Journal of Educational Development and Practice (JED-P)
Vol. 5 N0. 1, December 2015, pp. 14-30

PRE-SERVICE TEACHERS' USE AND PERCEPTIONS OF GEOGEBRA SOFTWARE AS AN INSTRUCTIONAL TOOL IN TEACHING MATHEMATICS

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Abstract
This paper presents a case study of 85 pre-service mathematics teachers from the University of Cape Coast, Ghana; who enrolled in an instructional technology mathematics course to develop competencies in teaching mathematics using the GeoGebra software which was being introduced to them for the first time. The study focused on an in-depth investigation of the pre-service teachers' perceptions and use of GeoGebra in teaching mathematics. Questionnaire, interviews and lesson artefacts developed by the teachers were the data sources of the study. Descriptive, t-test and effect size statistics were used to analyse the quantitative data whereas the interview data and lesson artefacts were analysed qualitatively. Statistical analysis confirmed that the use of the GeoGebra helped pre-service teachers expand their own understanding of mathematical concepts as well as their knowledge of Instructional strategies. The study also indicated that two perceived barriers; lack of awareness of the GeoGebra software and time constraint in designing GeoGebra lessons hinder pre-service teachers' use of the tool. That notwithstanding, the pre-service teachers' perceived developed attitudes and pedagogical views on the use of GeoGebra point to its potential as an instructional tool in developing their experiences in technology integration within an initial teacher education programme in Ghana.

Introduction

The introduction of information and communication technology (ICT) has become an essential tool that supports innovative teaching and enhances students' continuous learning process (Kirschner, 2001; García-Valcárcel Muñoz-Repiso, & Tejedor, 2006). For instance, Bos (2009) and Page (2002) held that when technology is used with appropriate pedagogy in mathematics classroom, it improves students' academic achievement. Bos (2009) asserted that "if mathematics is seen as problem solving and thoughtfully teamed with technology, deep conceptual learning can be a reality" (p. 527). ICT learning environments give students fluency in varieties of representational systems, provide opportunities to create and modify representational forms, develop skill in making and exploring virtual environments, and emphasise mathematics as a fundamental way of making sense of the world (Ang & Lee, 2005; Yu, 2008). The National Council of Teachers of Mathematics, NCTM, (2003) affirmed that technology is an important tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology. Furthermore, NCTM explained that effective teachers maximise the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics. When technology is used strategically, it can provide access to mathematics for all students (NCTM, 2003).

The literature reviewed suggests that the use of technology in teaching and learning of mathematics yields positive results and teachers are considered most instrumental agent in educational changes. However, mathematics teachers have not widely used technology in teaching (Yuen, Law, Lee & Lee, 2010). This condition can also be said of mathematics teachers in Ghana; Agyei and Voogt (2011) reported that mathematics teachers in Ghana are yet to fully integrate technology in teaching and learning of mathematics because of a number of reasons, which include: lack of knowledge about ways to integrate ICT in lesson, lack of training opportunities for ICT integration knowledge acquisition and lack of application software that they can use in mathematics lesson.

This study focused on the areas that require further attention to enable teachers use ICT in mathematics teaching. In particular, a professional development scenario that will assist pre-service teachers develop skills in ways to integrate ICT in their teaching processes was one of the significant issues identified by the researchers. Bearing in mind the complexity of the problems most mathematics classroom in Ghana face in terms of ICT infrastructure and lack of application software, the GeoGebra open software that offers a technology readily available and user friendly among mathematics classroom with the potential to enhance teachers' knowledge and skills of integrating technology in teaching mathematics (Wakwinji, 2011; Mainali & Key, 2012) and to support students' higher-order thinking in mathematics was proposed for use in professional development programmes.

GeoGebra is dynamic mathematics software for teaching and learning mathematics from middle school through college level (see Hohenwarter & Preiner, 2007). It combines the ease-of-use of dynamic geometry software with some basic features of computer algebra systems. Although primarily focused on secondary school curriculums, GeoGebra is also an interesting tool for college level courses as it can help to bridge concepts from geometry, algebra, and calculus. The use of GeoGebra in this study will ensure that pre- service teachers will be able to use existing hardware and software in creative and situation specific ways to design ICT resources to accomplish their teaching goals in the future.

Enhancing the potential of GeoGebra in teaching mathematics through professional development arrangement

Teachers play a central role in their students' learning and for that matter teacher professional development has become an essential component of most of the educational policies (Petras, Jamil & Mohamed, 2012). Teacher professional development is far and wide recognised as the most effective strategy to promote teacher change. Professional development involves comprehensive, intensive, and effective approaches in raising teachers' familiarity with requisite skills and content they are teaching (Knapp, 2003). Numerous studies have involved a wide range of strategies in preparing teachers to integrate GeoGebra software in teaching mathematics effectively.

Lu (2008) used exploratory and multiple-case studies approach to investigate two English and two Taiwanese upper-secondary teachers' conceptions of technology and their pedagogies incorporating dynamic manipulation with GeoGebra into mathematical discourse. The results of his study revealed that some teachers tended to perceive GeoGebra as not merely a tool but rather an environment for teaching and learning mathematics. He also found that the teachers employed a wide variety of strategies to integrate GeoGebra into their teaching practices, such as preparation for teaching materials, presentation of mathematical content and concepts, classroom activities for interaction with pupils and investigation of mathematics. Lastly, he found that teachers' teaching practices are considerably influenced by their conceptions of GeoGebra in relation to mathematical knowledge and their cultural traditions.

