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Status of Teachers' Technology Uptake and Use of GeoGebra in Teaching Secondary School Mathematics in Kenya

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Abstract

The uptake of technology and specifically, GeoGebra software, in teaching mathematics has had mixed success in spite of its documented benefits. This study investigated teachers' perspective towards training and eventual use of GeoGebra as a tool to enhance learning of mathematics. In this article we share findings from a larger study that was conducted in Kajiado County in Kenya (Africa) on GeoGebra use in teaching Secondary School Mathematics. This article presents the relationship between observed teachers' perceptions towards the uptake of GeoGebra, a technology based tool and the actual uptake of GeoGebra using the Diffusion Innovation theoretical framework. Data was collected from practicing mathematics teachers who were exposed to GeoGebra through a series of training sessions. The findings after training sessions with the mathematics teachers showed willingness to use GeoGebra in their classes. The teachers identified Geometry as the topic where use of GeoGebra would be most relevant due to its abstract nature. Teachers' responses indicated that GeoGebra was perceived as useful for teaching and learning Mathematics and that it would help learners grasp concepts in Geometry. However, the study also found out that systemic support would sustain teachers' engagement with GeoGebra at classroom level as actualization of Geogebra use did differ significantly from teachers' perceptions.

Key words: GeoGebra; Geometry; Technology; Secondary school mathematics

Introduction

In Kenya where a central curriculum is followed, Geometry is one of the mathematics strands that is studied at secondary school mathematics level. Other strands offered at this level include Algebra, Calculus, numbers and operations, Probability and statistics. Secondary school learners find most of these strands abstract and they struggle with conceptual understanding of mathematics. Technology has been used in various areas in mathematics including Algebra (Wilson 2000), in statistics (Abrahamson and Wilensk, 2007) and in Geometry (Cobo, Fortuny, Puertas and Richard 2007) as an enabler for conceptual learning. However, students' access to these technologies is dependent on teachers' uptake. Some of the computer software available for teaching and solving mathematical problems include Spreadsheets, Dr Geo, dynamic geometry software, Matlab, and GeoGebra among others. In this study, we focused on teachers' perception and uptake of GeoGebra and how it can be useful in the Kenyan Mathematics curriculum, specifically in the area of Geometry.

GeoGebra is a community-supported open-source mathematics learning environment that integrates multiple dynamic representations, various domains of mathematics, and a rich variety of computational utilities for modeling and simulations. Invented in the early 2000s, the aim of GeoGebra was to implement in a web-friendly manner the research-based findings related to mathematical understanding and proficiency as well as their implications for mathematics teaching and learning. The teachers assumed subject matter competence is important for student access to this software. According to Bu and Schoen (2011) a mathematically competent person has the ability of coordinating various representations of a mathematical idea in a dynamic way in order to further gain insight into the focal mathematical structure. In the fields of learning sciences and instructional design there has been several highlights by researchers on the theoretical and practical implications of *mental models* and *conceptual models* involving complex human learning (Milrad, et al, 2003) accordingly, GeoGebra's ability to enhance visualization in Geometry supports this position. It is this premise that forms the thesis for this study.

According to Battista (2001); Geometry is a complex interconnected network of concepts, ways of reasoning, and representation systems that is used to conceptualize and analyze physical and imagined spatial environments

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(Battista 2001). Geometry is also defined as a branch of Mathematics that is concerned with shapes, sizes, relative position of figures and the properties of space. Geometry is the branch of mathematics concerned with lengths, areas and volumes (En.wikipedia.org/wiki/geometry). Geometrical definitions have to do with space and shape. Hence when defining a geometrical shape, properties such as angles and measurements are used. Effective teaching of Geometry is aimed at enhancing learners' spatial abilities. According to (Battista, 1990) "underlying most geometric thought is spatial reasoning which is the ability to see, inspect and reflect on spatial objects, images, relationships and transformations". In the process of teaching topics and concepts involving Geometry, the teacher expects his/her students to be able to visualize figures, shapes and planes that many not be very obvious to the student. This concept is what makes geometry unique and challenging to learn and teach. GeoGebra promises to alleviate this complication when used knowledgeably Complications experienced in teaching and learning of Geometry as sited in the second handbook of research on mathematics teaching and learning (Battista 2007), include:

(i) Perception: Conception affects perception since what one sees is affected by what one knows and conceives.

