure 10).The students explored several concepts through the opportunities the interactive spreadsheet offered and this was evident in the marked difference in performance of students' activities before and after the lesson. In figures 11 and 12 a case in point of a groups' solution of activities they performed (before and after the lesson respectively) are presented.

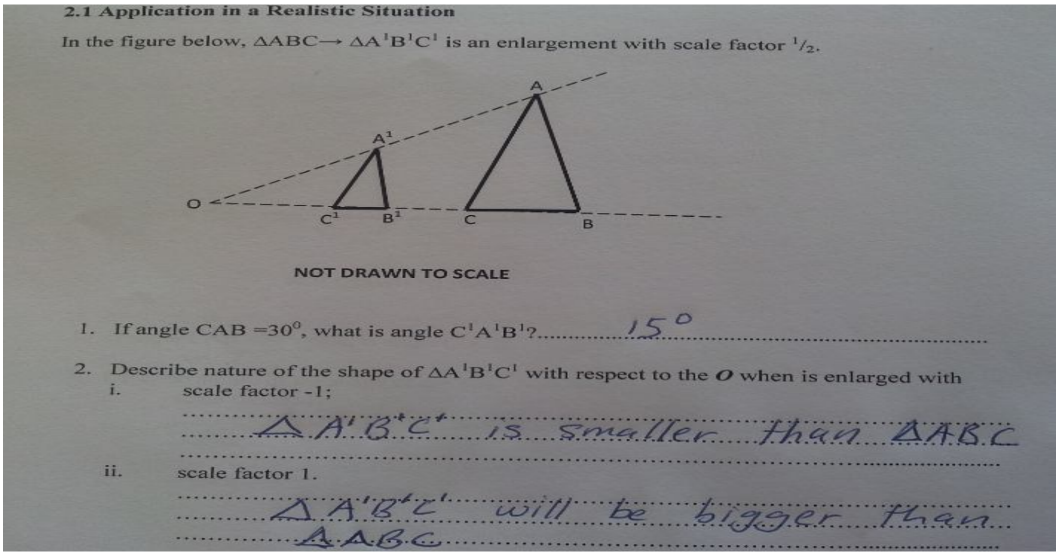


Figure 11: Snapshot of a student group's activity (before lesson delivery)

The dialogue that went on between this group (S22 and S23) and the teachers (T33) before the lesson delivery was:

T33: what is $\Delta\ C^1A^1B^1$
S22: 15^0
T33: why?
S23: since the scale factor is a multiplier, "we multiplied the 30^0 by $^1/_2$"
T33: ok! what about the answers for b? how did you describe the nature of the image when ΔABC is enlarged by scale factor -1?
S23: $\Delta A^1B^1C^1$ will be smaller than ΔABC….; **S22**: yes!
T33: how did you come by that answer?
S22 and **S23**: because the scale factor is negative
T33: what about if the scale factor is 1?
S22: then $\Delta A^1B^1C^1$ will be the same as ΔABC
T33: but why? the scale factor is positive!! (No response from **S22** and **S23** and appears to be in doubt). This statement generated informal discussion among other students. Teacher calls another student
Student: $\Delta A^1B^1C^1$ will be bigger than ΔABC because the scale factor is positive.

These responses by the student gave a clear indication that though they had been taught the lesson in the junior high school year 3, the concept of a scale factor was still not clear to them. When **T33** had delivered the lesson, the dialogue continued after the exercise had been repeated for the same group of students:

