PARADIGM SHIFT IN TEACHING AND LEARNING OF QUADRATIC EQUATIONS IN SECONDARY SCHOOLS

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TABLE OF CONTENT

CHAPTER ONE

METHODOLOGY IN MATHEMATICS EDUCATION

According to Wikipedia online Encyclopedia (2010) "methodology can be the analysis of the principles of methods, rules and postulates employed by a discipline or the systematic study of methods that are, can be, or have been applied within a discipline". Methodology, hence, includes a philosophically coherent collection of theories, concepts or ideas as they relate to a particular discipline or field of inquiry. Obviously, methodology refers to the rationale and the philosophical assumptions that underlie a particular study relative to the scientific method. Umar, Egunjobi, Olude, Zubairu and Mu'azu (2006) defined methodology as "the study of the methods of teaching or the study and practice of various methods of teaching". This implies that methodology is both the study of different methods and the systematic means of presenting subject matter and learning experiences. Many of the methods of teaching have their origins in the various theories of learning. The study of methodology covers not only the philosophy of methods but also the influence of psychological principles involved in learning.

Akinsola, et. al (2006) posited that early attempts to develop a methodological foundation of mathematics attempted to vindicate it as a discipline free of error that did justice to its arrogant and secular epithets as the most perfect of all sciences. Kekere (2009) argued that if mathematics is, as the Platonist tradition suggested, just an entity out there waiting to be discovered, then it will be enough for schools to present the curriculum instruction as a mere collection of facts, definitions and algorithms. In that regard, teaching mathematics would be like just transmitting an immutable body of knowledge that students have to accept as a perennial fact without any reasoning. However, if mathematics is an empirical activity, then learners are in the position of constructing their own mathematics knowledge regardless, of how different their methodology may be from cannon of orthodox and classical mathematics. This later view forms the basis of this study.

Miller (2010) observed that which instructional method is "right" for a particular lesson depends on many things, and among them are the age and developmental level of the students, what the students already know and what they need to know to succeed with the lesson. Also important are; the subject matter content, the objective of the lesson, the available people, time, space, material resources and the physical setting. Another more difficult problem or challenge before the mathematics teacher is to select an instructional method that best fits his particular teaching style and the lesson situation. Miller further suggested that for highly effective mathematics teaching, the teacher should strive to teach for understanding of mathematical concepts and procedures, the "why" something works and not only the "how" should be emphasized. The "how" something works is often called procedural understanding. The child knows how to work long division, or the procedure of fraction addition or division for example. It is often possible to learn the "how" mechanically without understanding why it works. Procedures learnt this way are often forgotten very easily. The relationship between the "how" and the "why" or between procedures and concepts is complex. One doesn't always come totally before the other, and it also varies from child to child. Conceptual and procedural understanding actually helps each other.

Conceptual knowledge (understanding the "why") is important for the development of procedural fluency, while fluent procedural knowledge supports the development of further understanding and learning. It is prescribed that as a rule of thumb, the mathematics teacher should not leave any mathematics topic until the student both knows "how" and understands the "why".

Mayer (2001) held that one ultimate goal of learning school mathematics is to enable students navigate their lives in this ever- so- complex modern world. Hence, mathematics education as a whole should enable the students to understand information around us. In today's world, being able to read through information and make sense of it requires knowledge of basic mathematical concepts. Our youngsters need to be able to handle money wisely, deal with purchases, shopping, loans and budgeting and all these require good understanding of mathematics. Mathematics educator should help students see some beauty of mathematics and learn to like it, or at the very least, make sure the students do not feel negatively about mathematics. These attributes form the basis for the design of the BASIC Quadratic Equation Game used in this study.

CHAPTER TWO

CONCEPT AND APPLICATIONS OF QUADRATIC EQUATIONS

The term “Quadratic” comes from “Quadratus” which is the Latin word for “square”. Wikipedia online encyclopedia (2010) defines Quadratic Equation as a polynomial equation of the second degree with the general form $ax^2 + bx + c = 0$, where a, b, and c are real numbers with $a \neq 0$. Another name for a Quadratic Equation in x is a second- degree polynomial equation in x. The Babylonians, as early as 2000BC displayed on old clay tables, evidences that they could solve a pair of simultaneous equations of the form $x + y = P$, $xy = q$ which are equivalent to the equation $x^2 + q = px$. In the sulba Sutras in ancient India Circa 8th century B.C, Quadratic Equations of the form $ax^2 = C$ and $ax^2 + bx = c$ was explored using geometric methods. Babylonian Mathematicians from Circa 400BC and Chinese mathematicians from 200BC used the method of completing the square to solve Quadratic Equations with positive roots, but did not have a general formula (Bittinger and Beecher, 2004).

