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Comparative Effects of Concept Mapping and Problem-Solving Strategies On Geometry Performance among Upper Basic Students in Kano State, Nigeria

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Abstract

This quasi-experimental study investigated the "Influence of Concept Mapping and Problem-Solving Strategies on Geometry Performance of Upper Basic Students in Kano, exploring the potential of these strategies to enhance entrepreneurial innovation and skills, contributing to poverty reduction initiatives in Nigeria. Samples of 367 out of the population of 999,486 students from 1,001 public Upper Basic Schools were used. The experimental group 1 was exposed to Concept mapping, experimental group 2 to Problem solving and Control group was exposed to Conventional method respectively. Three research questions were raised and three null hypotheses were formulated to guide the study. The researcher developed an instrument, Geometry Performance Test (GPT) which was designed to test the performance after treatment in four areas of Geometry; angles, triangles, polygons and circles. Result of the t-test statistics revealed significant difference between the performances of the three groups. Findings from the study underscore the importance of innovative pedagogies in enhancing mathematical skills, promoting an entrepreneurial mindset, and ultimately addressing socio-economic challenges. Recommendations proffered based on the findings, includes; integrating the use of concept mapping in the teaching of geometry among Upper Basic Students so as to enhance students' performance, Mathematics teachers be sent on in-house trainings, workshops and seminars where modern teaching strategies are discussed such as MAN, STAN Conferences among others. Teachers' welfare should be improved to meet life challenges and teacher education at all levels should be carefully managed to incorporate all socio-cultural, environmental, economic and political aspects of life for the teachers.

Keywords: Concept Mapping, Problem-Solving Strategies, Geometry Performance,

Introduction

Mathematics is recognized globally as a key tool for national development. Geometry, as a branch of mathematics, develops spatial reasoning, logical thinking, and problem-solving skills essential for technical and vocational occupations (Clements & Battisa, 1992). In Nigeria, Upper Basic students' poor performance in geometry continues to limit their ability to acquire practical skills needed for self-employment. Concept Mapping and Problem Solving Strategies have been identified as learner-centered approaches that can enhance understanding and retention in mathematics (Novak &

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Gowin, 1984; Danjuma & Bajon, 2022). Beyond academic achievement, improved geometry performance has direct implications for Entrepreneurial Innovation in areas such as construction, tailoring, furniture making, and surveying; vocations that can drive poverty reduction in Kano State (Becker, 1993). Despite curriculum reforms, students in Kano State still perform poorly in geometry. Wanlor, Dalong, & Falade (2023) reported that "only 34% of upper basic students demonstrated competence in geometry" in Plateau State, a trend mirrored in Kano. In Kano State, failure in Mathematics in the Placement Examinations is very common. It was noticed that the performance in Mathematics at this level normally falls between 30-35% (KERC, 2024). Students' attempts in answering the Geometry sections of the yearly questions papers depict the need to undertake this study. This unfortunate development trail the student to Senior Secondary School Class thereby causing the students to perform poorly in Senior School Examinations. Records of the students' performance in Mathematics at the Upper Basic Placement Exams for 5 years (2020 – 2024) in Kano State revealed the need for the study. Traditional lecture methods have failed to connect classroom geometry to real-life applications (Shu'iabu & Sidi, 2020).

Geometry is foundational to many entrepreneurial activities in Kano; from architectural drawing to fashion design. The Sustainable Livelihoods Framework argues that education that builds practical skills reduces vulnerability and promotes income generation (Chambers & Conway, 1992). Therefore, improving geometry performance through innovative strategies like concept mapping and problem solving could translate to entrepreneurial skills and poverty reduction. Upper Basic students in Kano, Nigeria continue to exhibit poor performance in geometry (Wanlor et al., 2023). This poor foundation limits their capacity to engage in geometry-related vocations that are critical for entrepreneurial innovation. Consequently, many youths remain unemployed or underemployed, thereby perpetuating poverty in the state. The purpose of this study is to investigate the influence of Concept Mapping and Problem-Solving Strategies on Geometry Performance of Upper Basic Students in Kano, Nigeria and to examine the implications of improved geometry performance for entrepreneurial innovation and poverty reduction. Specifically, the study seeks to determine whether these instructional strategies can equip students with the mathematical competence needed to engage in self-reliant, income-generating activities, thereby contributing to poverty reduction in line with Sustainable Development Goal number 1: "No Poverty" (UNDP, 2015).

