Impact of Structured Pedagogigal Approach of Translating Word Problems into Mathematical Equations in Nigeria Secondary Schools

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Abstract- Mathematics as a school subject has become a powerful tool for communication and global understanding that helps to organize and prevent chaos in over lives, it encourages logical reasoning, critical thinking, problem-solving, and even effective communication skills. However, it is evident that the crux of learning mathematics that would make it functional and utility-oriented anchors on word problems. Evidence abounds that students experience difficulties in solving word problems in Mathematics. This study therefore investigated the effects of structured pedagogical approach of translating word problems into mathematical equations. The study adopted quasi-experimental design which involved 120 participants. Two instruments were used in the study: Achievement Tests in Mathematics (ATM), and Mathematics Attitude Questionnaire (MAQ). Data collected were analyzed using t-test and chi-square. The findings indicated that the treatment is more sensitive and effective at improving students' ability in translating word problems into mathematical equations. The study also showed that there is an improvement in students' attitudes towards mathematics emanating from diverse explanations with illustrations on basic facts embedded in the treatment that enhances optimal understanding of the concepts. Based on these findings, this approach is hereby recommended for teachers of Mathematics, stakeholders and curriculum reviewers.

Indexed Terms- Academic Achievement, Global Understanding, Word Problem, Structured Pedagogical Approach

I. INTRODUCTION

Mathematics is essential in the natural sciences, engineering, medicine, finance, computer science and the social sciences. Although mathematics is extensively used for modeling phenomena, the fundamental truths of mathematics are independent from any scientific experimentation (Wikipedia), some areas of mathematics, such as statistics and game theory, are developed in close correlation with their applications and are often grouped under applied mathematics, other areas are developed independently from any application (and are therefore called pure mathematics), but often later find practical applications.

The importance of mathematics in our daily life is diverse and includes everything from managing finances, decision-making and problem-solving to technology advancements, scientific discoveries, and educational success. Mathematics is a universal language that is applicable across different cultures and professions making it an essential tool for communication and collaboration in today globalized world. It is a known fact that understanding and appreciating the importance of mathematics can help individuals make informed decisions and succeed in various fields, contributing to a more productive and prosperous society. It is a powerful tool for communication and global understanding that helps to organize and prevent chaos in our lives. Mathematics is also important to students. It teaches them perseverance, financial literacy; it makes them a better cook and career uses mathematics. Mathematics encourages logical reasoning, critical thinking, problem-solving ability, and even effective communication skills.

Onasanya (2022) presents the following reasons why mathematics is important:

- Learning mathematics is good for your brain. Children who understand mathematics are able to recruit certain brain regions more reliably and have greater gray matter volume in those regions, than those who perform more poorly in mathematics.
- Mathematics helps you analyze time and season.
- Mathematics helps you in game and sport.
- Mathematics helps you with your finances. It can be helpful for balancing one's bank account, for example, it is an important life skill that requires mathematics in order to subtract balances, people who know mathematics are therefore less likely to go into debt because they did not know how much money they had versus how much money they spent.
- Mathematics makes you a better cook (a baker). With knowledge of mathematics, for example, you can quickly deduce that a half-cup of flour is the same as eight table spoons of flour.
- Mathematics helps us have better problem-solving skills. Mathematics helps us think analytically and have better reasoning abilities. Mathematics is used in practically every career in some ways.
- Mathematics is all around us and helps us understand the work better. To live in a mathematically driven world and not understand Mathematics is like walking through an art museum with your eyes closed.
- Mathematics can help you shop a good sale.
- Mathematics as a school subject is an indispensable tool for our daily lives.

Mathematics educators, mathematics teachers', stakeholders in education industry and education policy makers had put in several and divergent strategies, methods, approaches and techniques at ensuring students' optimal learning outcomes and sustainable academic performance in the subject. Research evidence shows that strategies and methods such as cooperative learning, computer-assisted instruction, concepts mapping, and problem-solving technique among others have been put in place in the art of teaching and learning process of mathematics with appraisable improvements in some concepts in the subject.

Teaching and learning with 'understanding' means accommodating the different levels of mathematical knowledge. According to Dossey, McCrone, Giordano, and Weir (2002), mathematical knowledge can be divided into three related areas: concepts, procedures, and problem solving. When students deal with concepts, they are learning "what something stands for". For example, knowing that a triangle is a figure having three sides, students show conceptual understanding when they are able to 'use concepts and their representations to discuss or classify mathematical objects". In other words, conceptual understanding is used to compare and contrast objects, as well as to form interrelationships between concepts and principles. Students exhibit procedural knowledge when they "select and apply procedures correctly" (Dossey et al., 2002, p. 49). The third area of mathematical knowledge is problem-solving. Problem-solving requires students to recognize situations, abstract their core structure, model the relationships involved, manipulate those relationships, and communicate the results.