Euclid, the Greek mathematician, produced more abstract geometrical method around 300BC. In 628 AD, Brahmagupta, an Indian mathematician gave the first explicit (although still not completely general) solution of the Quadratic Equation. The Backhshali manuscript written in India in the 7th century AD contained an algebraic formula for solving Quadratic Equations, as well as Quadratic indeterminate equations (originally of type ax/c=y). Mohammad bin Musa Al- kwarismi (Persia, 9th century) developed a set of formulas that worked for positive solutions based on Brahmagupta. The Catalan Jewish mathematician Abraham bar Hiyya Ha- Nasi authored the first book to include the full solution to the general Quadratic Equation.

The writing of the Chinese mathematician Yang Hui (1238-1298 AD) represents the first in which Quadratic Equations with negative co- efficient of ‘x’ appear although he attributes this to the earlier Liu Yi. The first appearance of the general solution in the modern mathematical literature is evidently in an 1896 paper by Henry Heaton (Larson,Hostetler and Hodgkins, 2000).

Methods of solving Quadratic Equations include; factorization, completing the square, General formula and the graphical methods. Factorization techniques is based on the zero- factor; if $ab = 0$ then $a = 0$ or $b = 0$. To use this property, re write the left side of the standard form of a Quadratic Equation as the product of two linear factors. Then find the solutions of the Quadratic Equation by setting each factor equal to zero. The zero – factor property applies only to equations in standard form in which one side of the equation is zero. A Quadratic Equation of the form $ax^2 + bx = 0$ where $c= 0$ and $b \neq 0$ will always have zero (0) as one solution and a non- zero number as the other solution.

Quadratic Equations of the type $ax^2 = p$ can be solved by applying the principle of square roots, which states that a positive number has two square roots. The number 0 has one square root, 0. Thus, the equation $x^2 = d$ has two real solutions when $d > o$. The solutions are $\sqrt{d}$ and $-\sqrt{d}$ or simply $x = \pm \sqrt{d}$. The equation $x^2 = 0$ has only 0 as the solution but $x^2 = d$ has no real number solutions when $d < 0$ (ie negative). Quadratic Equations of the type $x^2 + 8x + 16 = 49$ can be solved using the principle of square root because the expression on the left side is the square of a binomial, $(x +4)^2$. This procedure is the basis for a method of solving Quadratic Equations called completing the square. To complete the square of an expression like $x^2 + bx$, take half of the coefficient of x, square it and add the result to it.

Bittinger and Beecher (2004) summarized the steps involved in completing the square as follows; for $ax^2 +bx +c = 0$

1. If $a \neq 1$, multiply by $1/a$ so that the x^2 coefficient is 1.

2. If the x^2 coefficient is 1, add so that the equation is in the form $x^2 + bx = -c$ or $x^2 + bx/a = - c/a$ if step 1 has been applied.

3. Take half of the x – coefficient and square it. Add the result on both sides of the equation.

4. Express the side with the variables as the square of a binomial.

5. Use the principle of square roots and complete the solution.

The Quadratic general formula can be derived by solving $ax^2 + bx + c = 0$ using completing the square method to get the solution $x =$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

To use this formula in solving any Quadratic Equation, one has to identify the values of a, b, and c and substituting those values correctly into the formula. The expression underneath the square root sign ($b^2 - 4ac$) is called the discriminant of the Quadratic Equation and is often represented using an uppercase Greek Delta

Δ, $\Delta = b^2 - 4ac$.

Larson, et al (2000) explained that Quadratic Equation with real co- efficient can have either one or two distinct real roots, or two distinct complex roots. The discriminant determines the number and nature of the roots. There are three cases associated with this; (i) if this discriminant is positive, $b^2 - 4ac > 0$, the equation has two distinct real solutions or roots both of which are real numbers. For Quadratic Equations with integer coefficients, if the discriminant is a perfect square, then the roots are rational numbers. In other cases, they may be Quadratic irrationals. (ii) If the discriminant is zero, $b^2 - 4ac = 0$, there is exactly one distinct repeated real root or solution, sometimes called a double root, given by $x = -b/2a$. (iii) However, if the discriminant is negative, $b^2 - 4ac < 0$, the equation has no real roots or solutions. Rather, there are two distinct non- real or imaginary complex roots which are complex conjugates of each other; $x = -\frac{b}{2a} + i\frac{\sqrt{4ac-b^2}}{2a}$ and $\frac{-b}{2a} - i\frac{\sqrt{4ac - b^2}}{2a}$

Where i is the imaginary unit.

