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TELLA Adedeji and OLAPADE Kehinde Esther

Department of Science and Technology Education, Faculty of Education
University of Ibadan, Ibadan

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TELLA Adedeji and OLAPADE Kehinde Esther

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Abstract
Mathematics forms the bedrock of cognitive development for students logical reasoning and problem-solving abilities. However, the high failure rate among students in the subject remains a significant concern. Previous studies on students' achievement in mathematics concentrated more on cooperative-based interventions than on game-based strategy using sudoku puzzles. Therefore, this study investigated the effects of sudoku puzzles on primary school pupils' learning achievement in mathematics in Oyo state, Nigeria. It also examined the moderating effect of gender on dependent measures. The pretest-posttest control group quasi-experimental design with a 2x2 factorial matrix was utilised. The instruments used were the Pupils Mathematics Achievement Test (r=0.76) and the Teachers' Instructional Guides. The treatment lasted six weeks. Data was analysed using Analysis of covariance and Scheffe post-hoc analysis at $p<0.05$. There was a significant two-way interaction effect of treatment and gender on pupils' achievement in mathematics ($F_{1,109)}$ =28.89, partial η^2=0.042). Although, the boys (19.67) benefited more from the treatment package than the girls (19.12), it was not significant. There were no significant main of treatment on pupils' achievement. Sudoku puzzles instructional strategy improved pupils' achievement in mathematics in Oyo state, Nigeria. Mathematics teachers in primary schools should adopt sudoku in teaching mathematics.

Introduction

Mathematics has been a core subject in the school curriculum from nursery level up to tertiary level of the education system since the inception of formal education in Nigeria. This is in view of its contribution to individual capacity building and nation's advancement in science and technology and over all development. Mathematics has been recognized as one of the subjects vital in people's lives, which can be in science,

technology, business, or in other walks of life to produce persons who will be orderly, logical, accurate, and precise in thought (Akorede et al., (2019).

Hence, mathematics is a subject that is an integral part of everyone's life. It affects virtually every field of human endeavor, especially pupils in primary schools. An average man needs mathematics to survive no matter how rudiment knowledge acquired. There is no doubt that critical thinking is criterion in learning mathematics by which individual can be active performing without knowing how to read and write, but can passive performing without knowing how to count, measure, add and subtract when unable to think and reason arithmetically (Rasheed and Ogundokun, 2016).

Onuoha-Chidiebere (2015) noted that Mathematics is the foundation upon which technology is built. In this regard, advancement in science and technology is largely dependent on knowledge of Mathematics. The author further noted that Mathematics is a systematic and dynamic field of knowledge that cuts across all spheres of life. It is versatile in nature in the sense that Mathematics can be applied in different subjects and occupations. The National Policy on Education (FME, 2013) states that mathematics education at the primary level should aim to develop the child's mathematical ability and confidence, as well as to provide a solid foundation for further study of mathematics. The NPE emphasizes the importance of making mathematics a meaningful and enjoyable subject for children and using hands-on and practical activities to help them understand mathematical concepts and develop critical thinking and problem-solving skills. It recognizes the need to prepare children for the demands of a rapidly changing world and the increasing importance of mathematical skills in many aspects of modern life.

In elementary stage, mathematics helps to develop mental ability in the form of observation skill, drawing and mapping problems and creativity or innovativeness in nature. The value of mathematics to any developing country is not debatable and this is why the supremacy of mathematics over every other subject is extolled by the national policy on Education (FRN, 2004), when it stated that mathematics should be made a core subject at the primary and secondary school levels as earlier mentioned. There is hardly any area of human endeavor devoid of mathematics and its application. As important as Mathematics is to the individual and society, students often think that Mathematical issues can either not be learned or can only be learned with great difficulty (Yasar 2016).

Despite the efforts of educators and policymakers on demystifying mathematics, the teaching and learning of mathematics often faces challenges related to learner engagement, understanding of complex concepts, and low levels of enthusiasm among learners. These challenges underscore the need for innovative approaches that can reinvigorate mathematics education and contribute to improved learning outcomes. In recent years, there has been growing interest in alternative teaching methods and tools to enhance

mathematics education It is therefore important to search for more, simple, and interesting methods/ ways by which teachers could continually sustain students' attention in Mathematics classrooms, as the strategies adopted by the teacher during instruction will no doubt play a prominent role in influencing the attitude of the students towards the subject. One of such proposed strategies is the incorporation of puzzles in the teaching and learning of Mathematics.