(ii) Diagrams as data or representations: It is through analyzing the geometrical diagrams that concepts are derived. According to (Chazan and Yerushlmy 1998), "diagrams are aids for intuition and are not necessarily the objects of study themselves" P70. The diagrams used in mathematics are representations of the actual object. In teaching the concepts of geometry therefore, the teacher is faced with the task of helping learners 'see' the objects represented in the image and further derive some meaning from it. The proponents of GeoGebra posit that teachers can use this tool to provide learners with a convincing demonstration of Geometry concepts and hence minimize these complications.

Theoretical Framework

This study used the Diffusion of innovation model (DIM) by Rogers (1995) as a lens for interpreting teachers GeoGebra uptake tendencies. DIM is a theory that seeks to explain how, why, and at what rate new ideas and technology spread through cultures. In this study the assumption is that teachers' perception and rate of GeoGebra uptake explains the status of use of GeoGebra in mathematics classrooms. DIM explains four main elements that influence the spread of a new idea. These elements include: innovation, communication channels, time, and social systems. The Diffusion of Innovation model is the main model that explains how adoption of technology takes place since it is mostly used by marketers for new innovations. Innovators of technology are normally the least in number, making up only 2.5% of a population while the early adaptors are few and make up 13.5% of a population. Early majority take up the software to use it only if they are sure that it will work and that it is useful to them. These require that the dots are joined and their questions are answered. This group requires encouragement to use an innovation. On the other hand, the late majority group wants to see the innovation working then they can use it. In every population, according to the diffusion model, there is a group of 16% of the population that fear change and will not accept change. These require extra training and evidence of what has been achieved using the innovation. Figure 1 illustrates the categories of innovation as per the Rogers Diffusion of Innovation

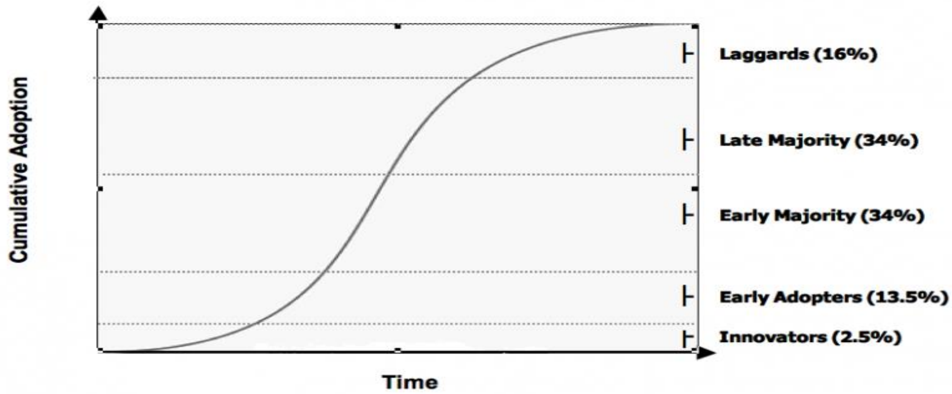

Figure 1. Categories of innovation as per the Rogers Diffusion of Innovation

Each of the levels in the DIM model can be used to explain the feasibility of using GeoGebra in Kenyan secondary schools. This paper evaluates the response of teachers to technology, in this case GeoGebra. In which category do the mathematics teachers in Kenya fall? Are they early adopters, early majority, late majority or laggards?

Problem Statement

GeoGebra according to studies have showed promise of supporting learner understanding of abstract concepts such as those found in the Geometry strand. The Kenya Secondary school mathematics curriculum affords learners several topics in the Geometry strand. They include; measurement (Area, volume,) three dimensional geometry (geometrical constructions, trigonometry), Euclidean geometry, motion geometry and solid geometry which can directly benefit from the GeoGebra software.

According to Kenya National Examinations Council (KNEC) reports, Mathematics' mean scores in geometry (table 1) have remained low over the years an indication that teachers have not fully utilized opportunities provided by the GeoGebra tool, despite the awareness that has been created of this technological advancement. The Annual Kenya certificate of Secondary examination (KCSE reports have indicated that over 50 % of the questions are geometry related and students' challenges in this strand could be a contributing factor to the dismal performance observed in mathematics over the years. The report also identifies inappropriate teaching strategies by teachers in this milieu

Table 1. Number of questions listed as difficult in KCSE.