The roots of Quadratic Equations are distinct if and only if the discriminant is non-zero and the roots are real if and only if the discriminant is non-negative. Let a, b and c be real numbers with $a \neq 0$.

The function of x given by f (x) = $ax^2 + bx + c$ is called a Quadratic function. The solutions of the Quadratic Equation $ax^2 + bx + c = 0$ are also the zeros of the quadratic function: $f(x) = ax^2 + bx + c$ since they are the values of x for which f(x)=0. If a, b and c are real numbers and the domain of F is the set of real numbers, then the zeros of f are exactly the x – coordinates of the points where the graph touches the x – axis. It follows from the above that; if the discriminant is positive, $b^2 - 4ac > o$, the graph touches the x – axis at two points, if the discriminant is zero, $b^2 - 4a = 0$, the graph touches the x – axis at one point, and if the discriminant is negative, $b^2 - 4ac < o$, the graph does not touch the x –axis.

The graph of a Quadratic Function is called a parabola. It is "U" shaped and can open upward or downward. All parabolas are symmetric with respect to a line called the axis of symmetry, or simply the x – axis of the parabola. The point where the axis intersects the parabola is the vertex of the parabola. If the leading coefficient is positive, the graph of $f(x) = ax^2 + bx + c$ is a parabola that opens upwards, and if the leading coefficient is negative, the graph of $f(x) = ax^2 + bx + c = 0$ is a parabola that opens downward (Larson, et. al, 2000). Bittinger and Beecher (2004) summarized the tips for graphing quadratic equations as follows; "Graphs of Quadratic Equation $y = ax^2 + bx + c$ are all parabolas. They are smooth cup- shaped symmetric curves, with no sharp points or kinks in them. The graph of $y = ax^2+bx+c$ opens up if $a > 0$. It opens down if $a < 0$."

Larson, et. al (2000) identified four basic types of applications involving Quadratic Equations as;

(i) Applications in problems dealing with area.

(ii) Applications involving falling objects or objects vertically projected into air.

(iii) Applications involving the hypotenuse of a right triangle (Pythagorean theorem). and

(iv) Applications involving a Quadratic model.

The four methods of solving Quadratic Equations discussed above are all components of the BASIC Quadratic Equation Game and all the four applications outlined above also are relevant for senior secondary 2 students who form the subjects of this study.

CHAPTER THREE

PEDAGOGY OF MATHEMATICS GAMES

The Mobile Systems English Dictionary (2007) defined game as “a form of play or sport”. It further defined sport as “a competitive activity involving physical effort and skill”, and play as “games taken part in for enjoyment”. Ezeamenyi (2004) stated that “Games are social activity with a set of rules in which the hallmark is to win. Educational games are thus recreational activity, which teach people how to utilize their “Leisure time” in constructive manner”. Variously, games have been described as subset of activities with special characteristics within the context of simulation; competitive interactions among participants to achieve pre- specified goals; and competitive play with great appeal to learn, with set of rules and goals (Hall, 1976; Twelker and Layden, 1972; mill 1979 all in Ezeamenyi, 2004).

According to Obodo (2004), mathematical games can take the form of puzzles, magic tricks, fallacies, paradoxes, or any type of mathematics, which provides amusement or curiosity. Such games provide enjoyment and recreation. They also stimulate mathematical thinking and also generate excitement and spirit of competition. Ukeje and obioma (2002) held that mathematical games are one of the most potent means of stimulating interest in mathematics. Similarly, plato (427-347Bc) in Ukeje and Obioma (2002) suggested that “Amusement and pleasure ought to be combined with instruction in order to make the subject more interesting”. In every culture, children play games either as part of learning to grow up in the culture or as pass- time or leisure. Some of the games are miniature adult activities and they help the children to learn adult activities, which help them to grow satisfactorily into active adult members of the culture.

In education, play method is a veritable pedagogic process. In fact, the Montessori Method is predicated on the efficacy of play as an effective learning strategy. Learning through play makes learning less boring and less tasking. Learning through play can be exciting, interesting and at the same time academically rewarding (Azuka, 2009).