The application of puzzles into educational settings has gained attention as a strategy to promote active learning and improve students' performance in various subject areas, including mathematics. Puzzles generally enhance effective teaching-learning processes. Shapiro (2005) defines puzzles as problems or game that challenge ingenuity. Aremu and Aiyelagbe (1997) describe puzzle as anything in form of toy, usually requiring children to put pieces of materials together to form a specialized whole. They claim that puzzles make learning to be fun and exciting to the learner, thereby leading to the achievement of desirable outcomes. One of these puzzles that might lead to better achievement is the Sudoku puzzle, a number-based logic puzzle known for promoting critical thinking and mathematical reasoning.

The issue of gender in the process of learning and teaching Mathematics cannot be overlooked as Mathematics tends to be regarded as a masculine domain. Also, many people and society believe that females are less mathematically capable than males' gender. Asante (2010) asserts that gender issue in mathematics achievement and ability has remained a source of concern as educational stakeholders seek to address the under-representation of female at the highest levels of mathematics. But studies have shown that gender issues in the learning of mathematics cannot be explained in a simplified manner because there are a multiplicity of forces and environments that operate apart from gender, which influences a child's learning of mathematics. The issues of gender in mathematics may vary due to socioeconomic status and ethnicity, school environment, the mindset of the teacher among other things.

Fakorede (1999) stress the view that gender differences predicted academic achievement in favour of male students. Esugbohungbe (2000) also reveals that boys had an edge over girls in academic achievement. Okeke (2001) in his review of studies equally concludes that gender differences exist in student's achievement in science and any other subject.

Statement of the problem

Mathematics is the science of patterns and layouts. It is also a universal language written with symbols and shapes that involves information processing (editing, analyzing, interpreting, and sharing), producing, predicting, and solving problem (MEB 2009) but the rate at which students fail mathematics is alarming and has been a bone of contention in the Nigerian Educational system. Researchers have recognized the need to explore alternative teaching methods that can address challenges in mathematics education and

foster better learning outcomes, especially at the primary school level. Therefore, the study examined the effects of Sudoku puzzles on primary school pupils' achievement in mathematics. Since puzzles are fun filled and enjoyable. This raises the question of whether the introduction of Sudoku puzzles at primary level can address the existing challenges and contribute to improved pupils' achievement in mathematics. The moderating effects of gender were also examined in the study.

Objectives of the Study

The major objective of this study is to:

1. Determine the main effect of Sudoku puzzles on pupils' achievement in Mathematics.
2. Examine the main effect of gender on pupils' achievement in Mathematics.
3. Determine the interaction effect of Sudoku puzzles and gender on pupils' achievement in Mathematics.

Hypotheses

The following null hypotheses were tested at 0.05 level of significance.

$H_0$1: There was no significant main effect of Sudoku puzzles on pupils' achievement in mathematics.

$H_0$2: There was no significant main effect of gender on pupils' achievement in mathematics.

$H_0$3: There was no significant interaction effect of Sudoku puzzles and gender on pupils' achievement in mathematics.

Methodology

Research Design

The study adopted the pre-test, post-test, control group, quasi-experimental design with a 2x2 factorial matrix to gather the data available from the population included in the study. This is the most appropriate design, since intact classes were utilized as experimental and control groups. The control and experimental groups were both pretested, after which the control group was exposed to teaching through traditional/conventional method without Sudoku while the experimental group was exposed to the teaching through reasoning approach with Sudoku puzzles.

Population of the Study

The population for the study is primary four pupils in public schools in Ibadan. All pupils are eligible to participate in the study. Random sampling technique was used in selecting two locals governments from within Ibadan. Random sampling was also used to select four schools, two from each local government. The participants were randomly selected into experimental and control groups respectively.

Instrumentation

Instrumentation can be defined as the application of an instrument in the form of systems or devices, to accomplish some specific objective in terms of measurement or control or both.

The instruments to be used for data collection are given below:

1. Pupils' Mathematics Achievement Test (PMAT)
2. Instructional Guide on Sudoku Puzzle (IGSP)
3. Instructional Guide on Conventional Teaching Strategy (IGMCTM)

Pupils' Mathematics Achievement Test (PMAT)

The instrument was divided into two sections, A and B. Section A consists of the demographic data of the participants including the gender, age, local government, and school. Section B consists of twenty-three multiple choice items with four options (A-D), prepared based on the primary IV pupils' curriculum in mathematics, utilizing the Blooms' taxonomy of educational objectives. The instrument was validated using experts review and the internal consistency reliability measure was calculated with KR-20 formula and it yielded 0.