The Australian Curriculum (Australian Curriculum, Assessment and Reporting Authority, 2012) recognizes four important strands in mathematical proficiency. These include understanding, fluency, problem-solving and reasoning. National Research Council (2001) classifies mathematical proficiency into five important strands which are interwoven and interdependent. These are:

- Conceptual understanding- comprehension of mathematical concepts, operations and relations;
- Procedural fluency – skill in carrying out procedures flexibility, accurately, efficiently and appropriately;

- Strategic competence- ability to formulate, represent and solve mathematical problems;
- Adaptive reasoning – capacity for logical thought, reflection, exploration, and justification;
- Productive disposition – habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a brief in diligence and ones' own efficacy.

Based on the different strands of mathematical proficiency, the National Research Council (NRC, 2001) makes explicit recommendations for teaching for mathematical proficiency. Developing proficiency in mathematics teaching is directly linked to the five interwoven strands of mathematical proficiency outline above. For example, parallel to the *conceptual understanding* strand, the NRC notes that teachers must have conceptual understanding of the core knowledge required in the practices of teaching. Furthermore, as expressed under sub strands *strategic competence* and *adaptive reasoning*, teachers must also be able to represent mathematical problems in real contexts and be able to reason logically.

Word problem that does not have a solution but has multiple solutions uses to be referred to as non-standard problems (Daroczy, Wolska, Meurers&Nuerk 2015). While research findings indicate that students face significant difficulties handling such word problems it was expected that teachers would be able to pick out these limitations and comments on the appropriateness of the word problems accordingly.

Powell, Namkung and Lin, (2019), observed that word problems involves interpreting a combination of numbers and words to develop a problem solution (e.g. Shola has 2 pens in her backpack; Laide has 5 pens in her lunchbox. How many more pens does Laide have?). Many students are inadequately prepared to set up and solve such word problems (Garcia, Jimenez and Hess, 2006).

- Word-problem solving and instruction in the General Education Classroom

Word-problem proficiency proves critical for helping students connect mathematics to real life and to succeed in school and beyond, yet solving word problems remains one of the more difficult mathematics tasks for students in the elementary grades (Daroczy, Wolska, Meurers, &Nuerk, 2015). Word problem solving requires students to comprehend text (Boonen, de Koning, Jolles, & Van der Schoot, 2016) as well as access and utilize long-term memory and working memory (Lee, Ng, & Bull, 2018). Word problems often overwhelm students due to their complexity; students often are required to follow multiple steps to develop a solution.

Some specialist educators often teach students to solve word problems using a general approach or meta-cognitive strategy (Cornoldi, Carretti, Drusi, &Tencati, 2015; Wilson, 2013; Woodward et. al., 2018). Kajamies, Vauras, &Kinnunen (2010) give guidelines for these, on what students need to do as follow:

1. Read the problem;
2. Construct a problem representation, including drawing a picture of important relationships;
3. Make a plan for solution;
4. Complete necessary calculations;
5. Interpret and determine the answer; and
6. Check the solution

Some mathematics teachers also instruct students to solve word problems by recognizing a word problem as belonging to a specific schema or situation and using a schema-specification model to determine a problem solution (Brissiaud& Sander, 2010: Carpenter, Hiebert, & Moser, 1981; Verschaffel, Greer, & De Corte, 2000). With a focus on word-problem schemas, Griffin et al., (2018) states that students may use a meta-cognitive strategy to:

(1) determine the word-problem type (i.e. schema);
(2) organize the information into a diagram (underline the label and circle, rectangle, or triangle important information)
(3) write a number sentence, and
(4) solve the number sentence and check their work.

Several commonalities emerge across these word-problem approaches. First, students learn to read and interpret the word problem. In our experience, many students start solving a word problem before reading the problem; these approaches encourage students to fist the word problem. Second, students identify relevant content in the word-problem prompt and organize this information by schema. Third, students use visual or graphic organizers or equations to organize the information from a word problem (Bebout, 1990; Van Garderen, Scheuermann, &Poch, 2014). These general problem-solving approaches prove beneficial by lessening the working memory load activated during word-problem solving and by instructing students to approach problem solving in a consistent and organized manner.