In spring 2010 and 2012, Bu, Mumba and Henson (2013) conducted two studies in which they integrated GeoGebra in an online professional development courses to develop mathematical problem solving skills for K-8 in-service elementary school teacher in a rural region of a Midwest state in the United States of America. The professional development activities included incorporating a variety of pedagogical components such as video-based demonstration, affective intervention, and social and cognitive scaffoldings to support 58 teachers' exploration of the new technologies and the mathematical content. After intensive online instruction, a 25-item questionnaire was administered to collect data on participants' attitudes, curricular awareness, mathematical content, and pedagogical reflection regarding the integration of GeoGebra. The results showed that the use of GeoGebra challenged teachers' views about the nature of mathematics and student-teacher interactions and further enriched their mathematical knowledge and pedagogical choices. Bu, Mumba and Henson (2013)'s study confirmed that a "well-designed GeoGebra integration may eventually help control the complexity and provide genuine mathematics learning experience to teachers and students alike" (p. 75).

Mainali and Key (2012) also used a four-day introductory workshop to explore the teachers' impressions and beliefs about the use of GeoGebra in mathematics teaching and learning. The study used fifteen mathematics teachers in Nepal. They found that the potential for using GeoGebra to teach and learn mathematics in Nepal is very large. The study also showed that participants who took part in the study had positive impressions, feelings, and beliefs about the use of the GeoGebra in classroom.

From the foregoing discussion, one can infer that when teachers begin to explore new technology through mathematical content and pedagogy, it is likely that they may succeed in bringing innovative change in their classrooms. This was reiterated by Cross (2009) that once teachers saw some positive results with their students they were more likely to continue using the GeoGebra in their classrooms.

In this study, a professional development programme was designed to prepare pre-service teachers to integrate Geogebra software as a tool in designing lessons within a mathematics-specific teacher education programme. The characteristics of the professional development arrangement are discussed in the next section.

The Professional Development Arrangement

In Ghana there are two universities that train mathematics teachers for senior high schools in the country. These universities are University of Cape Coast (UCC) and University of Education, Winneba. In University of Cape Coast, the Department of Science and Mathematics Education is responsible for the training of senior high school mathematics teachers. This study was conducted in that department where the researchers taught the final year students in an instructional technology course. The course was designed to enable students develop and use instructional materials to enhance teaching and learning in the classroom.

Based on the rationale of the course, the researchers introduced the GeoGebra for the first time in the course to enhance pre-service mathematics teachers' knowledge and skills in developing technology-based instructional materials in mathematics. Out of the twelve teaching weeks of the semester, three weeks (week 5, 6 and 7) were used to take the pre-service teachers through the use of the GeoGebra. In each week, the researchers met the pre-service teachers twice: two-hour lecture and another one-hour lecture on different days. The two-hour lectures were mostly the researchers-led activities where the students were introduced to the various constructing tools in the GeoGebra window and how to use them.

The one- hour lectures were mostly hands-on-activities by the students. Here, the students worked in pairs to practice GeoGebra-based activities based on the previous lesson.

In lesson 1, students were introduced to how they could access GeoGebra software online and how to make a construction, format it, and produce a worksheet using GeoGebra software. In lesson 2, the students were guided through the following activities: drawing regular and irregular polygons, drawing of graphs of given functions, transformation of points/objects (reflection, rotation, translation by a vector, enlargement) and how to export work developed in GeoGebra to MS word. In lesson 3, they used the GeoGebra to find mean, median, mode, standard deviation and variation; draw histograms, box whisker diagram and scatter plots; construct tangent to the graph of functions; and determine area under a curve using Riemann sum and definite integral. At the end of the three weeks, the pre-service teachers were asked to select mathematical topics suitable for teaching with GeoGebra, make use of the affordances of the application software and design learning activities that will foster higher order thinking in mathematics among learners. They were to work in teams of two to design these lessons and prepare to teach them subsequently in their future classrooms. The pre-service in this study developed a number of lessons including polynomial functions, calculus, statistics and plane geometry. The lesson artefacts they developed contained the following: GeoGebra-based lesson plan which was to guide the teacher to deliver the lesson, student worksheet to ensure hands on activities by student in the lesson delivery and the designed GeoGebra interface which provided an interactive learning environment for modelling mathematics concepts. They did this over a period of two weeks.

Research Questions and Research Design

The study examined pre-service teachers' use and perceptions of GeoGebra use in teaching and learning mathematics at the senior high school level. It was also to identify the extent to which GeoGebra as a tool can help pre-service teachers develop their content, pedagogy and technology knowledge. The following research questions were asked to guide the study.

1. What are the perceived barriers of pre-service teachers in using GeoGebra as an instructional tool to teach mathematics?
2. What are the perceived opportunities of pre-service teachers in using GeoGebra as an instructional tool to teach mathematics?
3. To what extent do pre-service teachers develop their knowledge and skills needed to design and enact GeoGebra supported lesson in mathematics

A case study of pre-service teachers in the teacher education programme in UCC was applied. The study focused on an in-depth investigation of the pre-service teachers' perceptions and use of GeoGebra in teaching mathematics. Consequently the units of analysis were the pre-service teachers and the case was the professional development arrangement which was organised within the context of the mathematics teacher education programme at the University of Cape Coast. The study employed an embedded mixed method of quantitative and qualitative evidence. This was to ensure that a more comprehensive understanding required to inform decision making is reached.

