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Development of *algebrameter* for remediating junior secondary school students' learning difficulties in mathematics

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ABSTRACT

The purpose of the study was to develop mathematical instructional card game titled *algebrameter* and determine its efficacy in remediating junior secondary school (JSS) students' learning difficulties in algebra and geometry. The study employed research and development design. A sample of 120 JSS II students drawn from a population of 4800 JSS II students in Nsukka Education Zone, using multi-stage sampling procedure participated in the study. Algebra and geometry achievement test (AGAT) comprised 30 multiple choice questions developed by the researchers was used for data collection. The internal consistence of AGAT was determined using Kuder-Richardson formula 20 (KR-20) formula, which yielded α value of 0.82. Research questions were answered using mean and standard deviation while the hypothesis was tested using analysis of covariance. The results of this study revealed that students who were exposed to *algebrameter* significantly performed better than students who were not exposed to *algebrameter* package.

Keywords: mathematics, mathematical game, algebra, geometry, achievement in mathematics

INTRODUCTION

Mathematics is one of the subjects that help to inculcate problems-solving and critical thinking abilities in students. Mathematics is seen as tool for science, technology and industrial development (Ekwueme et al., 2013), hence, it is made compulsory for every student in primary and secondary schools in Nigeria. It has been pointed out that, for any nation to achieve social, economic and technological development, such nation must invest in teaching and learning of mathematics (Musa & Dauda, 2014). Mathematics as a discipline can be directly or indirectly applied in all facets of human activities depending on the level of understanding to which the students have about the principles and concepts of mathematics (Okpube & Anugwo, 2016). Understanding mathematics entails understanding its branches, which include algebra, geometry, trigonometry, statistics, calculus, and number and numeration.

Algebra is the branch of mathematics that deals with finding unknown variables; it enables us to transform real-life problems into mathematical equation using letters and symbols (Koirala & Godwin, 2000). In economic sector, algebra is needed as the medium through which mathematical problems are translated, written and manipulated to give the required answer that is interpreted for a given situation (Inyang, 2005). Because of the inter-relatedness of the entire branches of mathematics, the knowledge students gain in algebra, will boost their achievement in other areas of mathematics, such as geometry.

Geometry is a branch of mathematics that deals with the measures and properties of points, lines, curve and surfaces (Achor et al., 2010). Geometry can be precisely defined as the study of shapes and their properties (Odili, 2006). Students come across different shapes (both regular and irregular) on daily bases. These regular shapes, which junior secondary school (JSS) students are expected to have good knowledge of, and manipulate include spheres, circles, kites, rhombus, trapeziums, triangles, squares, cylinders, cones, pyramids, and frustums. Good intellectual background in geometry prepares students to excel in many professions such as architect, civil engineering, aviation, and building construction. Every year, students are being tested in algebra and geometry both in the external and internal examinations, yet there has been continuous recording of underachievement in mathematics examinations at all levels of the educational system (Azuka & Awogbemi, 2012).

Evidence has also shown that from the year 2004 to 2015, students obtained less than 50% pass (at credit and above) in at least five subjects (including English language and mathematics) (Musa & Dauda, 2014). It is also pointed out that students perform poorly in algebra and geometry related questions (West Africa Examination Council [WAEC], 2014-2022). Students' poor performance in WAEC (2014-2022) mathematics examinationns could be as a result of poor foundation the students carried over

from primary through junior to senior secondary school (Kurumeh & Eniagen, 2008). In other words, could be as a result of accumulated learning difficulties the students have in learning mathematics, which calls for remediation.

