GEOGEBRA: AN EFFECTIVE PACKAGE FOR MATHEMATICS INSTRUCTION IN NIGERIA

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Introduction

GeoGebra is interactive software on geometry, algebra, statistics and calculus application, intended for teaching and learning of Mathematics. It is dynamic Mathematics software that combines geometry, algebra, and calculus. It is a dynamic geometry system, (CNET, 2011). It is "Dynamic Mathematics Software (DMS) designed for teaching and learning Mathematics in secondary school and college level", (Preiner, 2008). The software combines the ease of use of a Dynamic Geometry Software (DGS) with certain features of a Computer Algebra System (CAS) and therefore, allows for bridging the gap between the mathematical disciplines of geometry, algebra, and even calculus (Hohenwarter and Preiner, 2007b). GeoGebra can be used to visualize mathematical concepts as well as to create instructional materials. It has the potential to foster active and student centred learning by allowing for mathematical experiments, interactive explorations, as well as discovery learning (Bruner, 1961).

GeoGebra is a Dynamic Mathematics Software that integrates Geometry, Algebra and Calculus. It has elements of Dynamic Geometry Software (DGS) and Computer Algebra Systems (CAS). Runs on any platform that supports Java. It is freely available for online installation from www.geogebra.org/webstart or downloadable for local installation at www.geogebra.org. (Ogwel, 2009).

Background Information about GeoGebra

GeoGebra, the free, open-source Mathematics software is majorly designed for Mathematics in classrooms in secondary schools, but anyone who uses geometry, algebra, or calculus should check it out. It combines a flexible, easy-to-use geometry tool with direct input of equations and coordinates. It can create points, vectors, lines, segments, conic sections, and more using preconfigured tools and handle variables for vectors, numbers, and points. It's available in many languages and is supported by a community of users and developers. It could be used to construct points, vectors, segments, lines, conic sections as well as functions and change them dynamically afterwards. Additionally, equations and coordinates can be entered directly. Thus, GeoGebra has the ability to deal with variables for numbers, vectors and points, finds derivatives and integrals of functions, and offers commands like Root or Extremum. It is free and open source software (CNET, 2011).

GeoGebra can either be launched directly from the Internet using GeoGebra Web Start or an installer file can be downloaded. Since the software is based on Java, it is truly platform independent and runs on every operating system. Furthermore, GeoGebra is multilingual, not only in its menu, but also in its commands, and was

translated by volunteers from all over the world. According to GeoGebra Community Newsletter (2012, 2013), the GeoGebra is a free and multi-platform dynamic Mathematics software, for all levels of education, that combines geometry, algebra, tables, graphing, statistics and calculus in one easy – to – use package and is currently available in over 44 languages. It is an interactive Mathematics software package incorporating geometry, algebra, and calculus, each of which can be used separately. In the context of a developing country, open source (public domain) software like GeoGebra is most important since it can be downloaded without cost by anyone with internet access (Mainali and Key, 2013).

GeoGebra was designed specifically for educational purposes, it can help students grasp experimental, problem-oriented and research-oriented learning of Mathematics, both in the classroom and at home (Bruner, 1961). Students can simultaneously use a computer algebra system and an interactive geometric system; by doing this, they can increase their cognitive abilities in the best way, (Dikovic, 2009). GeoGebra's popularity is growing rapidly all around the world. As of March, 2008, its webpage received about 300,000 visitors per month from 188 different countries. The programme's developer estimated that more than 100,000 teachers already use GeoGebra all over the world for teaching Mathematics and creating static as well as interactive instructional materials to enhance their students' learning, (Preiner, 2008). "GeoGebra is the first among other ICT tools which are currently being explored in order to achieve integration of ICT in education", Ogwel (2009) disclosed. "We barely scratched the surface of the many ways users can customize GeoGebra and use it to teach, learn, and perform Mathematics. It's flexible, very easy to use, and very well supported, too. For anyone who can use it, we recommend it", CNET (2011) recommended.

Short History of GeoGebra

The software, GeoGebra was developed in 2001 as Markus Hohenwarter's Master's thesis project at the University of Salzburg, Austria. After studying Mathematics Education as well as Computer Engineering, he started to implement his idea of programming software that joins dynamic geometry and computer algebra, two mathematics disciplines that other software packages tend to treat separately, (Preiner, 2008). His main goal was to create educational software that combines the ease of use of a Dynamic Geometry Software with the power and features of a Computer Algebra System, which could be used by teachers and students from secondary school up to college level. After publishing a prototype of the software on the Internet in 2002, teachers in Austria and Germany started to use GeoGebra for teaching Mathematics, which was, at this point, rather unexpected by the creator, who got a lot of enthusiastic e-mails and positive feedback from those teachers, (Hohenwarter and Lavicza, 2007).