Objectives of the Study

The objectives of the study were to:

1. Investigate the influence of Concept Mapping Strategy on geometry performance of Upper Basic students in Kano, Nigeria.
2. Examine the influence of Problem-Solving Strategy on geometry performance of Upper Basic students in Kano, Nigeria.
3. Find out the differences between the Concept Mapping Strategy and Problem-Solving method on Upper Basic Students' Performance in Geometry.

Research Questions

In line with the objectives of the study, the following research questions guided this study:

1. What is the effect of Concept Mapping Strategy on geometry performance of Upper Basic students in Kano, Nigeria?
2. What is the effect of Problem-Solving Strategy on geometry performance of Upper Basic students in Kano, Nigeria?

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3. What is the difference between Concept Mapping Strategy and Problem-Solving method on the Geometry Performance of Upper Basic Students in Kano, Nigeria?

Null Hypotheses

Based on the research questions, the following null hypotheses were formulated and tested at α = 0.05 level of significance

Ho_1: There is no significant difference between the mean performance scores of the students exposed to Concept Mapping and those exposed to conventional method.

Ho_2: There is no significant difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method.

Ho_3: There is no significant difference between the mean performance scores of the students exposed to Concept Mapping and those exposed to Problem Solving.

Theoretical Framework for the Study

This study is anchored on multiple interrelated theories drawn from educational psychology, Entrepreneurship and development economics. The central premise is that the use of Concept Mapping and Problem-Solving Strategies can improve Geometry Performance of Upper Basic students and that this improvement has direct implications for Entrepreneurial Innovation and Poverty Reduction. The following theories provide the conceptual foundation for this study. Ausubel's Theory of Meaningful Learning (1968) provides the basis for concept mapping. Ausubel asserted that "the most important single factor influencing learning is what the learner already knows. According to this theory, learning is meaningful when new information is consciously and explicitly linked to relevant concepts already in the learner's cognitive structure. Novak and Cañas (2008) extended this idea by developing concept mapping as a graphical tool for "organizing and representing knowledge; they facilitate meaningful learning". In the context of geometry, concept mapping enables Upper Basic students in Kano to visually connect theorems, properties, and constructions. This aligns with the Van Hiele Theory of Geometric Thought (1986), which proposes that learners progress through five levels of geometric understanding, from visualization to rigor. Concept mapping helps students move from concrete visualization to abstract reasoning, a skill essential for technical fields. Another study which is grounded in Polya's Problem Solving Theory (1945), described problem solving as "a practical art, like swimming; you learn by doing". He proposed four stages: *understanding the problem, devising a plan, carrying out the plan and looking back*. This systematic approach mirrors the process entrepreneurs use to identify market gaps, design solutions, and evaluate outcomes. Similarly, Vygotsky's Social Constructivism Theory (1978) supports collaborative problem solving. Vygotsky argued that "what a child can do in cooperation today, he can do alone tomorrow". When students engage in group problem solving and brainstorming in geometry, they operate within the Zone of Proximal Development, building both mathematical competence and teamwork skills required in cooperative businesses. Moreover, Bandura's Social Cognitive Theory (1986) explains the motivational dimension. It stated that "people's level of motivation, affective states, and actions are based more on what they believe than on what is objectively true". As students experience success in geometry through concept mapping and problem solving, their self-efficacy increases. Higher self-efficacy in mathematics has been linked to greater interest in STEM careers and entrepreneurial ventures. This is critical where youth need confidence to start small enterprises in *c*onstruction, fashion design, furniture making and surveying; all of which require geometric knowledge.