- Translating English Sentences into Mathematical Equations and solving

Mathematical equations can be used to describe many situations in the real world. To do this, we must learn how to translate given information into an algebraic equation. Although no single method will work for solving all applied problems, but structured pedagogy approach would be tried in the problem-solving process.

Addition	Subtraction	Multiplication	Division	Equals
Sum; increased by; more than; plus; total; combined; added to; in all	Difference; decreased by; less than; minus; fewer than; reduced by; take away	Product; times; of; multiple of; doubled; tripled	Quotient; divided by; ratio of; per	Is/are; was/were; will be; gives; yields

Table 1: Key Words and Phrases in Mathematics Word Problems

- Structured Pedagogical Approach

Structured pedagogy approach is a coordinated instructional improvement teaching method that includes lesson plans for teachers, student textbooks, teacher training focused on skills and ongoing teacher support on learners. When teacher understand and implement good pedagogy in his lesson, it helps him to reconnect with his pupils and builds a better, more collaborative relationship. There is understanding from both parties such that he may be working towards a shared goal.

Pedagogy always improves the overall quality of teaching by making the learner more receptive during lessons. As a result, this enhances the pupil's level of participation and contribution during the learning process. A well-developed pedagogy assists to impart education to leaners using a range of learning styles. It enables students to develop deeper attention, and more meaningful understanding of topic be taught.

Mathematics structured pedagogy approach for solving word problems has the following steps:

1. Extracting difficult words or mathematical terms or key words from the given problem with appropriate explanations and illustrations.
2. Teaching students the features of different types of equations - simple equation, quadratic equations, simultaneous equations, and cubic equations with illustrations.
3. Explanations on some basic roots in equations and indices e.g. square root of x, fourth root of k.
4. Explanations on mathematical terms involved with illustrations e.g. double, product, quotient, subscript, inverse, signs when used in product. (-x- = +, +x+=+, -x+= -, + x- = -)
5. Teach a concept at a time and do not muddle up e.g. Word problems on linear equation, then simultaneous equation, quadratic equation, cubic equation etc.
6. Teaching mathematical proficiency e.g. Mathematical terminologies, symbolism

7. Comprehension of text
8. Using the following problem-solving technique steps:

- Understand the problem
- Device the solution plan
- Carry out the solution plan
- Examine the solution

- Statement of the problem

Word problems in the art of teaching and learning episode of mathematics is a determining factor to access students competencies or otherwise in the subject. Researchers had in previous times attributed students' difficulties in translating word problems into mathematical equations to several factors such as: students' inability to understand what the problem is requesting them to do, deficiency in English Language, where it is not a mother tongue, inability to appraise appropriately some mathematical terms, lack of understanding in symbolic representation, difficulty in identifying appropriate equations, inability to deduce relevant features of the equations involved in each of the word problems.

- Therefore, this study investigated the impact of structured pedagogical approach of translating word problems into mathematical equations through quasi-experimental design.

- Research Hypothesis

The following research hypotheses were generated, based on the statement of the problem, and tested at 0.05 level of significance.

H_{01}: There is no significant difference on students' attitude between structured pedagogical approach of solving word problem and the conventional method.

H_{02}: There is no significant difference between the effects of structured pedagogical approach on solving word problem and the conventional approach on students' academic achievement.

H_{03}: There is no significant relationship between the structured pedagogical approach and students' academic performances.

- Methodology
- Research Design

The study adopted a post-test, non-equivalent control group design in a quasi-experimental design setting.

- Sample and Sampling Technique

Simple random sampling technique was used to select one senior secondary school in each of the three Senatorial Districts of Oyo State to make a total of three schools. Forty senior secondary school two (SSII) students were randomly selected from each of the schools which twenty of them were grouped into treatment class and twenty in conventional class, resulting into a total of one hundred and twenty students of sixty in treatment class, sixty in conventional class; and three treatment classes and three convectional classes.

- Research Instruments

Two instruments were used in the study: Achievement Test in Mathematics (ATM) and Mathematics Attitude Questionnaire (MAQ). The achievement test is made of ten mathematics word problem which students were allowed to work out their solutions under the time frame of one hour. The questionnaire comprises of two sections A & B. Section A is designed to elicit responses in relation to students' bio-data section B is made up of 10 items requesting participants to indicate their attitude towards the study of mathematics based on a four-point Likert-scale of Strongly Agreed, Agreed, Disagree, and Strongly Disagree; which respondent picked one on each item.