In 2002, Hohenwarter received the European Academic Software Award EASA in Ronneby, Sweden, which finally inspired him to go on with the development of GeoGebra in order to enhance its usability and extend its functionality. Further development of GeoGebra was funded by a DOC scholarship awarded to Hohenwarter by the Austrian Academy of Sciences, which also allowed him to earn his Ph.D in a project that examined pedagogical applications of GeoGebra in Austrian secondary

schools. During the next four years GeoGebra won several more software and media awards in different European countries, including Austria, Germany, and France (Hohenwarter, 2005).

GeoGebra's ongoing development, since 2006, has continued at Florida Atlantic University, USA, where Hohenwarter works in a teacher training project funded by the National Science Foundation's Mathematics and Science Partnership Initiative. Since then, GeoGebra has enhanced by including a range of important features. This enhanced functionality enabled the creation of user defined tools and significant simplification in the steps required for user creation of interactive instructional materials, the so called *dynamic worksheets.* The future plans to further extend and enhance GeoGebra involve the implementation of a dynamically linked spreadsheet, as well as a computer algebra extension, pushing the software further towards the goal of being a versatile and easy to use software package that can be used for a wide range of different grade levels and mathematical contents by students and teachers around the world, (Preiner, 2008).

Design of GeoGebra

There are two types of educational software that connect the mathematical fields of geometry and algebra and are used for Mathematics teaching and learning presently. Firstly, there is Dynamic Geometry Software (DGS) that allows users to create and dynamically modify Euclidian constructions. Geometric properties and relations between objects used within a construction are maintained because manipulating an object also modifies dependant objects accordingly. Some dynamic geometry programmes even provide basic algebraic features by displaying the equations of lines or conic sections, as well as other mathematical expressions which usually can't be modified directly by the user.

Again, there are Computer Algebra Systems (CAS) which symbolically performs algebra, analytic geometry, and calculus. Using equations of geometric objects, a computer algebra system can decide about their relative position to each other, and display their graphical representations. Many computer algebra systems are also able to plot explicit and sometimes even implicit equations. Generally, the geometric representation of objects can't be directly modified by the user, (Preiner, 2008).

GeoGebra is an attempt to join these two types of software, whereby geometry, algebra, and calculus are treated as equal partners. The software offers two representations of every object: the numeric algebraic component shows either coordinates, an explicit or implicit equation, or an equation in parametric form, while the geometric component displays the corresponding solution set (Hohenwarter, 2002). Numerous research results suggest that these software packages can be used to encourage discovery, experimentation and visualization in traditional teaching of Mathematics, Diković (2009). In GeoGebra, both representations can be influenced directly by the user. The geometric representation can be modified by dragging it with the mouse, whereby the algebraic representation is changed dynamically. The algebraic representation can also be changed, using the keyboard causing GeoGebra to automatically adjust the related geometric representation.

This new bidirectional dynamic connection between multiple representations of mathematical objects opens up a wide range of new application possibilities of Dynamic Mathematics Software for teaching and learning Mathematics while fostering student understanding of mathematical concepts in a way that was not possible several years ago, (Preiner, 2008).

Advantages of Using GeoGebra

Researchers suggested that, for the majority of teachers, the main problem is how to provide the technology necessary for the successful integration of technology into teaching (Ruthven & Hennessy, 2004). Therefore, the suggested solution for integrating technology into the teaching of Mathematics is the software package, GeoGebra. According to Diković (2009), the advantages of using GeoGebra are:

• In comparison to a graph calculator, GeoGebra is more user-friendly. GeoGebra offers easy-to-use interface, multilingual menus, commands and help.

• GeoGebra encourages students` projects in Mathematics, multiple presentations and experimental and guided discovery learning, (Bruner, 1961).

• Students can personalize their own creations through the adaptation of interface (e.g. font size, language, quality of graphics, colour, coordinates, line thickness, line style and other features).

• GeoGebra was created to help students gain a better understanding of Mathematics. Students can manipulate variables easily by simply dragging "free" objects around the plane of drawing, or by using sliders. Students can generate changes using a technique of manipulating free objects, and then they can learn how the dependent objects will be affected. In this way, students have the opportunity to solve problems by investigating mathematical relations dynamically.