Year of Exam	Paper	Number of Questions Listed as Difficult	Questions in Geometry	Percentage of the Difficult Questions in Geometry
2008	1	6	4	67
2008	2	7	4	57
2009	1	10	5	50
2010	1	7	4	57

Source: KNEC reports (2008, 2009 and 2010)

If GeoGebra can support learners in conceptualizing geometry concepts, it is important to establish teachers perception and uptake of this technology with a view to increasing its use at classroom level.. This study tried to assess mathematics' teachers' willingness to embrace technology, specifically GeoGebra in teaching Geometry in secondary schools in Kenya.

In this article we consider two of the study objectives

a) To establish mathematics teachers' readiness by way of perception towards training and competences with the use of GeoGebra
b) To establish Mathematics teachers actual use of GeoGebra in mathematics classes

Method

The aim of this study was to establish the uptake of GeoGebra, a software technology tool among the Secondary School Mathematics teachers in the county the study used a mixed method design that incorporated both quantitative and qualitative approaches. The study was conducted in secondary schools in Kajiado County, Kenya, East Africa.). A mathematics teachers' questionnaire (attached as appendix A) was used to collect data from the mathematics teachers currently teaching in high schools in Kenya. The sampled teachers included 10 teachers from the boys' secondary schools, 10 teachers from the girls' secondary schools and 13 teachers from the mixed secondary school.

The target population was all the Secondary school mathematics teachers in the study location. The sampled 33 teachers formed 22% of the target population whose sampling followed a stratified and simple random sampling procedure. To gauge teachers' perception towards use of GeoGebra, these teachers were trained on the use of GeoGebra for teaching Geometry over a period of six weeks. All the topics for the data collection period were discussed. The teachers were then required to fill in a questionnaire on their experiences during training and their expectations in using the software.

The questionnaire was divided into 3 parts, personal data, response to training on GeoGebra use and perceived usefulness of the application. The mathematics teachers' questionnaire was tested for reliability using the Cronbach alpha. The instruments were found to have an alpha of 0.79 which implied that the questionnaire had internal consistency. The teachers were then observed when teaching using the tool and challenges documented. The findings were then analyzed and reported in form of a frequency tables and narratives.

Results and Discussion

Demographic Data of the Teachers in the County

Kajiado county had 149 mathematics teachers by 2nd term 2014, this number is however not static since there is high mobility of teachers from one school to another and also by exiting from the service. The researcher sampled 33 of these mathematics teachers, both male and female. This is 22% of the total mathematics teachers in the county. Table 2 shows the population of male and female mathematics teachers in the county.

Table 2. Population of mathematics teachers in Kajiado county by gender

	Frequency	Percent
Male	107	71.8
Female	42	28.2
Total	149	100.0

SOURCE: TSC office Kajiado County.

As Table 3 shows, the teachers' sample was comprised of 23 male and 10 female teachers. These figures represent 21.5% of all the male teachers and 23.8% of the female mathematics teachers in the study location. This shows that there was a fair distribution in terms of percentage of the total male and total female teachers.

Table 3. Gender of the sampled teachers

	Frequency	Percentage
Male	23	69.7
Female	10	30.1
Total	33	

The sampled teachers were proportionately picked through simple random sampling. Out of a total of 149 mathematics teachers in the county, only 28% comprised of female teachers while the higher percentage of mathematics teachers were male. This low number of female mathematics in the study location is reflected in the sample. This study does not therefore consider gender as a factor in explaining the status of technology uptake and use in mathematics classrooms. This seems to be in agreement with the report of Hill, Cobertt, & St. Rose, (2008**)** on "Where the girls are:" the report shows that there are few women Science, Technology Engineering and Mathematics (STEM). However, studies have shown that students of both genders have a high affinity towards technology which implies that GeoGebra is a technology based software tool can be used by both boys and girls to learn mathematics on a common platform and can be supported by either teacher gender. To confirm this, the study purposefully used three types of schools; boys only schools, girls only schools and mixed gender (Co-educational) schools. Table 4 shows how the teachers' sample was distributed in the three types of schools

Table 4. Teachers' distribution in the three schools

	Frequency	Percent
Boys only School	9	20.0
Girls only School	9	20.0
Mixed gender School	15	60.0
Total	33	100.0

A look at Table 4 shows that a similar (27%) frequency of the total participating number teachers taught in each of the single sex schools while 45.5 % taught in mixed gender schools providing a balanced view of learning centers. This was important for the study because the researcher needed the perspectives of teachers teaching male and female students separately and when the learners were in co-educational classroom setting.