Instructional Guide on Sudoku puzzles (IGSP)

The guide was designed for the teachers who were train for the study and were randomly assigned to teach using the Sudoku puzzle. The guide (researcher) gave directions to the mathematics teachers on their roles in class and the activities the pupils should engaged in. The instructional guide was subjected to validation using face and content validity through expert review.

Instructional Guide on Conventional Teaching Method (IGCTM)

The instrument was developed and used to teach pupils in the control group. The researcher prepared the lesson which included three main parts (introduction, presentation, and conclusion), based on Mathematics topics.

Treatment Implementation

Study procedure includes, One week for the training of research assistants. One week each for the administration of pre-test and posttest. The treatment lasted six weeks. Each school was randomly assigned to experimental and control group. The research assistant (Mathematics teacher) in the experimental group was given guide prepared by researcher. Pupils in the conventional (control) class will not be given any special treatment. The teacher taught the pupils with the conventional approach prepared by the researcher. The researcher occasionally supervises the lessons in each of the groups to ensure that the teachers are implementing the instructions.

Method of Data Analysis

The data collected were analyzed using Analysis of Co-variance (ANCOVA) to determine the main and interaction effects of the post-test scores with pretest scores as covariates and was used to test the hypotheses at 0.05 level of significance. A post-hoc analysis (Scheffe test) was conducted to show the direction of significant, if any.

Results

Ho1: There was no significant main effect of treatment on pupils' achievement in mathematics.

Table 4.2: Analysis of Covariance (ANCOVA) of Post-Achievement by Treatment and Gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	105.108	4	26.277	4.136	0.004	0.136
Intercept	4077.560	1	4077.560	641.789	0.000	0.859
Pre-Achievement	84.981	1	84.981	13.376	0.000	0.113
Treatment	12.806	1	12.806	2.016	0.159	0.019
Gender	.620	1	0.620	0.098	0.755	0.001
Treatment * Gender	28.899	1	28.899	4.549	0.035*	0.042
Error	667.110	105	6.353			
Total	39952.000	110				
Corrected Total	772.218	109				

R Squared = 0.31 (Adjusted R Squared = 0.29) * denotes significant at $p<0.05$

Table 4.2 revealed that treatment had no significant main effect on pupils' achievement in mathematics ($F_{(1, 109)} = 2.01$; $p>0.05$). Therefore, hypothesis 1a was not rejected. This means that treatment had no effect on pupils' achievement in mathematics. However, in order to determine the magnitude of the difference across treatment and control groups, the estimated marginal means of the groups were carried out and the result is presented in Table 4.3

Table 4.3: Estimated Marginal Means for Post-Achievement by Treatment and Control groups.

			95% Confidence Interval	
Treatment	Mean	Std. Error	Lower Bound	Upper Bound
Sudoku Puzzle Package (SPP)	19.22	0.33	18.56	19.88
Conventional Package (CP)	18.53	0.36	17.82	19.23

Table 4.3 indicated that pupils in the Sudoku Puzzle Package (SPP) treatment group had the higher adjusted mean score in mathematics post-achievement (19.22) as against their candidates exposed to the Conventional Package (CP) control group (18.53). This order is represented SPP > CP. However, this difference in their mean scores was not significant.

Ho2: There is no significant main effect of gender on pupils' achievement in mathematics.

Table 4.2 revealed that the main effect of gender on pupils' achievement in mathematics ($F_{(1, 109)} = 0.10$; $p>0.05$) was not significant. Hence, hypothesis 2a was not rejected. This implies that gender had no effect on pupils' achievement in mathematics.

Ho3: There is no significant interaction effect of treatment and gender on pupils' achievement in mathematics.

Table 4.2 indicated the interaction effect of treatment and gender on pupils' achievement in mathematics was significant ($F_{(1; 109)} = 4.55$; $p<0.05$; partial $\eta^2 = 0.04$). Table 4.2 showed the effect of 4.0%, implying that 4.0% of the variance in pupils' post-achievement scores in mathematics is because of the significant interaction effect of the treatment and gender on pupils' achievement in mathematics. Therefore, hypothesis 1a was rejected. To explore the interaction effect, Figure 4.1 presents the interaction in line graph.