Remediation of student' learning difficulties in algebra and geometry entail provision of effective interventions that are capable of reducing or elimination the identified learning difficulties in these areas. It has been suggested that game activities, which are designed to contain mathematical problems ranging from easy to difficult should be incorporated in teaching and learning mathematics for remediating learning difficulties in mathematics (Musa & Dauda, 2014). Educational game is one of the strategies that have been found to enhance the attitude and academic achievement of students in many subjects including mathematics (Azuka & Awogbemi, 2012). Students' affective, cognitive and psychomotor domain will be enhanced if the teachers and students imbibe the culture of utilization of appropriate games in teaching and learning different mathematical concepts (Akukpe & Anugwo, 2016). Unfortunately, Odili (2006) lamented that not much attempt has been geared toward exploring games in complementing secondary school mathematics instruction. Odili further observed that there is lack of attention paid to mathematical games by most secondary school mathematics materials and texts in Nigeria. Similarly, Azuka and Awogbemi (2012) asserted that many mathematics teachers lack the knowledge of the roles of mathematical games, how to make, and play mathematical games in classrooms. Azuka and Awogbemi (2012) maintained that mathematical games are not played in many schools in most parts of Nigeria. One could ask whether the unpopularity of mathematics games in Nigeria, as observed by Azuka and Awogbemi (2012) and Odili (2006) be attributed to mathematics teachers' ignorance of the concept of mathematical games?

Games attract various definitions depending on the perspective of the one that defines the concept. Game can be seen as problem-solving activities approached with a playful attitude (Schell, 2008). When a game is used for both entertainment and for facilitating the actualization of educational purpose, it is referred to educational games. Educational games are enjoyable social activities with goals, rules, and educational objectives (Stephen & Carry, 1994). The major focus of educational games is to achieve learning objective with less stress on both the teachers and the students (Offenholley, 2012). Instructional games are not just games that could enhance learning, they are games developed by integrating a particular curriculum content of interest in designing the games (Michael, 2016). Application of games in learning is an activity, which has play, relaxation, and fun as its technique but learning as its ultimate goal (Akabogu & Obiezu, 2015). Educational games have potentials in building students' self-confidence, learning engagement, retention, problem-solving, computer literacy skills, and remediating students' learning disorder (Odomosu, 2012; Zirawaga et al., 2017). Game is an activity designed to help learners practice and develop understanding of concepts. In mathematics, the use of portable and appropriate mathematical games helps the students practice what they have been taught either in school or at home. Hand-held games, if properly designed, increase students learning participation (Shin et al., 2006) and reduce boredom associated with learning of mathematics (Garris et al., 2002).

Despite the numerous potentials and advantages of the use of mathematical games in learning mathematics, in Nigeria, mathematical games seem not to be easily available for both students and teachers. For instance, the level of availability of mathematical games (such card games, board games, computer games, among others) was found to be unsatisfactory despite mathematics teachers' high perception of mathematical games (Ogbu & Emeji, 2023). It ispointed out that there are even doubts as to whether many of the secondary school teachers' education programmes in mathematics pay enough attention to enabling prospective teachers of the subject acquire necessary competencies in designing and using mathematical games (Odili, 2006). Hence, the use of game in Nigeria secondary school remains at peripheral (Ajibade & Ndububa, 2008). Unfortunately, with large number of students in the classrooms demanding the attention of the classroom teachers, the teachers might not have enough time and resources for development of instructional games needed for teaching and learning of mathematics. Sadly, experts who have attempted working mathematical instructional games in Nigeria seem to have neither make the games easily available for teachers and students nor give detailed procedure involved in development of the mathematical games for replication purposes. It is for these reasons that a research on developing a card game package titled *algebrameter* for remediating students' learning difficulties in algebra and geometry is not only imperative but also timely.

Statement of the Problem

Evidence abound of the poor achievment of secondary school students in mathematics despite the importance of mathematics for individuals, organizations, and the nation at large. Of all the factors that have been found to account for the ungly state of affair, students' poor interest in mathematics and teachers' inability to utilize appropriote instructional materials have been attributed to be the most crtitical. It is shown that effective mathematical games have the capabilities to remediate students' learning difficulties in mathematics by arousing students' interest in mathematics. However, literature is repleted with evidence of the mathematics teachers' lack of skills in developing and utilizing mathematical instructional games, which implies that the ugly situation would remain as long as the solution to the problems is not sought. Thus, the problem of the study is: what is the possibility of developing mathematical instructional card game titled *algebrameter* for remediation JSS students' learning difficulties in algebra and geometry.