Findings on Teachers' Teaching Experience

The study sought to establish how teaching experience can count for GeoGebra uptake. Studies have shown that teachers with long teaching experience have better mastery of content which is important in uptake of GeoGebra. However, this cohort of teachers may have established styles of teaching and were more likely to resist change. Figure 2 shows a presentation of the duration for which the teachers had been teaching mathematics by the time the study was conducted.

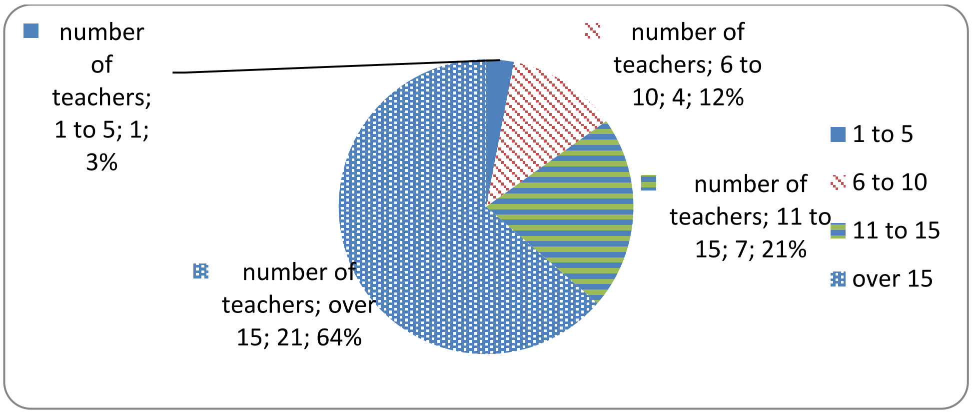

Figure 2. Duration respondents had been teaching mathematics

An examination of Figure 1 shows that 21 of the teachers, accounting for 64% of the sampled teachers had been teaching mathematics for more than 15 years. Only four of the teachers had taught for less than ten years. The study benefited from the fact that the teachers sampled had many years of teaching experience. They not only had teaching skills developed over many years, they also understood the challenges of teaching mathematics in secondary school and could identify the most difficult and poorly performed topics. It was important to establish their level of technology uptake which was a recent development in the study location and this gave both experienced and less experienced teachers a level exposition advantage

Teachers' Level of Professional and Pre-service Training

Level of professional training has been found to contribute to teachers' perspectives and believes about how learning occurs, this study investigated both teachers professional and pre service training (Table 5)

Table 5. Teachers' level of training

	Frequency	Percent
Masters Degree	7	21.0
Bachelors Degree	25	76.0
Diploma	1	3.0
Total	33	100.0

Table 5 shows that 25 teachers had bachelor's degrees while five had masters' degrees in various fields. Only one teacher had a diploma. Therefore, the teachers who participated in this study could be said to be sufficiently qualified to teach mathematics by virtue of their levels of training. In addition, all the teachers except on had computer related training and qualification. Figure 2 shows the computer related skills the teachers have mastered