- Validation and Reliability of Achievement Test in Mathematics

The instruments were validated by specialists in mathematics education department of two of Nigeria public universities. Pilot test on thirty senior secondary school II students in the state gives reliability coefficient of 0.78 for the achievement test and 0.83 for the questionnaire.

- Administration of Instruments

Two researchers taught the three treatment classes for two weeks using the structured pedagogical approach in solving word problems leading to simultaneous equation, while the remaining two researchers taught the three conventional classes on the same topic for the same two weeks using conventional method. The achievement test was administered to all the students after the end of two week teaching, while the questionnaire was administered to all students in treatment classes after the test.

Results and Findings

Data collected were analyzed using t-test and chi-square statistics.

H_{01}: There is no significant difference on students' attitude between structured pedagogical approach of translating word problem into mathematical equations and the conventional method.

Student's attempt to solve each question in the achievement tests whether correct or not earn the student five points for attitude for the question. The analysis of the attitude points was presented in table 2 below.

Variables	N	$\bar{x}$	SD	Df	t-cal	t-crit
Structured pedagogical approach (SPA)	60	33.67	13.4	118	2.03	1.96
Conventional Approach (CA)	60	26.33	11.03			

Table 2: T-test Analysis on Students' Attitude on Structured Pedagogical Approach of Mathematics Word Problems.

From the table t-cal = 2.03, while t-crit = 1.96. It implies that the first null hypothesis has to be rejected and accept the alternative one. Therefore, there is a significant difference on students' attitude between structured pedagogical approach of translating word problem into mathematical equations and the conventional method.

H_{02}: There is no significant difference between the effects of structured pedagogical approach on solving word problem and the conventional approach on students' academic achievement.

Each question in the test is of maximum of ten marks. The marks of the students were analysis with student t statistics and presented in table 3 below.

Variables	N	$\bar{x}$	SD	Df	t-cal	t-crit
Structured pedagogical approach (SPA)	60	78.7	7.63	118	2.74	1.96
Conventional Approach (CA)	60	43.5	11.82			

Table 3: T-test Analysis on Students' Achievement on the Effects of Structured Pedagogical Approach.

From the table, t-cal = 2.74 is greater than t-crit= 1.96, this implies that the second null hypothesis is rejected and the alternative hypothesis is accepted. Therefore, there is a significance difference between the effects of structured pedagogical approach on solving word problem and the conventional approach on students' academic achievement.

H_{03}: There is no significant relationship between the structured pedagogical approach and students' academic performances.

The responses of treatment students in the questionnaire were analyzed with chi-square in the table 4 below.

N	d.f.	Cal. χ^2	Crit.χ^2	P	Decision
60	15	71.2232	24.996	0.000001	Reject H_{03}

Table 4: Chi-square statistical test on relationship between treatment and students performances

Sincecalculated χ^2 = 71.2232 > critical value χ^2=24.996 at degree of freedom = 15, the finding is significant. So, the third null hypothesis is rejected while the alternative one is upheld. Therefore, there is a significant relationship between structured pedagogical approach and students' academic performances.

- Discussion of findings

The findings revealed that there is a significant difference on students' attitude between structured pedagogical approach of translating word problem into mathematical equations and the conventional method. This finding is in line with Daroczy, Wolska, Meurers&Nuerk (2015) which states that mathematics word problems usually affect pupils' attitude towards learning of mathematics.

The second finding shows that students taught with structured pedagogical approach performed better than those taught with conventional method. This finding is supporting Van Garderen, Scheuermann, &Poch (2014) that word problems need special pedagogy to teach.

Relationship was found to exist between the structured pedagogical and students' academic performances. This is not in support of Brissiaud& Sander (2010) which believes that any teaching methodology can produce good result if it is handle properly by teacher.

CONCLUSION

Based on the findings of this study, structured pedagogical approach proved to be more sensitive and effective at improving students' understanding in translating word problems into mathematical equations resulting in optimal performances in the subject.

RECOMMENDATIONS

Based on the findings of this study, it is hereby recommended that teachers of mathematics should consider the usages of structured pedagogical approach in the art of teaching-learning process of mathematics. Also stakeholders, policy makers and curriculum reviewers in education should incorporate this approach into the school curriculum. Authors of mathematics textbooks should also endeavour to utilize this approach with illustrations on this concept of translating word problems into mathematical equations.

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