Rmiszowki (1981) in Ezeamenyi (2004) described games as an activity which promotes four types of learning namely;

(i) Learning by doing through role playing.

(ii) Learning by imitating through observers' reactions.

(iii) Learning by feedbacks through observer and role player interactions during de- briefing and

(iv) Learning by Analysis through de- briefing looping. Games, thus, ensure all- round training; the brain, the mind and the hands.

In addition, Ukeje and Obioma (2002) noted that generally, games like activities may not necessarily be competitive in nature. They are rather, social situations where-in the teachers and/or the pupils perform moves, counter moves and other maneuvers which are by certain rules prescribed or agreed upon. The moves, countermoves and other maneuvers form part of the procedures. These special features of game-like activities underscore the philosophy underlying mathematical games. They further explained that with these features borne in mind, the teacher will strive to minimize any distraction that may be associated with the mathematical games but rather to utilize the excitement in increasing the potentials of learning the required tasks.

On the use of mathematical games, mill (1979) in Ezemenyi (2004) advised that teachers should help motivate trainee to learn and this they can do more effectively through gaming. Thus, in this dispensation, every teacher should be a game master and in trying to defend this position to the best of his knowledge, He should;

i. Resist temptation to correct minor errors in order to prevent frustration.

ii. Resist the temptation to offer a better strategy that the students do not perceive in order to prevent inhibition due to "academic wave fronts".

iii. Resist the temptation to alter the results of the games in order not to be an "academic rigger".

iv. Resist the temptation to constraint the moderate physical movement, games may require in order not to induce "academic convulsion".

However, Hall (1979) in Ojo (2009) argued that it is not a matter of games being successful in practical class room but rather a matter of considering teachers' task in organizing, conduction and applying this approach within a set of criteria which act as yardsticks for relevant learning. He emphasized further, the need for the teacher to have some sense of why games support learning process more adequately than other possible means.

Consequently, obodo (2004) cautioned that a mathematics teacher has to be careful in planning how to utilize appropriate games for mathematics learning. In order to ensure adequate utilization of mathematical games during lessons, the following should be ensured by the teacher;

1. Choose a game which matches the needs of the children. Consider the interest profiles of the children in the class.

2. The games should be used at the appropriate time depending on the topic being taught and the objectives of the lesson or game.

3. Arrange the game in such a way as to actively involve all students in your class. Ensure that each student or group of students participate fully.

4. The game should be planned and organized in such a way that the informal nature of the game and the excitement of the game situation do not defeat the purpose of the game. Direct their attention to the objective for which the game is being used to learn mathematics concepts.

5. The responsibility of learning something from the game need to be emphasized. This requires drawing out very clearly the relationship between the game and the actual learning process in mathematics.

In the same vein, Kekere (2009) hinted that the choice of a mathematical game will depend on such factors as the class level, the nature of the children, the topic of interest, the environment of the school since some games can derive from the culture and environment. They further outlined the major factors that should be considered in using mathematical games as; needs of the class, proper time for use of the games, active participation by all, minimization of informality and excitement and ensuring that something must be leant from the game.

The afore-outlined factors were considered in the design of the Basic Quadratic Equation Game to be used in this study. Also, Class level, proper timing, minimization of informality, active involvement of the students was among others carefully taken into considerations.

CHAPTER FOUR

COMPUTER – AIDED INSTRUCTIONAL TECHNIQUES

The mobile systems English Dictionary (2007) defined computer as an electronic device for storing and processing information. Ezeliora (2004) described computer as an electronic automatic machine which is capable of receiving, storing, recalling or retrieving information put in it. In the same vein, Obianu in Olinya (2003) defined computer as a device for storing large amount of information called data, and processing these data in specified ways in very short period of time. To him, computer is a machine specifically designed for the manipulation of coded information; an automatic electronic machine for performing simple and complex operation far beyond the capacities of man.

Similarly, Osaisai (1996) in Ogugua, Ngwu, Olinya, Oyedapo and Rasaki (2008) defined computer as an electronic device that has the ability to accept data, internally store and automatically execute a program of instructions, perform mathematical, logical and manipulative operations on data, and report the result. To Oluwaniyi (2009), computer is a combination of hardware devices and programs, assembled to accomplish some specific tasks.

The term “computer” will undoubtedly suggest a machine used for computations, that is, mathematical calculations. This is certainly one of the functions of a computer, but to think of computers only as rather powerful calculating machines would seriously under- estimate the range of their possible applications. Computers today handle many tasks that involve little or no mathematical computations, and it is better to think of them as machines which handle information in a logical way.