METHODS

Participants

The study used 85 final year pre-service mathematics teachers (74 males and 11 females) in Bachelor of Education (Mathematics) programme at university of Cape Coast, Cape Coast, Ghana. The B.Ed (Mathematics) is a 4-year programme which prepares them to teach at the Senior High School when they graduate. Forty-four (51.8%) of them were between the age of

20-25 years, 23 (27.1%) were 26-30 years, 12 (14.1%) were 31-40 years and 3 (3.5%) were 41 years and above. All 85 participants responded and completed a questionnaire survey which was administered to them before and after the instructional technology course. Four teams of pre-service teachers whose lesson artefacts were sampled and analysed were also interviewed after the the course. Prior to this study, the pre-service teachers did not have any experiences in technology-supported lessons neither as part of their training nor in their pre-university education.

Instruments

A questionnaire consisting of 50 items adapted from Bu, Mumba, Henson and Wright (2013) was used to collect data on pre-service teachers' perceptions about the use of GeoGebra in teaching mathematics before and immediately after the course implementation.

The items were constructed on 6 sub-scales and were reported as: Awareness (pre-service teachers' consciousness about the use of GeoGebra as a tool in teaching mathematics) Conceptual Understanding (ones' understanding of mathematical concepts when GeoGebra is used as tool to enhance teaching/learning), Attitudes (affective, cognitive and conative) of pre-service teachers to use GeoGebra, Competency (pre-service teachers' ability to use Geogebra to teach mathematics), Pedagogical views related to the use of GeoGebra and Adaptation (applicability of GeoGebra with existing learning materials). For all the six sub-scales, a five-point Lickert scale (1=strongly disagree, 5= strongly agree) was used. The scores are interpreted as follows: 1 is the lowest possible score which represents a very strong negative response, while 5 is the highest possible score which represents a very strong positive response. Rescaling of some items worded negatively was done so that a high score was interpreted to mean the reverse. The number of items and Cronbach alpha reliability coefficients of the various sub-scales are reported in Table 1.

Table 1: Cronbach Alpha Reliability Coefficients of the various Constructs

Sub-scale	**Number of items**	**Cronbach alpha reliability coefficients**
Awareness	6	0.821
Attitudes	11	0.783
Adaptation	5	0.782
Conceptual Understanding	6	0.722
Pedagogical views	12	0.917
Competency	10	0.933

From the Table 1, the reliability coefficients are within the acceptable range (Pallant, 2001) for all the sub-scales. The questionnaire also had some open ended items to help participant express their views freely about their use of GeoGebra.

Following the administration of the questionnaire after the course, four teams of pre-service teachers whose lessons artefact were randomly selected and analysed were also interviewed. The interview focused on teachers' experiences and opinions of planning and preparing GeoGebra-based lesson whereas the lesson evaluation assessed evidence of technological and content knowledge in the GeoGebra written lessons.

To analyze the data, descriptive, t-test and effect size statistics were used to analyse the quantitative data whereas the interview data and lesson artefacts were analysed qualitatively using data reduction technique (Miles & Huberman, 1994).

RESULTS

Barriers to GeoGebra use as an Instructional tool

Research question 1 sought to explore barriers of pre-service teachers in using GeoGebra as an instructional tool to teach mathematics. What was perceived to be important barrier in using GeoGebra as an instructional tool was reported in pre-service teachers' lack of awareness about the use of GeoGebra as a tool in teaching mathematics. Respondents were asked to indicate their levels of agreement on awareness of the GeoGebra software as an important instructional tool for mathematics teaching on a five-point Likert scale before the course. Table 2 provides the mean scores and standard deviations of their responses.

Table 2: Pre- service teachers' awareness levels of GeoGebra software (N=85)

Item	Mean	SD
I am familiar with the GeoGebra software before I was introduced to it in this course.	1.46	0.895
I have used GeoGebra before in my mathematics lesson	1.68	1.177
The constructing tools in the GeoGebra are familiar to me	2.39	1.448
I have seen other teachers use GeoGebra in the classroom	1.86	1.338
I have downloaded the software from the internet before this programme	2.09	1.469
I know about some exemplary materials of GeoGebra	2.14	1.347
Overall Awareness level	**1.83**	**0.902**

The result shows that the pre-service mathematics teachers have very low level of awareness of the GeoGebra before the course (mean = 1.831, St. Dev. = .901). This means the pre-services teachers were unfamiliar with GeoGebra software before it was introduced to them in this course. They had neither use nor seen other teachers use GeoGebra in the mathematics classroom.

Pre-service teachers were also given the opportunity to enumerate barriers they perceive could hinder their use of the GeoGebra software as an instructional tool in the real classroom situation after the professional development programme.

Out of the total of 85 pre-service mathematics teachers, 40 (47.1%) of them did not indicate any perceive barrier using GeoGebra in their future lessons. Apparently, these participants did not encounter any peculiar problem using the tool during the programme or perhaps they were reluctant to provide any responses in this regard. Table 3 shows the distribution of possible barriers of GeoGebra use as were reported by the pre-service mathematics teachers.

Table 3: Pre-service perceived barriers of using GeoGebra tool in teaching (N=85)

Possible barriers	Number Respondents	Percentage
1. Time constraints	45	52.9
2. Lack of computer literacy skills	12	14.1
3. Irregular internet accessibility	15	17.6
4. Frequent power outage	18	21.2
5. Difficulty in using the GeoGebra to teach some topics in mathematics	8	9.4

The results show that 'time constraint' was the only significant barrier the pre-service mathematics teachers perceive could hinder their use of GeoGebra in their future lessons.