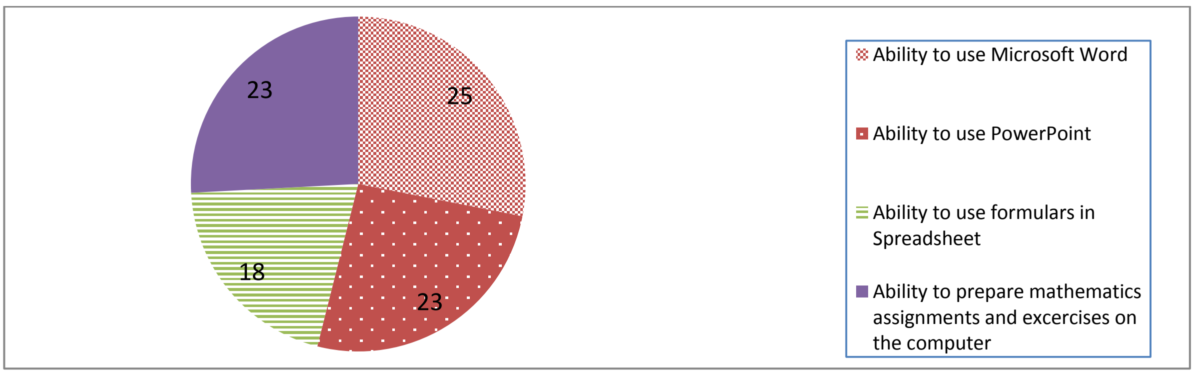

Figure 3. Teachers' computer skills

The study revealed teachers' computer skills (fig 2) as follows; all the teachers were capable of using Microsoft word and except two (6%) showed ability of using PowerPoint and preparing assignments and exercises on computers. Eighteen teachers were able to use formulas in spreadsheets. This information leads to the conclusion that most of the teachers are skilled in using computers therefore they would have no problems using teaching software such as GeoGebra.

Areas of Mathematics Teachers found Difficult to Teach

Teachers' subject content mastery is important for use of dynamic software, teachers' difficulty in teaching is an indicator of poor content mastery. The teachers participating in this study were asked to state the areas of mathematics they found difficult to teach and note the reasons behind difficulty teaching those areas. Their responses are presented in Figure 3

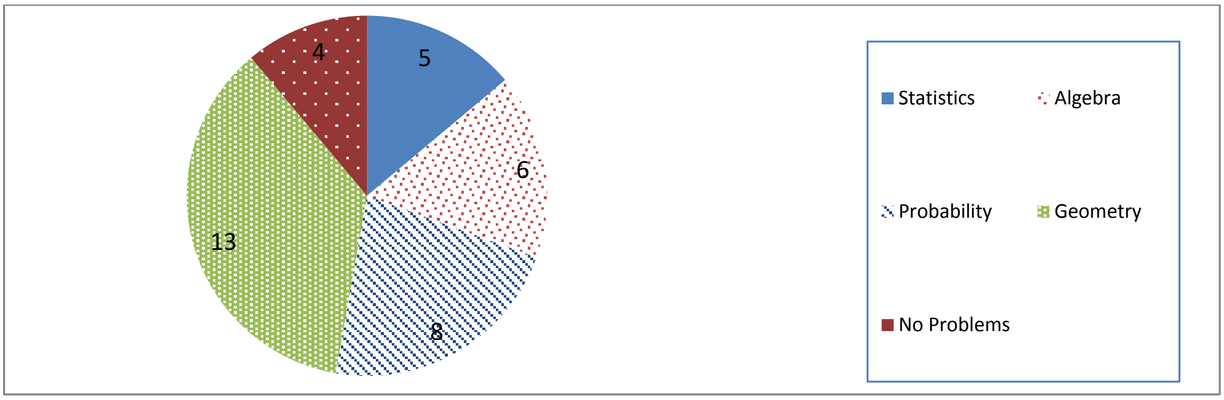

Figure 4. Teachers having difficulties teaching mathematics

The responses summarized in Figure 3 show that only four teachers showed confidence in teaching any mathematics of the strands in the questionnaire. Geometry strand was found to be the most challenging area to teach at 39.4%) followed by probability (24%). It is noteworthy that more than half (57.6%) the teachers face difficulty teaching geometry when combined with the six who face difficulties teaching algebra –these two topics that form the basis design for the GeoGebra tool. The teachers having trouble teaching geometry cited lack of resources for teaching, the abstract nature of geometry and students' inability to visualize 3-dimensional images as the main impediments. For algebra, they cited students' difficulties comprehending structural algebraic expressions and the abstract nature of this strand.