Purpose of the Study

The main purpose of this study is to develop *algebrameter* for remediating students' learning difficulties in algebra and geometry. Specifically, the study sought to determine the effect of the developed *algebrameter* on students' achievement in algebra and geometry.

Research Questions

The following research questions were formulated to guide the study:

RQ1. What is the possibility of developing *algebrameter* for remediation JSS students' learning difficulties in algebra and geometry?

RQ2. What are the mean achievement scores of students with learninng difficulties who were exposed to *algebrameter* and those not exposed to *algebrameter*?

Hypothesis

The following null hypothesis was formulated to guide the study and tested at 0.05 level of significant:

H1. There is no statistically significant difference in the mean achievement scores of students with learninng difficulties in algebra and geometry who were exposed to *algebrameter* and those not exposed to *algebrameter*.

MATERIALS AND METHODS

The study adopted research and development (R&D) design. R&D design aims at developing and testing the efficacy of educational products and services (Nworgu, 2015). The researchers considered R&D appropriate for the study since the study aimed at developing and testing the efficacy of *algebrameter*. The research was carried in Nsukka Education Zone of Enugu State. The choice for this area was based on the fact that there are insufficient locally produced mathematical games in this area. The choice of using JSS II students was born out of the fact that the content areas covered in *algebrameter* are meant for JSS II students. The population of the study comprised 4,800 JSS II students distributed in 62 public secondary schools in Nsukka Education Zone of Enugu State, for the 2020/2021 academic session (Planning Research and Statistics [PRS] Unit of Post-Primary School Management Board Nsukka, 2021).

The sample size for the study comprised 120 JSS II students. The sample size was selected using multi-stage stage sampling procedure. The first involved the selection of four schools out the 62 schools using simple random sampling by balloting. The second stage involved selection of students that have learning difficulties in algebra and geometry from four selected schools in first stage using purposive sampling technique. Pre-test scores obtained from "algebra and geometry achievement test (AGAT)" developed by the researchers were used to categorize students as having learning difficulties or not. A pre-test score of 15 and below indicated students with learning difficulties while a pre-test score above 15 indicated absence of learning difficulties. A total of 120 students were identified as having difficulties in mathematics. Third stage was the assigning of the students selected in second stage to experimental and control groups using simple random sampling by balloting. Two schools each were used for the experimental and control groups, respectively.

For the instrument development, the table of specification developed by the researchers was adhered to in development of AGAT to ensure content validiy. AGAT comprised 30 multiple choice questions with four response options. AGAT was validated by three experts from Education Mathematics and Educational Measurement and Evaluation Unit, Department Science Education, University of Nigeria Nsukka. The instrument was trial tested using students that did not participate in the study but were similar, in terms of their characteristics to the actual students that participated in the study. The reliability of AGAT was established using Kuder-Richardson formula 20 (K-R20) method because the items in the instrument were dichotomously scored. The internal consistency of AGAT yielded α value of 0.82.

The researchers first sought for the co-operation of the principal and teachers of the schools used to carry out the study. Mathematics teachers in the selected schools served as the research assistants. The researchers had explained to the teachers on how to use *algebrameter*. The study was carried during third term session. This was to esnsure, that since most of the content areas covered in the game are in first and second term scheme of work, that the teachers should have adequately covered the scheme of work for the students. Before the commencement of the experiment, the pre-existing differences in the students' achievement and as well as the students' learning difficulties in algebra and geometry were ascertained by administering AGAT to both experimental and control groups. The teachers in the experimental group allowed and guided the students to play *algebrameter* whereas those control group were not exposed to *algebrameter* at all. The experiment lasted for a period four weeks. The students in experimental group were allowed to play *algebrameter* two times a week under the guidance of their teachers. Finally, the researchers with the assistance of the teachers finally administered the post-test AGAT to the students. The results of both pre-test and post-test were collated and analyzed to answer the two research questions and to test the null hypotheses. Mean (M) and standard deviation (SD) were used to answer the research questions. The hypothesis was tested using ANCOVA at 0.05 level of significance. Pre- and post-test score obtained by the students were used as covariates to the students' post-test scores.