Computer in its various forms has become an essential part of the learning process. Two different types of computers use in education could be identified: class use of computers and supportive use of computers. Class use of computers include computer as tool for presentation, encouraging pupils to train skills and instructing pupils in the possibilities of computers, while supportive use of computers include administration, preparing work sheet for the pupils, looking for information on the internet for lesson preparation. (Van- Braak and Valcke, 2004).

Onah (2009) differentiated between computer in Education, Computer Education and computer through Education as follows; computer in Education is about the use of computer or Information and Communication Technology (ICT) to facilitate education. This involves the application of computer into teaching and learning, from planning through implementation and up to the point of achieving learning objectives. Computer or ICT Education refers to computer or ICT as a subject of study, this requires proper planning for designing and implementing the curriculum that will have a broader perceive of computer from the foundation to all levels of learners. Computer through Education refers to computer knowledge and skills acquired through education or acquiring computer knowledge and skills through the learning of other subjects. This work is based on class use of computers or computer in Education as described above.

Philips (1998) in Adegbenro (2006) identified three applications associated with educational use of computer, namely; computer Aided Instruction (CAI), computer managed learning (CML) and computer- Based Training (CBT). This work falls within the first category, that is, computer- Aided Instruction. Computer- Aided Instruction (CAI) is the general term used to describe virtually any learning activity that is promoted by computer or in which a computer is involved (Beech, 2003).

Van Braak et al (2007) listed the various modes and functions of CAI as follows; CAI functions are;

(i) Management of learning, (ii) Testing, (iii) Tutoring,

(iv) Exercising, (iv) Use of a computer for producing teaching materials, (iv) Dissemination of materials and (vii) medium of expression. CAI modes include, (i) problem solving, (ii) Drill and practice, (iii) Simulations and games (vi) Tutorial modes (v) Dialogue modes and (vi) Enquiring modes.

Depending upon the relative degree of involvement by the learner, two basic types of CAI were identified by Adegbenro (2006) as CAI which involves the use of computer as teaching/ learning aid, but there is no direct involvement by the students. In contrast, interactive CAI promotes active learning in which there are high degree of student's participation and involvement. Here the students' behaviour and responses to instructional materials can be used to help determine the most appropriate pathway through the body of knowledge coded in the CAI.

Philip (2005) prescribed that each of the two categories of CAI may be used at different levels, for instance, at the initial stage of introducing a new topic, passive CAI could be useful. On the other hand, interactive CAI could be useful in learning by discovery situation. The Basic Quadric Equation Game used in this study is an interactive CAI as this is most appropriate for the academic level and Average Age of the subjects of the study.

CHAPTER FIVE

BASIC COMPUTER PROGRAMMING LANGUAGE

Ogugua et. al (2008) defined computer programming as the art of conceiving a problem in terms of the steps to its solution and expressing those steps as instructions for a computer system to follow. In the same vein, Udeh (2007) defined computer program as a logical sequence of instructions written for the computer to execute in order to arrive at a solution to that given problem. Further-more Microsoft Encarta Encyclopedia (2005) defined a computer program as a sequence of instructions that tells the hardware of a computer what operations to perform on data. Computer programmers employ systems analysis and design tools, such as flowcharts and structure charts to formulate steps to the solution of the problem. To communicate the logic of the solution to the computer, programmers use any computer programming language.

According to Ogugua et. al (2008), a programming language is a collection of commands that direct the control of a computer system. Programming language is to computers what human language is to human beings. Similarly, Udeh (2007) explained that computer language consists of sets of instructions that might be in form of words, symbols and commands that the computers can understand. More-so, Microsoft Encarta Encdopedia (2005) described programming language simply as a particular pattern of binary digital information. It further distinguished between machine language, Assembly language and High-level language as follows; machine language is the computers own binary- based language. Assembly languages are shortened and simplified machine language devised by assigning a short (usually three- letter) mnemonic code to each machine- language command. High level languages often use English words such as LIST, PRINT OPEN, START, LET, END, and so on, as commands that might stand for a sequence of tens or hundreds of machine language instructions. BASIC programming language used in this study belongs to high level languages.