Pre-service teachers reiterated that preparing and enacting GeoGebra-based mathematics lessons could be time consuming and would require a lot of commitment from teachers who would want to use the software in his/her classroom. Apparently, the teachers needed more time to develop their skill in designing mathematics lessons in this new environment.

Opportunities to use GeoGebra as an Instructional tool

In answering research question 2, opportunities that existed to use GeoGebra as an instructional tool in teaching mathematics were explored in 3 areas: pre-service teachers' perceived developed attitudes, pre-service teachers' perceived pedagogical views related to the use of GeoGebra and their reported views about GeoGebra software applicability (adaptation) with existing learning materials.

Pre-service mathematics teachers' perceived attitude towards the use of GeoGebra in teaching

A comparison of attitudes of the pre-service teachers before and after the course was conducted. A paired sample t-test showed that pre-service teachers' attitudes toward the use of GeoGebra in mathematics teaching improved significantly after the course on all 11 items that were used to measure level of their attitudes. The overall attitudes (Before: *M* = 1.62, *SD* = 0.26; After: *M* = 4.13, *SD* = 0.61; *p*-value = .0001) also showed significant difference with a large effect size (d = 5.35) before and after the course. This is an indication that pre-service teachers developed positive attitudes as they got introduced to the tool and seem to suggest that when particular mathematical software is introduced to pre-service mathematics teachers, it turns to improve their attitude towards the integration of technology in mathematics teaching. Table 4 shows the results of the paired sample t-test for samples of the test items measuring the pre-service teachers' attitudes.

Table 4: Pre-service mathematics teachers' levels of attitude (*N* = 85)

Attitudes towards the use of GeoGebra	Before the course		After the course		*p*-value	Effect Size (d)
	M	***SD***	***M***	***SD***		
I like using GeoGebra	2.27	1.08	4.06	1.04	0.0001	1.68
I am open to explorations using GeoGebra	1.54	0.66	4.92	0.07	0001	7.20
I need a lot of time to think before I use GeoGebra software to teach mathematics.	1.19	0.47	3.28	1.13	0.0001	2.41
I will continue to learn and use GeoGebra.	1.27	0.51	3.93	1.12	0.0001	3.06
GeoGebra makes mathematics easy for me to learn and teach it.	2.87	0.82	4.46	1.39	0.0001	1.39

Level of significance, $\alpha = .05$

Pre-service teachers **perceived pedagogical views on the use of GeoGebra**

A paired sample t-test to compare the pre-service teachers' pedagogical views (before and after the course) was significant for all the measuring items (sample of items are shown in Table 5) with the largest area of change occurring in the item 'GeoGebra software can help me reach out to more students*'* (gain= 4.22). The item with the least reported change (gain= 0.79) was '*GeoGebra motivates me to find effective approach in teaching mathematics'*.

Table 5: Pre-service teachers Geogebra pedagogical views (N=85)

Pedagogical Views	**Before the Course**		**After the course**		**p-value**	**Effect size (d)**
	M	*SD*	*M*	*SD*		
Using GeoGebra can make my lesson practical.	1.42	0.67	3.22	1.26	0.0001	1.78
I can use the GeoGebra to a design a lesson to meet the needs of my students.	1.44	0.66	3.54	1.18	0.0001	2.20
GeoGebra software can help me reach out to more students.	1.46	0.63	4.27	0.70	0.0001	4.22
GeoGebra software will help me to design meaningful activities for students.	1.67	0.66	4.21	0.93	0.0001	3.15
GeoGebra motivates me to find effective approach in teaching mathematics	2.34	1.11	3.24	1.16	0.0001	0.79

Level of significance $\alpha = .05$

The overall views (Before: *M* = 1.79, *SD* = 0.44; After: *M* = 3.89, *SD* = 0.45, *p*-value = 0.0001) also showed significant difference with a large effect size (d = 4.71) before and after the course. Thus, the results suggest that GeoGebra environment appeared useful to pre-service teachers in designing and planning activities to teach ICT-enhanced lessons. This might have enhanced their pedagogical reasoning and views.

Adaptation (Applicability of GeoGebra with existing learning materials)

The extent to which pre-service teachers can apply the Geogebra tool to existing mathematics learning materials was also investigated.

Table 6: Applicability of the GeoGebra in the existing learning materials (N=85)

Item	***M***	***SD***
I can use GeoGebra hand in hand with manipulatives to teach mathematics	4.40	0.736
I can apply GeoGebra to teach mathematics with the existing syllabus.	3.95	0.830
I can use the GeoGebra with the teachers' mathematics handbook	3.40	0.720
I can apply GeoGebra to teach mathematics with a lesson plan	4..30	0.871
Overall	**4.01**	**0.558**

$\alpha = .05$, Std. Dev. = standard deviation

Table 6 shows the mean scores of pre-service teachers' responses provided after the course. The results of the study showed that existing materials such as manipulative (*M* = 4.40, *SD* = 0.736) for teaching mathematics, mathematics lesson plan (*M* = 4.30, *SD* = 0.871), mathematics teachers' handbook (*M* = 3.40, *SD* = 0.720) and mathematics syllabus *(M* = 3.95, *SD* = 0.830) all can be used alongside the GeoGebra software. Table 6 shows a descriptive statistics of pre-service teachers' responses.