Research Question One

What is the possibility of developing *algebrameter* for remediation JSS students' learning difficulties in algebra and geometry?

Development of algebrameter

Algebrameter was developed in line with the format suggested by National Mathematical Center (NMC, 2002), thus:

A. **Title:** *Algebrameter*

B. **Class level:** JSS II

C. **Contents:** Basic algebraic equations and basic geometric concepts

D. **Objective(s):** To use *algebrameter* for remediating students' learning difficulties in linear equations, fractional equation, and plane geometry.

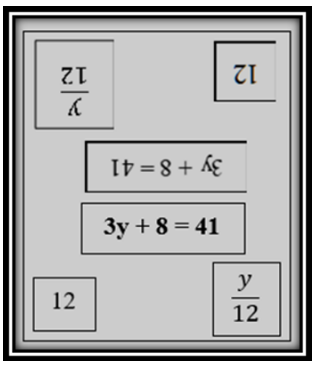

Figure 1. Example-1 (Source: a card game designed by the researchers)

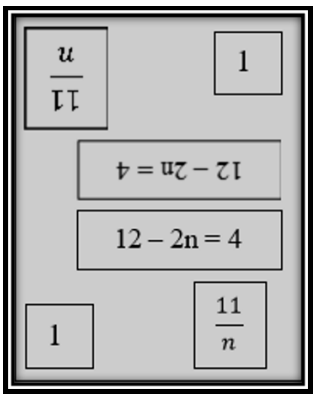

Figure 2. Example-2 (Source: a card game designed by the researchers)

E. **Materials:** *Algebrameter* is made up of 72 cards of equal sizes. Of these 72 cards, 15 contains y-variables, 13 contains x-variables, 13 contain m-variables, and 12 contain n-variables. Each card is designed in green and white colours.

F. **Plan:** This game is designed considering the basic algebraic and geometrical topics in JSS mathematics curriculum. The contents covered in this game include linear equations, fractional equations, triangles, and basic geometrical concepts. The game contains 24 questions on linear equations, 12 questions on fractional equations, 13 geometrical questions and 21 *special cards* that contain images and inscriptions. The essence of these *special cards* is to make the game very exciting and to encourage students with learning difficulties to participate in the game. *Algebrameter* can be played by two or more students. If players are many, it may be necessary to combine two or more packs of the cards.

G. **Procedure:** The players should be arranged in such a way that they do not allow other players to see what is written on their cards. The player to start the game should, first reshuffle the cards properly, after which he distributes about three or four cards to each of the players including himself. Having distributed about three or four cards to each player, the first player turns up one card. The other remaining cards will be faced down (it is from these cards the students/players pick cards(s) when they have no solution to the question posed by the last player). The first card played by the first player may be a "*question card*" or "*command card*".

A case, where the card is a "question card" (contains question)

Questions on the cards are expressed in terms of the letters (variables): *x*, *y*, *n*, *m*, or *t*. For example, if the first player turns up a "*question card*", that contains the question: **12-t=11t**, the next player (second player should be the closest player at the right side of the first player) can play any card that contains the variable "*t*" or any card that contains the solution to the question posed by the first students, that is, **12-t=11t**. Therefore, if the right answer to the question (**12-t=11t)** is **1**, the second student can play any card (irrespective of the letter) that has **1 written on it in the small box**. If he/she does not have any card that contains either ***t*** or **1**, but has a card written *algebrameter*, the second player can request any other variable of his choice by playing the card that contains *algebrameter*. However, if the second player does not have either a card that contains ***t***, **1**, or *algebrameter*, he has no alternative than to pick one card from the cards facing down. In this case, the second player is said to have gone to 'market' thereby giving the third player the opportunity to play. The same process the second player went through applies also to the third, fourth, fifth player and so on.