Teachers' Perception of their Competence in using GeoGebra after Training

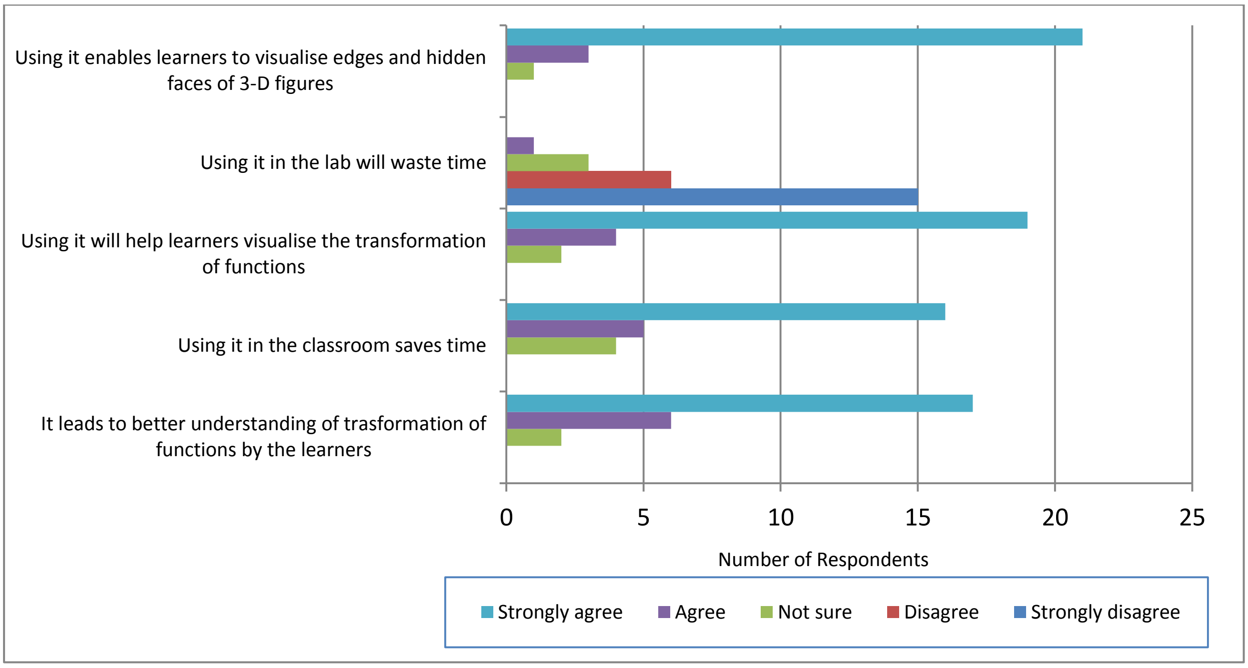

Figure 6. Teachers' perception of GeoGebra's usefulness

The study sought to find out teachers' perception of their competence with GeoGebra after they received training on how to use it to teach mathematics. The teachers were presented with five items to gauge their competence by responding on each item on a scale ranging from strongly disagree, agree, not sure, agree and strongly disagree. Figure 5 presents a summary of the teachers' perception of GeoGebra.The information presented in Figure 6 shows how teachers rated GeoGebra's usefulness in tackling various aspects of geometry. Only one teacher was unsure whether the software would enable learners visualize edges and hidden faces of three dimensional figures, two teachers were unsure whether it would help learners visualize transformation of functions and two teachers were unsure that the software would help learners understand the transformation of functions. All the other teachers believed the software was useful in achieving these goals. This finding shows that the GeoGebra software has the potential to improve the learners' ability to grasp concepts in geometry that they have difficulty understanding.

The information in Figure 6 also reveals that teachers found the software to be efficient in that it does not consume too much time. Twenty-three teachers out of the 33 teachers (69.7%) felt that it would save time when used in the classroom and only one teacher felt using it in the lab would waste time. This quality of GeoGebra is important because it will enable teachers save time hence cover the syllabus more efficiently. The teachers were asked to note factors that could aid or hinder adoption of the dynamic geometry software in their schools. Their responses are summarized in Table 7