Pre-service teachers' development of conceptual understanding and competencies

A major question dealt with in the study was how pre-service teachers developed their own conceptual understanding and skills needed to design and enact GeoGebra supported lesson in mathematics after the Instructional technology course. Analyses of pre-service teachers' self-report data and developed lesson artifact answer this question

Pre-service mathematics teachers' conceptual understanding

The result in Table 7 shows the extent to which the introduction of GeoGebra in the Instructional technology course enhanced pre-service mathematics teachers' content knowledge.

Table 7: Perceived GeoGebra use in enhancing mathematics content (N=85)

Item	*M*	*SD*
GeoGebra software helps me relearn some mathematical ideas.	4.34	.720
GeoGebra software makes mathematics more difficult for me.	2.00	1.123
I have learned some mathematics that would otherwise be difficult to learn.	4.01	1.000
GeoGebra software helps me see mathematics as a consistent system of ideas.	4.14	.758
I would like to learn more mathematics before using GeoGebra software.	3.22	1.257
I feel that a new kind of mathematics is being taught.	3.54	1.181
Overall	**3.87**	**0.554**

$\alpha = .05$, Std. Dev. = standard deviation

The results in Table 7 show that the use of GeoGebra can help to develop the mathematics content of the pre-service mathematics teachers (*M* = 3.87, *SD* = 0.554). For example, the pre-service mathematics teachers indicated strongly (M= 4.34 and SD= 0.720) that GeoGebra software can help them relearn some mathematical ideas. They also indicated that they have learned some mathematics that would otherwise be difficult to learn through the use of GeoGebra (*M* = 4.01, *SD* = 1.000). The pre-service teachers did not agree to the statements: *I would have to learn more mathematics before they could use the GeoGebra software* and *GeoGebra software makes mathematics more difficult for me*. The results suggest that the use of GeoGebra promotes pre-service mathematics teachers' subject matter knowledge expansion in mathematics. The results also imply that the pre-services mathematics teachers do not need to learn any new mathematics before they can use the GeoGebra software. The pre-service teachers' interview data confirmed this as shown in the excerpts from the interview between the researcher (R) and the pre-services mathematics teams (PSMT) below:

R: To what extent is the use of GeoGebra useful or not useful to you in terms of mathematics contents?

PSMT 1: Well, to me it has been very useful. It has made me learn a lot in mathematics. Initially, I did not know how to represent free vector for example $\overrightarrow{AB} = \begin{pmatrix} 3 \\ -4 \end{pmatrix}$ *on a Cartesian plane. Also, it was initially difficult for me to even write the vector itself if it is already drawn on Cartesian plane. Now, I understand that vector means movement. The x-component means move horizontally, if it is positive it means move rightwards and if it is negative it means move leftwards. The y-component means move vertically, if it is positive it means move upwards and if it is negative it mean move downwards. For example the vector* $\overrightarrow{AB} = \begin{pmatrix} 3 \\ -4 \end{pmatrix}$ *means that start at any point move 3 units right and then 4 units down.*

The pre-service teachers' lesson artefacts confirmed developed conceptual understanding.

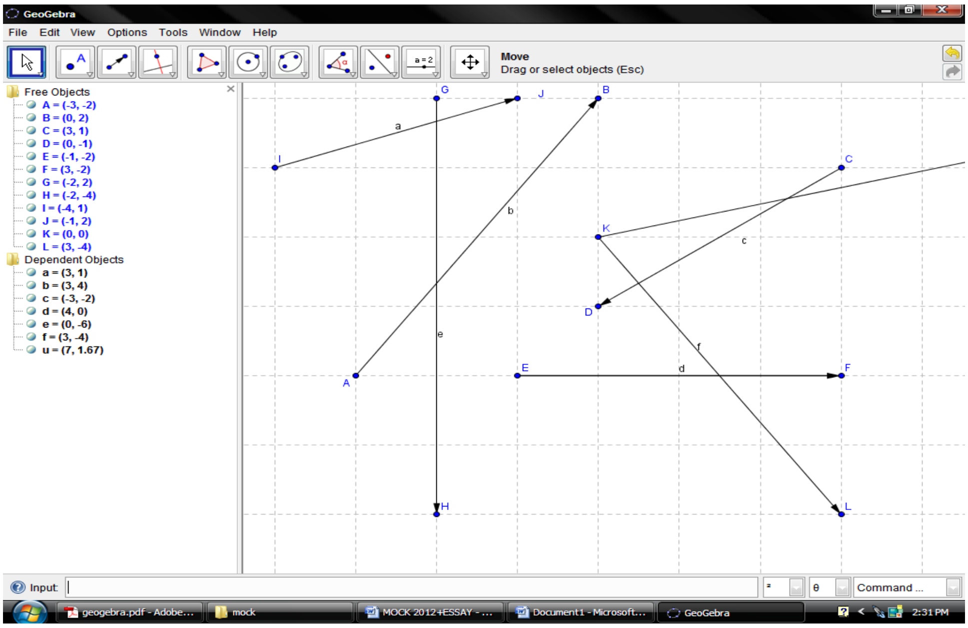

Figure 1: The snapshot of the sample work of PSMT 1 in GeoGebra window

Figure 1 is the snapshot of an excerpt of PSMT 1 lesson document in GeoGebra window when she was asked to draw the following vectors.

$$\hat{a} = \begin{pmatrix} 3 \\ 1 \end{pmatrix}, b = \begin{pmatrix} 3 \\ 4 \end{pmatrix}, \hat{c} = \begin{pmatrix} -3 \\ -3 \end{pmatrix}, \hat{d} = \begin{pmatrix} 4 \\ 0 \end{pmatrix}, \hat{e} = \begin{pmatrix} 0 \\ 6 \end{pmatrix}, \hat{f} = \begin{pmatrix} 3 \\ -4 \end{pmatrix}$$

The following are excerpts from interview with another pre-service teacher PSMT2.