BASIC is an acronym for Beginners All – purpose symbolic instruction code. It was developed by John Kemeny and Thomas Kurtz of Dartmouth College in the mid 1960s. Ogugua et al (2008) reported that BASIC is assumed to be the most popular programming language in the world today. BASIC has a small interpreter and this made it the choice for all mainframe and minicomputers, particularly in educational institutions. BASIC was originally designed as a teaching language and it indeed became that more so with the advent of micro computers (Van Braak et al, 2007). Microsoft Encarta Encydopedia (2005) described BASIC as a very popular high- level programming language, frequently used by beginning programmers. All these attributes of BASIC programming language make it most suitable for this study.

CHAPTER SIX

CONSTRUCTIVIST THEORY OF LEARNING

The theoretical framework underlying the design and implementation of this study comes from constructivist theory of learning. According to Wikipedia online Encyclopedia (2010) constructivism is a psychological theory of knowledge (Epistemology) which argues that humans generate knowledge and meaning from their experiences. Constructivism is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in. Each of us generate our own “rules” and “mental” models”, which we use to make sense of our experiences. Learning therefore is simply the process of adjusting our mental models to accommodate new experience.

Von- Glasersfeld (1984) stated that constructivism posits the notion that learners create or construct new knowledge. Richardson (2003) explained further that as learners access information through their senses, the construction of new knowledge comes from an interaction between their existing knowledge and new experiences and ideas with which they come in contact in the natural world and their culture.

Further-more, Akinsola, Olude, and Oluwi (2006) noted that for constructivist educationist, knowledge must be actively constructed as the learner is an entity with previous experiences that must be considered as “knowing being”. Learning is therefore seen as an adaptive and experiential process rather than a knowledge transference activity (candy, 1991 in Richardson, 2003). As learners encounter new situation, they look for similarities and differences against their own cognitive schemata. Those contrasts, also called cognitive perturbations, are the end product of confliction knowledge waiting to be resolved through re- organizing schemes of knowledge (Philip, 2005). In constructivist terms, Learning depends on the way each individual learner looks at a particular situation and draws his/ her own conclusions. People, thus, determine their own knowledge based on their own way of processing information and according to his/ her own beliefs and attitudes towards learning.

Murphm (1997), Woodcobb and Yackal (1991) in Akinsola et. al (2006) opined that constructivism gives recognition and values instructional strategies in which students are able to learn mathematics by personally and socially constructing knowledge. Constructivist learning strategies include more reflective oriented learning activities in mathematics education such as explanatory and generative leaning. More specifically, these activities include problem solving – group learning, discussion and situated learning. Constructivism is often associated with pedagogic approaches that promote active learning or learning by doing.

Summarily, Brooks (2000) in Azuka (2009) outlined the following four guiding principles of constructivism;

1. Learning is a search for meaning. Therefore, learning must start with the issues around which students are actively trying to construct meaning.

2. Meaning requires understanding wholes as well as parts. And parts must be understood in the context of wholes. Therefore, the learning process focuses on primary concepts, not isolated facts.

3. In order to teach well, we must understand the mental models that students use to perceive the world and the assumptions they make to support those models.

4. The purpose of learning is for an individual to construct his or her own meaning, not just memorize the “right” answers and regurgitate someone else’s meaning.

Formalization of the theory of constructivism is generally attributed to Jean Piaget (1896-1980) who articulated mechanisms by which knowledge is internalized by learners. He suggested that through processes of accommodation and assimilation, individuals construct new knowledge from their experiences. When individuals assimilate, they incorporate the new experience into an already existing framework without changing that framework. Piaget saw play as an important and necessary part of the students’ cognitive development and provided scientific evidence for his views (Akinsola et. al, 2006)

Adler (1971) in Obodo (2004) discussed some influences of Piaget's theory on the teaching and learning of mathematics as summarized below; since the child's mental development advances through qualitatively different stages, these stages should be considered when planning the mathematical experiences of a child at any given age. First, they should be experiences which he is ready for; in view of the stage of mental growth that the child has attained. On a second note, they should be of help in preparing the child to the next stage. A topic should neither be taught too early nor too late. A child should be tested to ensure that he has mastered all the prerequisites necessary for mastering a mathematical concept before introducing a new one. When the child is not ready to learn a concept, he should be provided with the necessary experiences that will help him to be ready to learn the concept. In order to encourage mental growth of children, the experience of seeing things from varied perspective is very necessary. Physical action is a base for learning. For a child to learn effectively, he must be an active participant in mathematical events or activities, not just a spectator.

These features characterize the BASIC Quadratic Equation Game method being studied in this work. More-so, the formal operational stage of the Piaget's classifications corresponds to the stage of the subjects of this study.

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