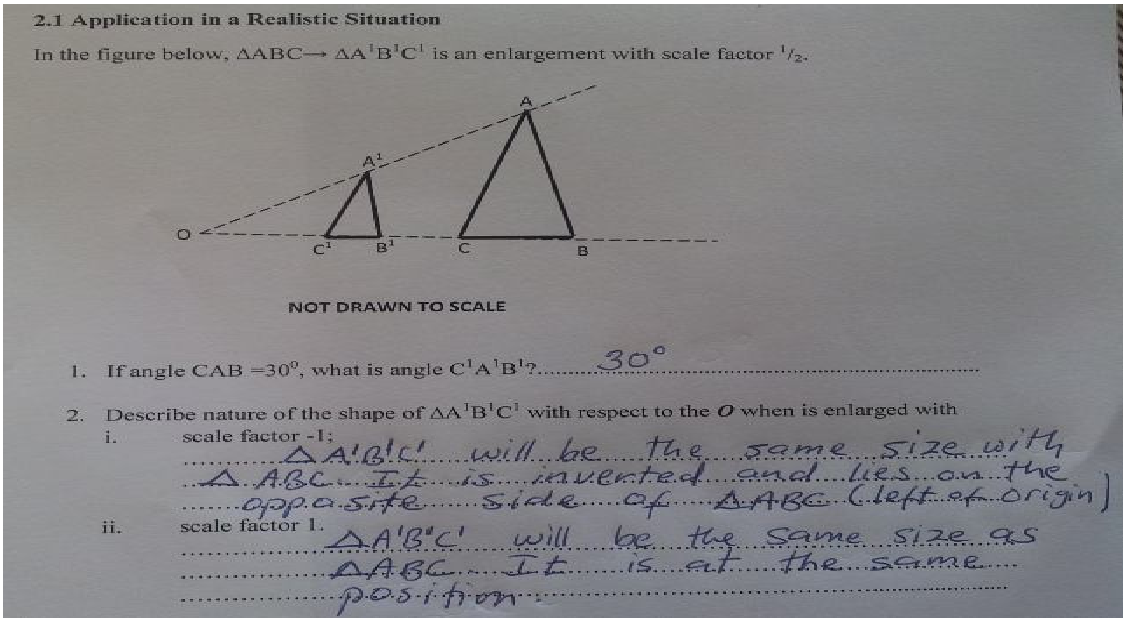


Figure 12: Snapshot of a student group's activity (after lesson delivery)

T33: did you have a different answer for $\Delta\ C^1A^1B^1$?
S22 and **S23**: yes! 30^0
T33: why the difference now?
S22: we found from the spreadsheet activities that when an object is enlarged the angle does not change.
T33: what about your answers for b?
S22: when the scale factor is -1, $\Delta A^1B^1C^1$ will be the same size as ΔABC but it is inverted and $\Delta A^1B^1C^1$ will be at the left of ***O...***
S23: when the scale factor is 1, $\Delta A^1B^1C^1$ will be the same size as ΔABC and remains at its original position...

It is worth noting that the solutions the students provided for *b* (regarding the nature of the image $\Delta A^1B^1C^1$ of ΔABC) after they have had the lessons were more precise and exhaustive addressing all issues regarding the nature of the image being: *size*, *location* and *shape*. This was not the case before the lesson; they only gave a response on the *size* of the image. Thus through the investigations, students were able to compare the graphs of enlargement and how changes in the scale factor affect the behaviour of the graph. They discovered that in enlargement the *shape* of the object is preserved but the *size* may change (i.e. both the object and its image are similar because the angles at the corners of both are congruent).

Linear Equations

The pre-service teachers (T11) of this lesson taught student in year one at the senior high school. The topic was a core mathematics one. The teachers developed the lesson by making up the standard or basic form of linear equation and gradually guiding students to observe and compare the graph of a linear function to its equation

$y = mx + k$ by varying the parameters m and k of the equation and exploring how the graph changes in response.