GeoGebra provides a good opportunity for cooperative learning, i.e. cooperative problem solving in small groups, or whole class interactive teaching, or individual/group student presentations.

• The algebra input allows the user to generate new objects or to modify those already existing, by the command line. The worksheet files can easily be published as Web pages.

• GeoGebra stimulates teachers to use and assess technology in: visualization of Mathematics; investigations in Mathematics; interactive Mathematics classes on site or at a distance; Mathematics and its applications, etc.

Components of GeoGebra

Ogwel (2009) highlighted the components (elements) of GeoGebra as follows:

Menus: File; Edit; View; Options; Tools; Window; Help.

Tools: Move; Points; Lines; Loci/Constructions; Polygons; Circles and Circular arcs; Conics; Measurements; transformation; Slider; Visibility; Toolbar Help.

Views:

    Graphics/ Geometry View: Default view and drawing pad on which geometrical objects   are constructed.

    Algebra View: Gives algebraic representation of objects.

Spreadsheet View: Every cell has a specific name and names of objects match the spreadsheet cells (See Fig 2.1).

Input Bar: Gives algebraic command as alternative to the geometrical tools on the toolbar.

Preiner (2008) noticed that "since GeoGebra joins dynamic geometry with computer algebra, its user interface contains additional components that can't be found in pure dynamic geometry software. Apart from providing two windows containing the algebraic and graphical representation of objects, components that enable the user to input objects in both representations as well as a menu bar are part of the user interface" (See Figure 2.1).

Toolbar: The tool bar consists of a set of tool boxes in which GeoGebra's dynamic geometry tools are organized. Tools can be activated and applied by using the mouse in a very intuitive way. Both the name of the activated tool as well as the toolbar help, which is placed right next to the toolbar, give useful information on how to operate the corresponding tool and, therefore, how to create new objects. In the right corner of the toolbar the Undo and Redo buttons can be found, which enable the user to undo mistakes step-by-step.

Graphics window: The graphics window is located on the right hand side of the GeoGebra window. It contains a drawing pad on which the geometric representations of objects are displayed. The coordinate axes can be hidden and a coordinate grid can be displayed by the user. In the graphics window, existing objects can be modified directly by dragging them with the mouse, while new objects can be created using the dynamic geometry tools provided in the toolbar (Compare Figures 2.1 & 2.2).

Algebra window: The algebra window is positioned on the left hand side of the GeoGebra window. It contains the numeric and algebraic representations of objects which are organized into two groups:

> • *Free objects* can be modified directly by the user and don't depend on any other objects.

> • *Dependant objects* are the results of construction processes and depend on 'parent objects'. Although they can't be modified directly, changing their parent objects influences the dependant objects.

Additionally, both types of objects can be defined as auxiliary objects, which mean that they can be removed from the algebra window in order to keep the list of objects clearly arranged. Algebraic expressions can be changed directly in the algebra window, whereby different display formats are available (e.g. Cartesian and polar coordinates for points). If not needed, the algebra window can be hidden using the View menu.

Input Field: The input field is placed at the bottom of the GeoGebra window. It permits the input of algebraic expressions directly by using the keyboard. By this means a wide range of pre-defined commands are available which can be applied to already existing objects in order to create new ones.

Menu Bar: The menu bar is placed above the toolbar. It provides a wide range of menu items allowing the user to save, print, and export constructions, as well as

to change default   settings of the programme, create custom tools, and customize the toolbar.
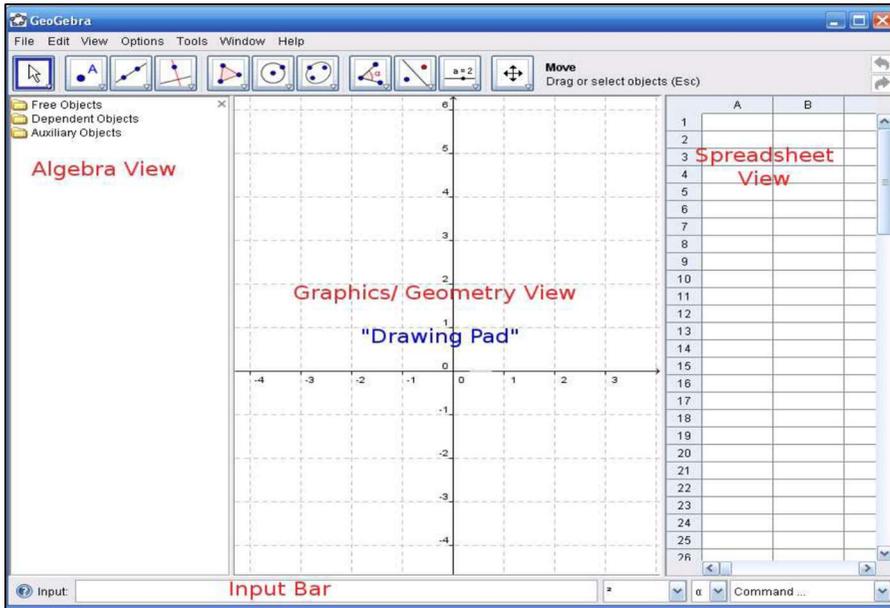