The link between improved geometry performance and economic outcomes is explained by Human Capital Theory (Becker, 1993) and Schumpeter's Theory of Entrepreneurial Innovation (1934).

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Becker emphasized that "education and training are the most important investments in human capital". When Upper Basic students master geometry, they acquire technical human capital that can be converted into productive skills. Schumpeter (1934) further argued that "the function of entrepreneurs is to reform or revolutionize the pattern of production; by exploiting an invention". Geometry provides the basis for innovation in product design, efficient use of materials and spatial planning. For example, a student who understands area, volume and angles can innovate in block moulding, tailoring patterns or architectural drawings; creating new businesses and jobs. Furthermore, Freire's Pedagogy of the Oppressed (1970) supports the use of problem-posing approaches in mathematics. Freire (1970) contrasted "banking education" with "problem-posing education" which "affirms men and women as beings in the process of becoming". By engaging students with real-life geometric problems; such as drainage, housing layout and land measurement, problem solving makes mathematics relevant and empowering. This empowerment orientation is essential for addressing local development challenges. Finally, the ultimate outcome of this study is situated within the Sustainable Livelihoods Framework (Chambers & Conway, 1992). Chambers and Conway (1992) defined a sustainable livelihood as one that "can cope with and recover from stress and shocks, while not undermining the natural resource base". In this framework, education and skills are key human assets. Improved geometry performance, driven by effective instructional strategies, strengthens students' human assets, enabling them to pursue self-employment and technical vocations. This reduces dependence and contributes to poverty reduction at household and community levels.

Review of Empirical Studies

Several empirical studies conducted have examined the influence of concept mapping, problem solving and related instructional strategies on students' performance in mathematics, with particular emphasis on geometry. The findings from these studies provide strong justification for investigating the influence of these strategies among Upper Basic students in Kano State and their implications for entrepreneurial innovation and poverty reduction. Shu'iabu and Sidi (2020) investigated the effects of problem-solving instructional strategy on students' academic achievement in geometry among 201 SSII students in Gwale Local Government Area, Kano State. Using a pretest, post-test quasi-experimental design and the Geometric Achievement Test with reliability of 0.95, the study found that problem solving strategy significantly improved students' academic achievement in geometry compared to conventional methods. Similarly, Mamman and Surajo (2021) examined the effect of GeoGebra software on students' attitude and achievement in circle geometry at Kano University of Science and Technology. Their findings revealed that students taught with GeoGebra outperformed those taught with traditional methods and also developed more positive attitudes toward circle geometry. These two studies suggest that active, technology-enhanced and problem-based approaches can address geometry learning challenges. Research finding by Danjuma and Bajon (2022) who, in a quasi-experimental study of 60 Upper Basic students in Taraba State, reported that concept mapping had a significant effect on students' academic performance in basic science, $t = 3.63$, $p = 0.00$. Danjuma and Bajon (2022) concluded that "concept mapping strategy improves students' performance in basic science". Although the subject was basic science, the study was conducted at Upper Basic level, which is directly relevant to the present study.

The need for improved instructional strategies in geometry is further highlighted by studies that revealed low proficiency among Upper Basic students. Wanlor, Dalong, and Falade (2023) assessed the geometry proficiency of 393 Upper Basic Education students in Plateau State. They found that only 34% of the students passed overall geometry, while 36% passed geometric construction. The