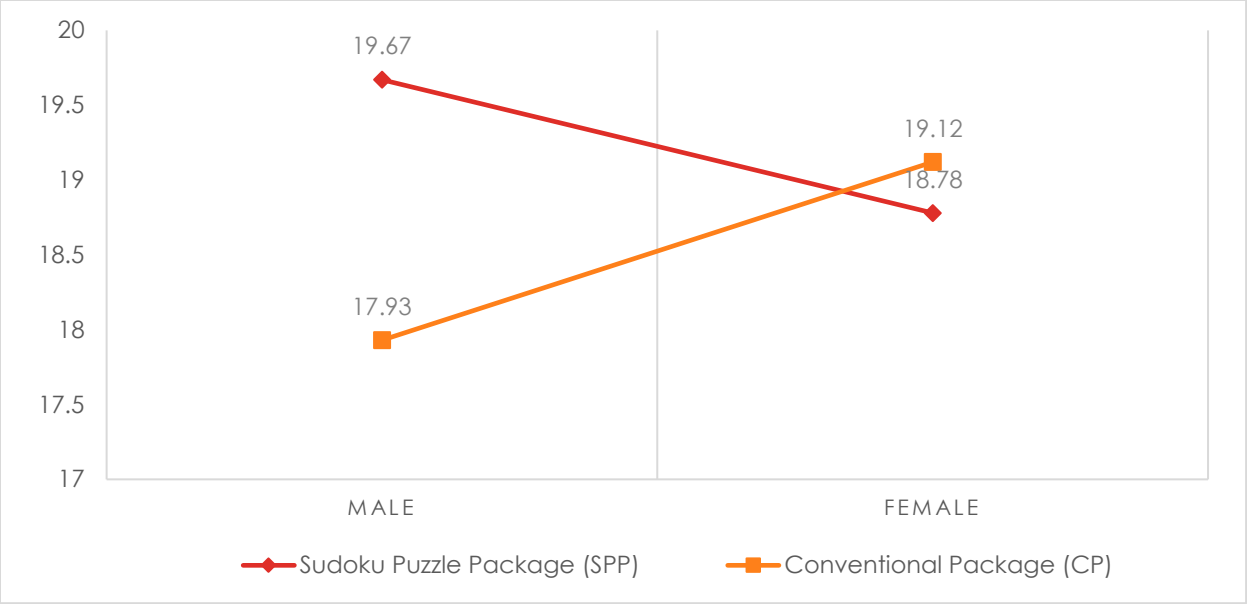

Figure 4.1: Treatment and gender on pupils' achievement in mathematics

Figure 4.1 indicated that male pupils exposed to the Sudoku Puzzle Package (19.67) had the highest post-achievement mean score in mathematics followed by female pupils in the Conventional Package (19.12), female pupils in the Sudoku Puzzle Package (18.78), and lastly, male pupils in the Conventional Package (17.93). The interaction is disordinal. This means that based on treatment, it is not the same group of gender that have better post-achievement in mathematics.

Discussion of the Findings

Effect of Treatment on Pupil's achievement in Mathematics

The result of this study showed that the treatment has no significant main effect on pupil's achievement in Mathematics. the experimental group (19.22) had the highest mean compared to conventional group (18.53) however, the difference was not significant. Therefore, there was no significant main effect of treatment on pupils' achievement. According to these findings, the use of puzzles may produce results slightly lower than those found when using paper-based activities for the supplemental mathematics instruction of learners.

The findings are consistent with studies done by Brophy and Hann (2014) who conducted an experimental study with large groups of students to address the question, "Does the Sudoku experience and Sudoku type affect puzzle-solving time and the ability solve the puzzle correctly?" Their results showed that students with Sudoku experience were more successful in solving puzzles correctly than students with no Sudoku experience. This may be due to the fact that the children may have not understood the questions correctly and may have also confused the Sudoku game with other games.

Some of the pupils would rather just learn mathematics concepts, instead of having to learn using Sudoku puzzle. In the current study the investigator used primary four pupils who may have preferred using conventional methods rather having to learn using Sudoku puzzle strategy first. Inadequate time to practice and internalize Sudoku puzzle strategy may have affected the use of Sudoku puzzle strategy.

Aligning the Sudoku puzzle with a particular instructional goal supports the Piaget's theory which emphasizes on cognitive and developmental stages and Sudoku puzzle may not align with the specific cognitive and developmental of the class used (Ya-Hui Hsieh et al., 2015). When an educator assigns specific puzzles or games that support the curricular content, the learners utilizing Sudoku puzzle may demonstrate more favorable results on the specific objective.

This study is in line with the findings of Mansureh, Atsusi and Haiyan (2010). Their findings indicated that prior mathematics knowledge/computer skills did not play a significant role in achievement and motivation of the participants who played the games.

Contrary to the above finding, the result contrasts with the previous finding of Kazima (2013) who states that when children feel appropriately challenged by a game, they become intrinsically motivated to discover the secret of winning or of avoiding a loss. The sheer pleasure of playing a particular game enables children to learn mathematical ideas embedded in it as a by-product of playing.