R: To what extent is the use of GeoGebra useful or not useful to you in terms of mathematics contents?

PSMT 2: In fact the GeoGebra is fantastic. I can use it to explore so many things. For example the slider in the GeoGebra constructing tools has helped me to *understand the orientation of the cubic function,* $y = ax^3 + bx^2 + cx + d$. *At first I have to create a table for an ordered pairs of points before I can sketch the graph of* $y = x^3$. *Now, I know that if the coefficient of* x^3 *is positive the graph will move* [he used the right hand to gesture the orientation of the graph of $y = x^3$ to show that the graph will increase then it will get to the point of inflexion and finally increase again]. *Sir, the value of d will tell me where the graph will cut the y-axis. Hmm sir there was something I never "know"* [he paused and continued]. *Unlike a quadratic equation which may have no real roots, a cubic equation always has at least one real root. It is so simple now. When it has to do with topics in transformation and statistics it is so simple now.*

Figure 2 is the snapshot of some mathematics contents he used the GeoGebra to generate.

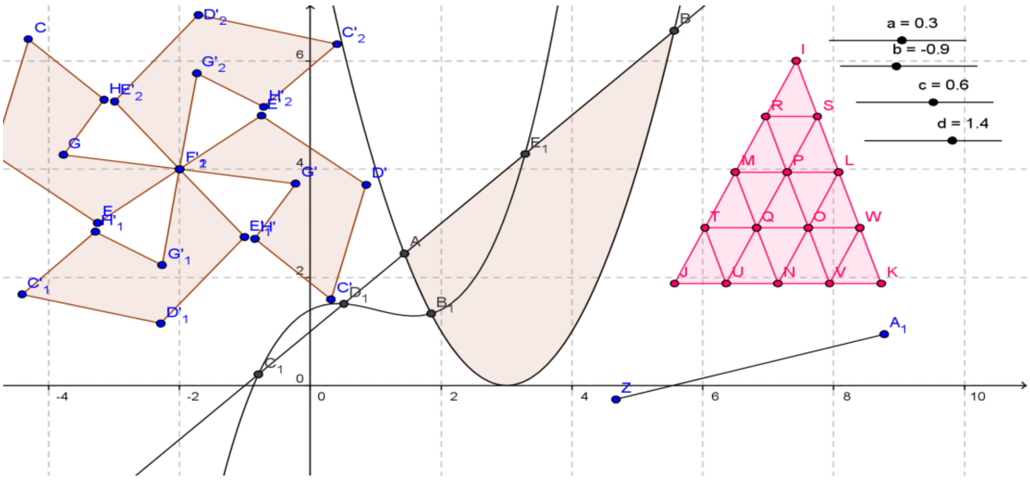

Figure 2: Snapshot showing sample work of PSMT 2 in GeoGebra environment

From the interviews and the sample output of their work, it is clear that the GeoGebra environment helped to enhance the pre-service mathematics teachers' content knowledge in mathematics. The GeoGebra helped most of the pre-service mathematics teachers to conceptualise some mathematical ideas that they have been deficient of earlier before the study. This was clearly shown in the work of PSMT 2. Interviews revealed that one of them had indicated that "*the slider in the GeoGebra constructing tools has helped me to understand the orientation of the cubic function* $y = ax^3 + bx^2 + cx + d$ ". He added that it the first time he understood that "*unlike a quadratic equation which may have no real roots, a cubic equation always has at least one real root. It is so simple now*".

It is apparent that the pre-service teachers in the study developed conceptual understanding of the various topics they worked on even though these were topics they had learnt several years ago and as teachers were supposed to be teaching them. Thus, the teachers expanded their knowledge about the mathematical concepts with the GeoGebra not because they were new, but because they realized they did not yet completely understand the concepts.

Pre-service mathematics teachers' competency in using GeoGebra

Pre-service teachers' competencies in using GeoGebra as an Instructional tool were ascertained before and after the Instructional technology course. Ten items were used to explore pre-service teachers' levels of performing specific tasks with GeoGebra. For each item, they were expected to indicate their ability level to perform the task: excellent (advanced) = 5, good (proficient) = 4, satisfactory (progressing) = 3, learning = 2 or poor (can't use it) = 1. The pre-post test scores of their responses are shown in Table 8.