Table 7. Factors that could aid or hinder adoption of GeoGebra

	Factors	Frequency	Percent
Factors that will aid	Availability of equipment like computers	15	48.4
	Availability of computer literate teachers	8	25
	Support from school management	25	83.9
	Positive attitude to ICT by teachers and students	5	16
	Computer literate students	2	6.4
Factors that will hinder	Insufficient resources like computers	16	51.6
	Lack of electricity	4	12.9
	Large number of students	20	64.5
	Teachers lacking ICT training	10	32
	Teachers reluctance to adopt ICT	1	3.2
	Computer illiterate students	1	3.2

As shown in Table 7, about on half of the teachers stated that availability of computers and other equipment would enable them use the software. The other half noted that absence of equipment as an impediment to implementing the software. Availability of computer literate teachers and a positive attitude towards ICT were also among the factors that teachers said would help them introduce the software to their schools. Absence of electricity and the large ratio of students to available computers were among the obstacles to using the software in some schools. There was a 64.5% response that a large number of students would hinder the use of the software in teaching mathematics at secondary school level. A large number of teachers 83.9% felt that support from school administration would be necessary to facilitate use of GeoGebra in Kenya.

Discussion

Although some teachers failed to use the software due to hindrances that were not within their control, such as lack of computers, lack of electricity and shortage of time, these findings are used in this study to generalize the uptake of GeoGebra among mathematics teachers of Kajiado County. According to Diffusion of Innovation, (Rogers, 1995), there are 5 stages of adoption of innovation. The first stage is knowledge, followed by persuasion and decision to use of technology. Having trained 33 mathematics teachers on GeoGebra use, the study sought to evaluate how they implemented what they had learnt from the training. From the earlier findings, trained teachers seemed enthusiastic about using GeoGebra in their classes. As indicated in figure 5 more than half of the sampled teachers felt that GeoGebra could enable students comprehend difficult and abstract concepts in geometry, however, only half of the male teachers used GeoGebra in their mathematics classrooms and only 20% of the female teachers practically used the software. It was observed that there were other teachers who were willing to use the software but were not able to, due to factors within the environment.

Some of the hindrances such as attitude, lack of support and large numbers of students in classes were some of the factors revealed by teachers who were asked to note factors that could aid or hinder adoption of the dynamic geometry software in their schools. According to Davis (1989) the main contributor to actual use of a new technology is its perceived usefulness, people primarily adopt new technologies based on their functions, rather than based only on how easy it is to perform the functions. Users are, for instance, willing to adopt a difficult system if it captures a critical function. However, in practical terms, about 90% of research done on Technology Adoption Models (TAM) also shows that there are direct effects of perceived ease of use on actual use (Schepers & Wetzels, 2007). In the case of the high school mathematics teachers in Kajiado County, less than 50% of the trained teachers used the technology in their mathematics classrooms. These according to the Rogers adoption model are the early adopters meaning that most of the teachers would fall in the category of late majority or the laggards as shown on Figure 1.

Conclusion

This paper concluded that uptake of GeoGebra especially in the teaching of Geometry and Algebra, areas in mathematics that teachers find difficulties when teaching was slow. However, after training, teachers believed using GeoGebra would enhance both effective teaching and learners understanding of these concepts. Some teachers were excited and got to explore its usefulness and to prepare material that would be used in teaching Geometry. The adoption of this innovation is likely to improve the teaching of learning of Geometry and algebra but this can only be tested after complete adoption of this innovation.

The study findings showed that teachers who had been trained on using GeoGebra appreciated its usefulness and most of them were willing to adopt it. Training exposed the teachers to GeoGebra and the feedback from the training sessions showed a positive perception towards GeoGebra use. However, this did not translate into actual use of the technology, as only 42% of the teachers who were trained to use the application actually used it. The study concludes that most mathematics teachers in Kajiado County are late majority or laggards in adoption of new technology. The findings of this study will be an eye opener for the teachers to accept and fully utilize technology in their mathematics classrooms which will aid the teaching and learning of geometry and algebra in the secondary school classrooms.

Recommendations

This study advocates for the use of technology in teaching mathematics to enhance understanding of mathematical concepts. It further recommends that teachers be trained to use GeoGebra as its effectiveness depends on how well teachers utilize it. Availability of technology is a key in enhancing teachers' competence in teaching Geometry.

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This paper would not have written without the sincere participation of Mathematics teachers of Kajiado county who sacrificed their time and effort to participate in the training session using GeoGebra and later allowing us to follow them up to observe their classes.

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