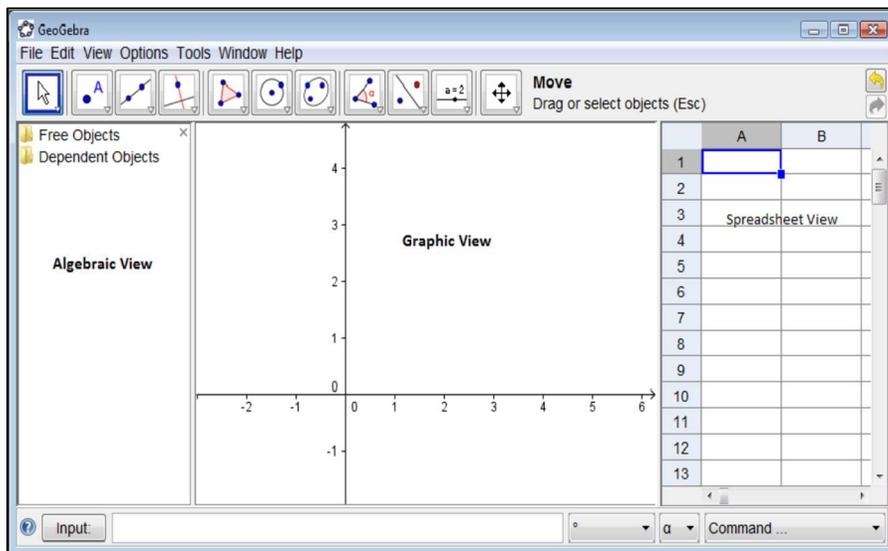**Fig. 2.1.**   Screen Shot of a GeoGebra Window (a)

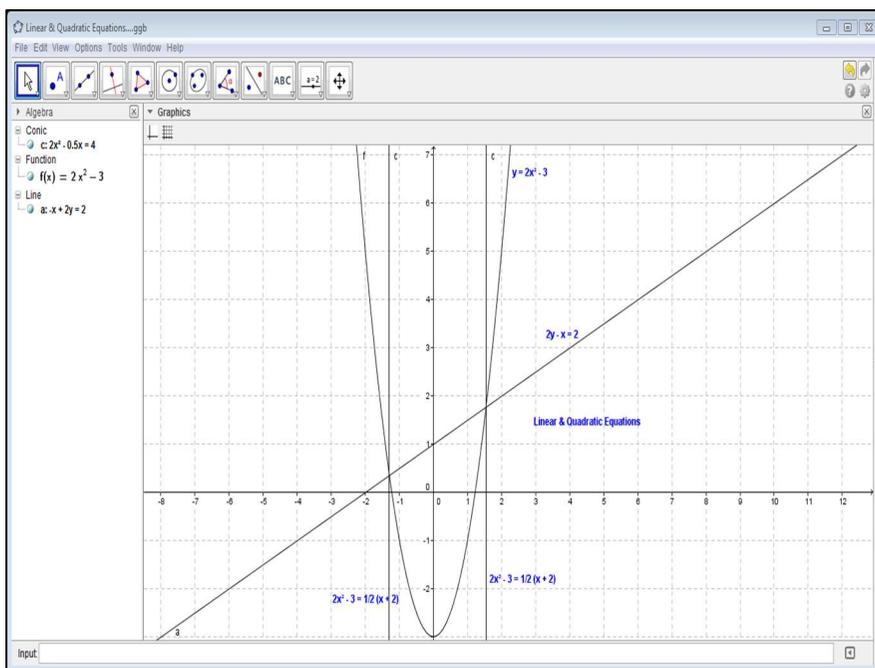**Fig. 2.2.**   Screen Shot of a GeoGebra Window (b)

Fig.2.3. Linear & Quadratic Equations

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