Table 8: Pre-service mathematics teachers' competencies (N=85)

Item	Before the course		After the course			Effect
	M	***SD***	***M***	***SD***	***p*-value**	**size (d))**
I can use the GeoGebra to develop lesson in polynomial functions.	1.39	0.66	3.46	1.02	0.0001	2.41
I can use the GeoGebra to teach graph of polynomial functions.	1.40	0.62	3.73	0.94	0.0001	2.92
I can use the GeoGebra to teach bar chart.	1.45	0.63	3.75	0.94	0.0001	2.87
I can use the GeoGebra to teach histogram.	1.66	0.75	3.75	0.90	0.0001	2.52
I can use the GeoGebra to teach box plot.	1.74	0.66	3.66	0.92	0.0001	2.40
I can use the GeoGebra to teach scatter plot	1.89	0.90	3.57	0.94	0.0001	1.83
I can use the GeoGebra to teach polygons.	1.93	0.88	3.78	1.02	0.0001	1.94
I can use the GeoGebra to teach differentiation.	2.00	2.35	3.22	1.17	0.0001	0.66
I can use the GeoGebra to teach integration.	2.14	1.12	3.19	1.13	0.0001	0.93
I can use the GeoGebra to teach circle theorems.	2.34	2.53	3.17	1.16	0.0001	0.42
Overall Teachers' Competency	**1.79**	**0.49**	**3.56**	**0.79**	**0.0001**	**2.69**

The results indicate that the pre-service mathematics teachers' ability to use the GeoGebra after the instructional technology course improved significantly (Before: $M = 1.79$, SD = 0.49; After: M = 3.56, $SD = 0.79$, p-value = 0.0001, effect size (Cohen d = 2.69).

Clearly, the responses from the pre-service mathematics teachers in this study indicate that when particular mathematical software is introduced in course it helps them to develop the knowledge and skills of technology integration in mathematics. A case in point is the lesson on Circle Theorems developed by Atobrah (Pseudonym) a member of PSMT 4. Figure 3 is snapshot of their lesson document. Atobrah was able to demonstrate clearly how learners could be assisted in the use of GeoGebra to deduce circle theorems. According to him, these are difficult concepts to teach when using the conventional method without the support of any technological tool. Thus, Atobrah explained that he had developed the skill of using GeoGebra and can assist his students to learn mathematics better because the tool will assist his students picture the mathematical concepts they are learning.

Agathar (from PSMT 3) also mentioned in an interview that having developed the skill of representing graphs on the GeoGebra window, she could easily guide her students to identify general patterns and properties of families of functions such as quadratic and linear functions.

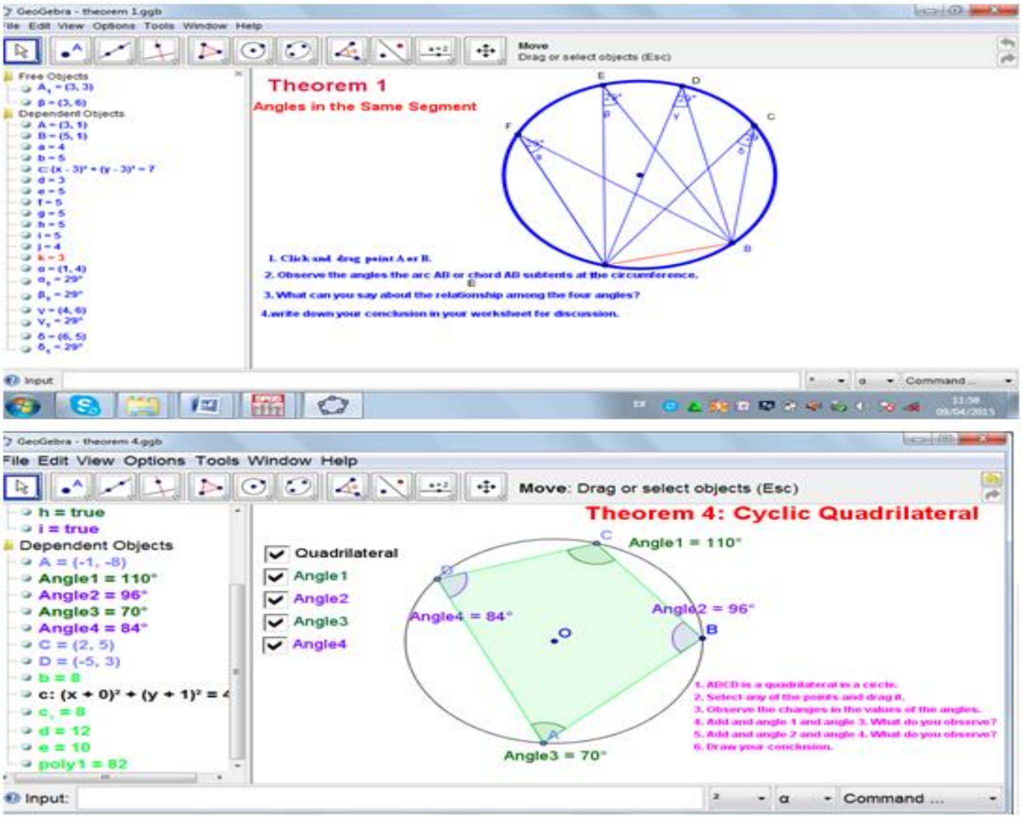

Figure 3: Snapshots of circle theorems developed by Atobrah

Pre-service teachers outlined a number of reasons why they would want to use the GeoGebra Instructional tool in their future lessons. Among major reasons they gave include: it makes teaching and learning easier, it enables student-centred learning, it gives pictorial presentation of mathematical concepts, and it makes the teacher to be flexible in the mathematics classroom.

Discussion

The focus of this study was to examine the pre-service mathematics teachers' use and perceptions about the use of GeoGebra software in mathematics teaching. Specifically, the study explored the potential of developing pre-service teachers' conceptual understanding of mathematics and their competency to design and enact GeoGebra supported lessons. The study also investigated the barriers and opportunities (as reported in pre-service teachers' perceptions) of using GeoGebra as an Instructional tool in teaching mathematics.