Furthermore, suppose that the first player plays the *question card* with the question: **12-t=11t.** The second player can play any card that contains the variable *t*, for example, the card that contains the question: 3***t***/5-***t***/3=4/5 (note that the second player is correct, since the card contains the same variable, ***t***). The third player can play (if he has) a card that contains the variable ***t*** or a card that contains the answer to the equation, 3***t***/5-***t***/3=4/5 or *algebrameter*. If the third player does not have the card(s) in variable, ***t***, he could solves the question and if the answer is **12**, he can play any card that contains **12 in the small box** for example, he can play the card shown in **Figure 1**.

Table 1. Mean & standard deviation of students' achievement scores of students with learninng difficulties who were exposed to *algebrameter* & those not exposed to *algebrameter*

Group	n	Pre-test		Post-test		Mean gain
		Mean	Standard deviation	Mean	Standard deviation	
Treatment	56	12.80	4.82	19.75	3.02	6.95
Control	64	13.60	4.70	15.17	3.63	1.57

The fourth player plays by looking at his card(s) to check if any contains the variable "***y***". If he does not have such card(s), the option is to solve the question posed by the last previous player (third player), which is **3y+8=41**. If he solves and gets the answer to be **11**, he checks his cards again to know if any contains **11** irrespective of the variable he can play (**Figure 2**).

The next player will respond to the question posed by the last player. If the next student to player does not have the "variable" posed and cannot solve the question and does not have the card that contains the answer to the question posed, the student will go "to market", except if he has *algebrameter* and wishes to make a request. The playing of the game continues in anti-clockwise direction until the winner emerges.

The first player to exhaust his cards becomes the winner if only two players are involved. If more than two players are involved, the first player to exhaust his cards becomes temporal winner as this can only give him/her the opportunity to participate in the next round. Therefore, when temporal winner emerges, the numbers on the cards of each other players will be summed up. The player(s) with highest value will be eliminated. The other players with lower values will continue the game with temporal winner. Once a player wins, player(s) will be eliminated. It continues in this procedure until the overall winner (the player that has not been eliminated throughout the game) emerges.

A case, where the card is a command card "contains command"

When two players are involved, and the first player to play turns up a card with the command: *PICK TWO*. The second player will pick two cards from those cards faced down. The first player plays again if he has a card that contains the variable in the first card or another *PICK TWO.* He can make a request if he has "*ALGERAMETER*". In absence of all these, he goes to "market" and the second player will play. This is applicable to other command cards such as: *PICK ONE* and *HOLD ON*. When more than two players are involved, the command is only meant for the next player, except *PICK ONE*, which is for everybody except the person that plays it. The person that plays *PICK ONE* needs to play "continue" before the person next to him/her plays accordingly. As a player is about to give out second to his last card, they should shout "last card".

Strategies: To outwit his opponents, a player should try to preserve the "command cards" and "dispose" cards with high values such as 11, 13, 14, and 10. Disposing these cards as quickly as possible keeps you in the game in case someone else wins. Preserving the "commands cards" enables you "attack" your opponent(s) when you hear "last card", (especially when two players are involved). At this point, with the "command cards" you have, you can tell your opponent to *PICK TWO*, *PICK TWO* again, *PICK ONE*, *HOLD ON*, "continue". This will disorganize his plan to win you and allows you to regroup. The inherent excitement in this game can be harnessed through proper rules and regulations that guide the game. For example, a player or group of players that play wrong answer for a given question receive two cards as penalty. However, if a player plays a card and one of the players or one of the groups claims that the answer is wrong, this can be verified by asking mathematics teacher (if it is teachers' copy) or by turning the back of the card that contains the question under consideration (if the card is students' copy). If indeed, the player gives the correct answer, two cards will be given to the person or the group that protested.