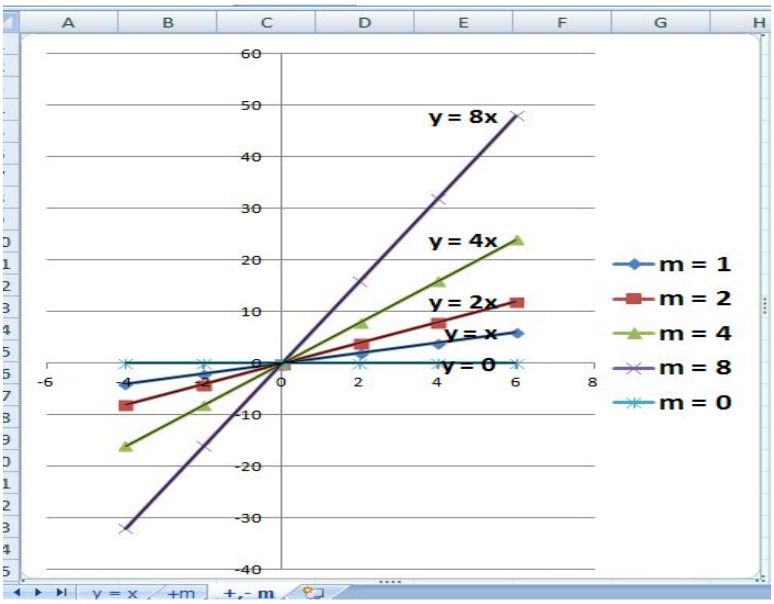


Figure 13: Snapshot of graphs of: $y = mx + k$, ($m \geq 0$)

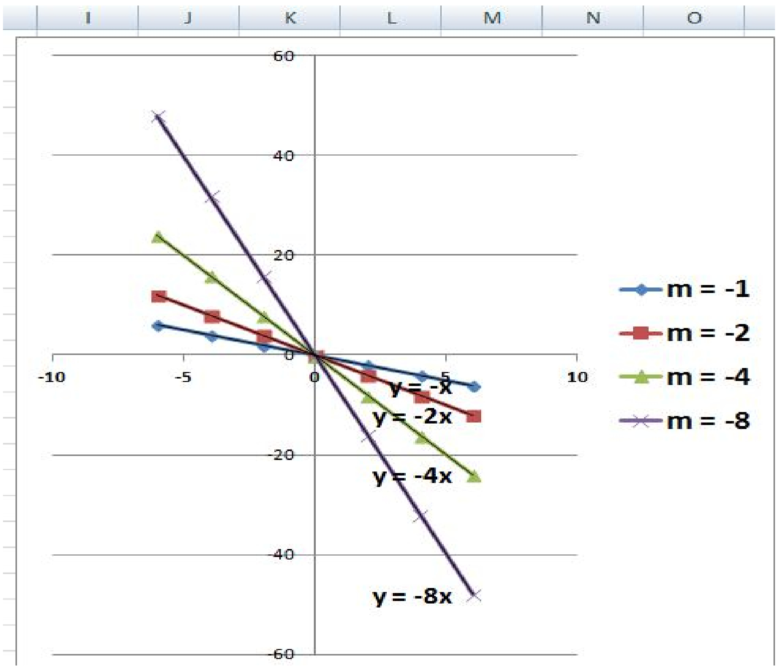


Figure 14: Snapshot of graphs $y=mx+k$, ($m<0$)

Students discovered a number of concepts. For instance when *m* was positive, the graph increased to the right (see figure 13) but decreased to the left when *m* was made a negative number (see figure 14). When m was set to zero, the graph became horizontal line with equation y = 0 which lied on the *x*-axis. What T11 found difficult for students to conceptualize was the effect of the absolute value of *m* on the graph. It appears the students could not connect the resulting changes in the graph (which is wider or steeper?) to changes in the numerically values (T11 displayed graph after graph on the same spreadsheet when the co-efficients were altered). After some time of struggle, the teachers were able to present the concept much better by demonstrating the different values of the co-efficient with their respective graphs on the same spreadsheet as shown in figures 13 and 14.This helped the student to discover that as the absolute value of *m* increases, the graph becomes steeper and less steeper as the absolute value of *m* decreases. Following the activities, the students were able to determine the *y* and *x*-intercepts and the relationship between the *x*-intercepts *m* and *k*. What was a struggle for most of the students was reading coordinates of the point of intersection for any two given line segments (eg. the coordinates of the *x*- and *y*-intercepts). The teachers however learnt how to zoom out on the co-ordinates of points and that was an improved way to allow students read and record their own values during the lesson. Another difficulty observed during the lesson was students' verifying graphical solution set (from the spreadsheets) of two linear equations in two variables by solving them algebraically either by the method of elimination or substitution. The graphical solution sets appeared approximated and in most cases did not match answers from the students' algebraic solutions of the same set of equations. "Increase decimal" button on the spreadsheet helped the teachers to show more precise values to verify algebraic solution sets in the lesson enhancing their students' conceptual understanding of the topic.