Despite the fact that GeoGebra software is free, easily accessible and easy to use, the results of this study indicated that the pre-service mathematics teachers had very low level of awareness of the software before it was introduced in the course. It was observed prior to the introduction of the software that the pre-service mathematics teachers were aware that the Ghana mathematics syllabus for senior school requires them to guide their students to competently use computers or calculator to solve realistic mathematically problem, however, the prospective mathematics teachers in this study were least aware of the potential of mathematical software to apply in the classroom. The pre-service teachers' lack of awareness about the use of GeoGebra as a tool is likely to impede its use in mathematics classrooms. This result is consistent with the findings of the study conducted by Adebowale (2012). Adebowale conducted a study on primary and secondary school teachers level of awareness of Nigeria's educational policy for integrating ICT in classroom teaching and learning. He found that only a small percentage of the respondents possess a high level of awareness of the country's educational policy on ICT. They went further to indicate that a considerable proportion of the respondents (35.1%) were either completely ignorant of the policy or possess poor levels of its awareness.

Inspite of the teachers' lack of awareness of the potential of the GeoGebra software as an Instructional tool, pre-services teachers who participated in the study demonstrated knowledge and skills in designing and preparing to enact GoeGebra-based lessons in their lesson plan artefacts after the Instructional technology course. This was confirmed by their significant gains in their perceived developed competencies as were reported. Thus, the introduction of the GeoGebra in teacher professional development course seems to be a good approach to enhance pre-service mathematics teachers' ability in using mathematics-specific software. This supports an observation by Yigit (2014) that pre-service mathematics teachers' competency to use technology in mathematics teaching and learning could be effectively enhanced through a lesson or a course

The findings also indicate that the pre-service teachers expanded their own understanding of mathematical concepts as they explored the GeoGebra supported lessons; the pre-service teachers improved their subject matter in various topics in mathematics they worked on. Consequently, the use of GeoGebra helped the pre-service teachers to develop their mathematics content significantly. This result confirms evidences that have been shown in literature that the GeoGebra software has the potential to promote conceptual understanding in mathematics; GeoGebra promotes learners' interests towards mathematics and advance their cognitive abilities as well (Antohe, 2009).

The study showed that several opportunities existed for pre-service teachers to be trained to be able to integrate GeoGebra in their teaching. Firstly, it was encouraging to find that contemporary mathematics teachers appeared generally supportive and confident to use GeoGebra in their future classrooms. The overwhelming large gains in their self-reported attitudinal measures after the Instructional technology course augers well for the pre-service teachers to use GeoGebra to improve teaching in their future lessons. Sabzian and Gilakjani (2013) and Teo (2006) remarked that the success of any initiatives to implement computer technology in an educational programme depends on the support and attitudes of teachers involved. The finding also aligns with the study conducted by Yildirim's (2000) on the topic: *Effects of an educational computing course on pre-service and in-service teachers: A discussion and analysis of attitudes and use*. Yildirim found that teachers' attitudes significantly improved after the computer literacy course.

Secondly, the extent to which the GeoGebra software can be used along with existing learning materials as were reported by the pre-service teachers is another opportunity worth noting. Similar to findings by Bu, Mumba, Henson (2013), the study showed that pre-service mathematics teachers can conveniently adopt GeoGebra to the existing teaching and learning materials such mathematics manipulative, mathematics lesson plan, mathematics teachers' handbook and the mathematics syllabus.

Lastly, the study showed that the pre-service teachers expanded their own knowledge of Instructional strategies for integrating GeoGebra learning activities in mathematics lessons. The pre-service teachers' perceived report on GeoGebra pedagogical views confirmed this. The pre-service mathematics teachers in this study indicated very strongly that they could use the GeoGebra to make mathematics lessons more practical, provide more effective ways of making lesson interesting and help to design lesson to meet the needs of students. This result confirms that the use of GeoGebra provides a real opportunity for teachers to rethink fundamental pedagogical issues in teaching and learning of mathematics along with the approaches to learning that students need to apply in classrooms (International GeoGebra Institute, 2015).

In spite of the opportunities discussed, the study highlighted time constraint as a significant barrier which could hinder pre-service teachers' use of GeoGebra in their future classrooms. They pre-service teachers reiterarted that preparing and enacting GeoGebra-based mathematics lessons could be time consuming and would require a lot of commitment from teachers who would want to use the software in his/her classroom. This finding illuminates that the teachers needed more time to practice this new approach to develop their repertoires and expertise in designing and teaching mathematics lessons with GeoGebra in a more desirable way. This is similar to findings from Fishman and Davis (2006) which explains that building expertise in teaching a subject matter with technology should be viewed as a long term trajectory that goes beyond pre-service teacher education in formal settings. Fishman and Davis argued that as teachers gain more experience, they can continue to expand their knowledge base as well as strengthen the connection between content, pedagogy and technology.

Conclusion and Recommendation

The study has shown that introducing the open source mathematics software in an Instructional technology course to the prospective mathematics teachers helped to develop their attitude towards the use of technology. It also improved their pedagogical skills, mathematics content knowledge levels, and technological skills. The study therefore recommends that for pre-service mathematics teachers to gain full competency in using technology in mathematics teaching, technology integration courses should feature prominently in mathematics education programmes. For successful implementations of such interventions, adaptation of technology which is readily available with the potential of supporting students' higher-order thinking in mathematics should be key.

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