H. **Follow-up activities:** This game is of two categories: students' copy and teachers' copy. In students' copy, answer to every question is on the back of the card that bears the questions. The teachers' copy has no answer on the back of the card. In classroom, the teachers copy should be used. Here, every argument or question will be addressed by the teacher. To see the power of *algebrameter* in enhancing cooperative learning among the students, a class size of 40 students can be grouped into five equal groups consisting of eight students, where each group plays against other groups. The teacher should encourage the students to cross check their answers before playing. More so, students in one class can bring out their representative to play against other class.

Research Question Two

What are the mean achievement scores of students with learninng difficulties who were exposed to *algebrameter* and those not exposed to *algebrameter*?

Table 1 shows that the treatment group (those exposed to *algebrameter*) had a pre-test mean achievement score of 12.80 with SD of 4.82 and a post-test mean achievement score of 19.75 with SD of 3.02. On the other hand, the pre-test mean achievement score of the control group (those not exposed to *algebrameter*) was 13.60 with SD of 4.70, while their post-test mean achievement score was 15.17with SD of 3.63. The treatment group had a mean gain score of 6.95 as against the mean gain score of 1.57 recorded by the control group. The result reveals that the students exposed to *algebrameter* achieved higher in in algebra and geometry than those not exposed to *algebrameter*.

Hypothesis One

There is no statistically significant difference in the mean achievement scores of students with learninng difficulties who were exposed to *algebrameter* and those not exposed to *algebrameter*. Results shown on **Table 2** indicate that *algebrameter* has a significant effect on students' achievement in algebra and geometry. This is because the F-value of 62.003 in respect of treatments is shown to be significant at 0.001 level with associated effect size of .346. This means that at 0.05 level, the F-value of 62.003 is

Table 2. ANCOVA of achievement scores of students with learninng difficulties who were exposed to *algebrameter* & those not exposed to *algebrameter*

Source	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Corrected model	711.052[a]	2	355.526	33.370	.000	.363
Intercept	3087.591	1	3,087.591	289.801	.000	.712
Pre-test	85.069	1	85.069	7.985	.006	.064
Group	660.589	1	660.589	62.003	.000	.346
Error	1246.540	117	10.654			
Total	37907.000	120				
Corrected total	1957.592	119				

Note. [a]R-squared=.363 (adjusted R-squared=.352)

significant. The result shows that the use of *algebrameter* significantly improved students' achievement in algebra and geometry. Thus, the null hypothesis that there is no statistically significant difference in the mean achievement scores of students with learninng difficulties who were exposed to *algebrameter* and those not exposed to *algebrameter* is rejected.

DISCUSSION AND RESULTS

The results of this study revealed that students who were exposed to *algebrameter* significantly performed better than students not exposed to *algebrameter* package. These findings are in line with Miller and Robertson (2010) who shown that gaming process is an optimal in teaching and learning of mathematics as games facilitate students' learning skills in mathematics. The findings also corroborated Hoon et al. (2010) who maintained that students need quality and exciting instruction to learn basic skills in simple equation, inverse equation, fractional equation, and solve simple geometrical problems. The reseason for the significant effect of *algebrameter* on students' achievement could be that *algebrameter* triggers students' interest and motivation to learn mathematics, which in turn result in improvement in students' achievement. Evidence abounds of effects of games on students' motivation and interest to learn (Akabogu & Obiezu, 2014).

CONCLUSIONS

Based on the findings of the study, it is concluded that *algebrameter* is an effective package in enhancing JSS students' achievement in mathematic. The mean achievement scores of students exposed to *algebrameter* was significantly higher than those not exposed to *algebrameter* package.

Recommendations

Based on the findings of the study, the followings were recommended:

1. Mathematics teachers at junior school level should incorporate *algebrameter* in teaching and learning of mathematics.
2. Every student at junior level should be encouraged to have a copy of *algebrameter* and play *algebrameter* both in school at homes for leisure and for academic exercises.
3. The federal and state governments, Mathematics Association of Nigeria (MAN), National Council for Teachers of Mathematics (NCTM), and Nigerian Educational and Research Council (NERDC) should organize worshops for training of mathematics teachers on the use of *algebrameter*.

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