Discussion

The study was conducted to explore the potential of spreadsheet as an instructional tool to impact pre-service teachers' instructional practices and classroom management as well as students' learning; enhancing and extending their knowledge on subject matter. The pre-service teachers recognized the advantages of using interactive spreadsheet as a tool to investigate and expand their knowledge of instructional strategies for integrating spreadsheet learning activities to enhance students learning. The use of the interactive spreadsheet allowed the teachers to make use of spreadsheet features that would not be possible using conventional means. For example, zooming in on different levels of details and automatic measurement of angles or areas or figures enhanced students understanding and concept formation. **Further,** the use of spreadsheets as an instructional tool influenced and changed pre-service teachers' pedagogies influencing them to synchronise their teaching methods with student learning. The spreadsheet environment appeared useful to engage pre-service teachers in the design of learning activities to support mathematics learning of students, such as: discussing presentations, collecting data (e.g. on the co-ordinates of an object), working in teams, making predictions. This variety of learning activities offered the pre-service teachers to orchestrate student learning in various ways (cf. Drijvers, Doorman, Boon, Reed & Gravemeijer, 2010). This is the kind of pedagogical reasoning (cf. Webb & Cox, 2004) that pre-service teachers need to undertake in their planning and teaching of ICT-enhanced lessons. **Inspite of its potential to** change the way classrooms operate and **promote a** more interactive and participatory teaching and learning, the study demonstrated some setbacks regarding the limited range of the potentials of interactive spreadsheet applications. A significant barrier affecting teachers' capacities for integrating spreadsheets in the curriculum was the difficulty in identifying appropriate topics and content in their own curriculum. Even with their chosen topics, the pre-service teachers in the study indicated that they faced challenges determining and integrating appropriate spreadsheet techniques for the learning activities. Another disadvantage with the use of the spreadsheet had to do with its inability to create learning environment for students to acquire the skill of graphing practically with paper and pen as well as doing their own calculations. These disadvantages notwithstanding, **the study demonstrated that spreadsheet enhances** conceptual understanding **of mathematical concepts if it is effectively utilized in classroom.** The pre-service teachers' in the study used the interactive spreadsheet to give students greater opportunities to verify results and consider general rules, making links between spreadsheet formula, algebraic functions and graphs, visualizing, analyzing and exploring number patterns and graphs within a shorter time thereby enhancing mathematical conceptions. This confirms similar studies (Özgün-Koca, Meagher & Edwards 2010), that pre-service teachers' understanding of technology shifts from viewing technology as a tool for reinforcement into viewing technology as a tool for developing student understanding of mathematical concepts. The use of the interactive spreadsheet also promoted **open-ended exploration of mathematical concepts and active learning among student supporting the constructivist teaching and learning theory.** Another major advantage of spreadsheet as identified in the study was that it saved time in many activities and created opportunities for demonstrating fundamental mathematical concepts (principles) making it easier for students to apply in higher-order thinking. In the study, interactive spreadsheet offered an environment in which students were able to develop early ideas regarding functions and equations and ways of representing and communicating them. The study also showed that *spreadsheet can greatly simplify the interpretations of mathematical ideas and provide ways of communicating them substantially to reduce students' misunderstanding and misconceptions of concepts they find difficult to understand.*

Conclusion

The preparation of secondary mathematics teachers who are able to use technology to enhance students' learning of mathematics is not a trivial matter. If spreadsheets are to be included as tools for learning mathematics, then mathematics teachers need opportunities to develop their personal knowledge and skills in using spreadsheets as tools for exploring and learning mathematics. Pre-service teachers need to develop technology skills, enhance and extend their knowledge of mathematics with technological tools, and become critical developers and users of technology-enabled pedagogy. They need support in redesigning the mathematics curriculum to include spreadsheets as tools for exploring mathematics while also guiding their students' development of knowledge and basic skills with spreadsheets (cf. Niess et al., 2007).