Also, another research found that puzzle games can bring out students' enthusiasm, thus encouraging their participation and stimulating their action in problem posing activities (Candiasa et al., 2018).

Since these results contrast with several research study findings, educators should not be daunted when considering the inclusion of Sudoku puzzles into their curriculum since the results of the current study were inconclusive. However, educators should rely on puzzles that are research based and aligned with instructional objectives to improve the achievement of learners in mathematics.

Effects of Gender on Pupil's achievement in Mathematics

The finding of the results revealed that there was no significant effect of gender on pupil's achievement in Mathematics. The results follow that of Abubakar and Adegboyega (2012) reported that gender was insignificant in the academic achievement of pupils in mathematics in Ogun State. Males and females adapt differently to different teaching methods, strategies and approaches and contradict to the findings of Kolawole (2007) who revealed that male students performed better than female pupils in the cognitive, affective and psychomotor skill achievements.

Therefore, the null hypothesis that there is no significant difference in the mean achievement scores of male and female students exposed to Sudoku puzzle was accepted. It was therefore concluded that there is no gender imbalance in pupils' achievement when using Sudoku puzzle in lesson delivery.

Interaction Effect of Treatment and Gender on Pupil's achievement in Mathematics

Result shows that there was significant interaction effect of treatment and gender as moderated causal link in enhancing pupils' achievement in mathematics among participants. This means that there was significant interaction effect in the posttest scores of treatments and gender in enhancing pupils' achievement in mathematics. Hence, this could be because the intensity of instructional strategy had significant impact on the participants based on gender.

Finding from this study shows positive effect of Sudoku puzzle as one of the instructional strategies that can be adopted in developing achievement learning of mathematics in primary school.

Furthermore, the result of analysis indicated that the difference in the post achievement mean score of boys and girls who learnt Mathematics with the use of Sudoku puzzle is statistically significant with the boys having greater mean score than the girls. This implies that the strategy benefited boys more than girls. This result is in line with a priori expectation. Boys are generally known to show greater interest in games than girls. Incorporation of games in the teaching and learning of Mathematics will no doubt enhance the attitude to mathematics of boys more than girls. This finding is at variance to the finding of other researchers who reported no significant difference in the achievement of boys and girls to mathematics due to instructional strategy (Abakpa & Iji, 2011; Ifeanacho & Ifeanacho 2015; Ihendinihu & Mkpa, 2015; Okigbo & Agu, 2010). It however corroborates Agomuoh (2010), Yamg and Chen (2010) who reported gender disparity in science and technology in favour of males.

Additionally, findings by Admiraal et al. (2014) demonstrated that males are more likely to have extensive gaming knowledge increasing their capacity to transfer those skills into digital learning games (Admiraal et al., 2014). In contrast to this, findings, females have demonstrated an increased incidence of seeking opportunities to assist their peers during mathematics activities resulting in the reinforcement of their own mathematics' skills (Jackson et al., 2013). This social behavior aligns with Vygotsky's Activity Theory that postulates learning occurs while working cooperatively, and increasing mathematical discourse may facilitate the progression of problem-solving skills (Asmundis et al., 2015).

Conclusion

Based on the findings of this research, it was concluded that Sudoku puzzles did not yield a significant main effect on primary school pupils' achievement in mathematics. Interestingly, the study reveals a significant interaction effect of treatment and gender on pupils' achievement in mathematics. This suggests that the impact of Sudoku puzzle varied based on gender. The teaching strategy for instructional delivery has the potential to make or mar pupils' achievement in mathematics.

Educational Implications

1. Educators should carefully select the type of instructional materials, considering the developmental stage and individual differences among pupils.

2. Policymakers need to consider the cultural relevance of instructional strategies to promote involvement and effectiveness in educational settings.

3. To promote equal educational experiences, teacher training programmes should place a strong emphasis on applying instructional strategies consistently across schools.

Recommendations

While the findings of this study present information regarding the effect of Sudoku puzzles on primary school pupils' achievement in Mathematics, the researcher recommends the following considerations when conducting future research:

1. More puzzles and games should be developed and used by teachers to teach mathematical concept, to improve the pupil's achievement in mathematics.
2. Mathematics educators in teacher training should be encouraged to use puzzles and games while teaching.
3. SUBEB, UBE, proprietors of schools and ministry of education should ensure that they supply instructional materials for the teaching and learning of mathematics.
4. The Ministry of Education should organize regular retraining workshop for mathematics teachers on the use of instructional materials such as Sudoku puzzle.
5. Data collection should include a larger number of pupils to determine if the results generalize to other pupils outside the study.

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