References

[1] Author (2012). Preparation of Pre-service Teachers in Ghana to integrate Information and Communication Technology in teaching Mathematics. Enschede: University of Twente
[2] Beauchamp, G., & Parkinson, J. (2008). Pupils' attitudes towards school science as they transfer from an ICT-rich primary school to a secondary school with fewer ICT resources: Does ICT matter? Education and Information Technologies, 13, 103-118.
[3] Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2^{nd} ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
[4] Collis, B.A., & Moonen, J.C.M.M. (2005). Lessons learned about technology and learning. In
[5] G. Kearsley (Ed.), Online Learning: Personal reflections on the transformation of education (pp. 36-46). NJ: Educational Technology Publications: Englewood Cliffs.
[6] Dettori, G., Garuti, R., & Lemut, E. (2001). From arithmetic to algebraic thinking by using a spreadsheet. In R. Sutherland, T. Rojano, A. Bell, & R. Lins (Eds.), Perspectives on school algebra (pp.191-207). Dordrecht, The Netherlands: Kluwer.
[7] Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: Whole-class teaching behavior in the technology-rich mathematics classroom. Educational Studies in Mathematics, 75(2), 213-234.
[8] Jones, K. (2005). Using spreadsheets in the teaching and learning of mathematics: A research bibliography. MicroMath, 21(1), 30-31.
[9] Keong, C., Horani, S., & Daniel, J. (2005). A study on the use of ICT in mathematics teaching. Malaysian Online Journal of Instructional Technology, 2(3), 43-51.
[10] Kissane, B. (2007) Spreadsheets, graphics calculators and mathematics education, In K. Milton, H. Reeves & T. Spencer (Eds), Mathematics: Essential for learning, essential for life. 21st Biennial Conference of the Australian Association of Mathematics Teachers (pp 331-339), Hobart: Australian Association of Mathematics Teachers.
[11] Koehler M., & Mishra P. (2009) What is Technological Pedagogical Content Knowledge (TPACK)? Contemporary Issues in Technology and Teacher Education, 9, 60-70.
[12] Liang, J., & Martin,L. (2008). An Excel-aided method for teaching calculus-based business mathematics. College Teaching Methods & Styles Journal, 4 (11), 11-23.

[13] Miles, M. B., & Huberman, A. M. (1994). An expanded source book, qualitative data analysis (2nd ed.). London: SAGE Publications.

[14] Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a Technology Pedagogical Content Knowledge. Teaching and Teacher Education, 21, 509-523.

[15] Niess, M. L., Sadri, P., & Lee, K. (2007). Dynamic spreadsheets as learning technology tools: Developing teachers' technology pedagogical content knowledge (TPCK). Paper presented at the meeting of the American Educational Research Association Annual Conference, Chicago, IL.

[16] Niess, M. L., van Zee, E., & Gillow-Wilese, H. (2010-11). Knowledge growth in teaching mathematics/science with spreadsheets; Moving PCK to TPACK through online professional development. Journal of Digital Learning in Teacher Education, 27(2), p. 42-52

[17] Nieveen, N., Handelzalts, A., Akker, J. J. H. van den, & Homminga, S. (2005, September). Teacher design teams: A scenario for school–based curriculum innovation. Paper presented at the European Conference on Educational Research.

[18] Oldknow, A., & Taylor R. (2003). Teaching Mathematics using Information and Communication Technology (2nd ed.). Wiltshire: The Cromwell Press.

[19] Ottevanger,W., van den Akker, J. J. H., & de Feiter, L. (2007). Developing Science, Mathematics and ICT education in Sub-Saharan Africa (SMICT): Patterns and promising practices, World Bank Working Paper (101), pp. 1-84.

[20] So, H. J., & Kim, B. (2009). Learning about problem based learning: Student teachers integrating Technology, Pedagogy and Content Knowledge. Australasian Journal of Educational Technology, 25(1), 101-116.

[21] Tilya, F. (2008). IT and educational policy in the sub-Saharan African region. In J. Voogt, & G. Knezek (Eds.), International handbook of information technology in primary and secondary education (pp. 1145–1159). New York: Springer.

[22] Voogt, J. (2003). Consequences of ICT for aims, contents, processes and environments of learning. Dordrecht: Kluwer.

[23] Webb, M., & Cox, M. (2004). A review of pedagogy rated to information and communications technology. Technology, Pedagogy and Education, 13(3), 235-286.