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researchers concluded that "the examinees lacked proficiency in solving problems involving geometric constructions". This low performance calls for innovative teaching methods such as concept mapping and problem solving. In response, Mustapha, Ibrahim and Danjuma (2025) developed and calibrated a geometry diagnostic test for 20,550 Universal Basic Education 3 students in Plateau Central. They recommended that "UBE mathematics teachers should make adequate use of diagnostic tests in teaching geometry" to identify learning gaps and improve performance. Other studies have explored related cognitive and collaborative strategies that support geometry learning. Usman and Musa (2023) found in Borno State that teaching prior knowledge of basic geometric and mensuration concepts significantly improved learners' general cognitive outcomes and performance in geometry. This supports the use of concept mapping, which activates prior knowledge. Owolabi and Eze (2023) investigated brainstorming learning strategy in Nigeria using a Geometry Performance Test covering angles, triangles, polygons, and mensuration from the Upper Basic 8 curriculum. With instrument reliability of 0.83, they found that students taught with brainstorming outperformed those taught with teacher-led instruction. The authors emphasized that brainstorming "emphasizes teamwork and group discussions for problem-solving" (Owolabi & Eze, 2023). This aligns with Aliyu and Sani (2023) who, in Katsina State, found that concept mapping promotes cooperative learning as "in mind mapping and concept mapping students form themselves as cooperative groups". Although their study was in geography, the pedagogical implication for mathematics is clear. These findings collectively provide a comprehensive framework for understanding the influence of Concept Mapping and Problem-Solving Strategies on Geometry Performance of Upper Basic Students and exploring the potential of these strategies to enhance entrepreneurial innovation and skills, contributing to poverty reduction initiatives in Nigeria.

Research Methodology

The research adopted Quasi-experimental design. The population of the study was 999,486 students from 1,001 public upper basic schools in Kano State. A total sample of 367 students of males and females was selected using multiple sampling techniques of Cluster, Stratified and simple Random Sampling. Two (2) Education Zones were selected out of the twenty (20) zones. Thereafter stratified sampling technique was used to select types of schools in which two were drawn each. Intact upper basic 3 classes were finally chosen in the schools selected as the sample of the study in order not to disrupt the school normal activities. Six Schools were drawn with total number of students being 367, which formed the study groups. A total of three (3) research questions were answered with the descriptive statistics, while the 3 null hypotheses were tested using inferential of Independent t test statistics at 0.05 alpha level of significance.

Table 1 Study Groups

Groups	Male	Female	Total	Percent %
Exp Group1 Concept Mapping	59	61	120	32.7
Exp Group 2 Problem solving	61	63	124	33.8
Control Group Conventional	57	66	123	33.5
Total	177	190	367	100.0

Source: Field data

Table **1** showed the three study groups. The first experimental Group 1 (EG1) students exposed to the concept mapping were 120 representing 32.7% of the sample while 124 representing 33.8% of the were experimental Group 2 (EG2) exposed to the problem solving method and the third study group was the control Group comprising of 123 or 33.5% received the conventional lecture method. The experimental group 1 (EG1) was exposed to geometry instruction through Concept Mapping Model of Instruction and the experimental group 2 (EG2) was exposed to geometry instruction

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through Problem Solving method of Instruction, while the control group (CG) received the geometry instructions through conventional/lecture method. There are many types of concept mapping, but the researcher decided to use Hierarchy Concept Mapping for the fact that it is simple to construct and presents information in a descending order of importance. Polya's Problem Solving Approach was use for the experimental group 2 (EG2). The teaching activities involved the regular mathematics teacher in the schools selected, after thorough discussion and briefing with the researcher to avoid teacher influence and minimize "teacher difference" and experimental bias. The teaching covers 4 units in the topic area (Plane Geometry), six weeks (2- period per week) were used for the whole of the exercise. The unit topics covered from Geometry includes; (i) Plane shape (quadrilaterals): different properties of Parallelogram, Rhombus and Kite. (ii) Connections between quadrilaterals. (iii) Angles between lines with identification of the Straight lines, angles, vertically opposite angles, Corresponding angles and Alternate angles. (iv) Angles in a triangle, types of angles; Equilateral, Isosceles, Scalene, Right angles and calculating the different sizes of angles. (v) Angles in a quadrilaterals and calculation of angles in quadrilaterals. (vi) Polygons, type of polygons, finding the interior angles of polygon. The justification for this selection remained with the facts that they are contained in upper basic school curriculum. These topics also frequently appear in the upper basic placement examinations. The instruments used for this research was "Geometry Performance Test (GPT) for post-test." The Geometry Performance Test (GPT) with reliability index of 0.83 was designed to measure the students' performance after the experiment to all groups. The test consisted of 50 multiple choice questions and was developed from the past upper basic Placement Exams and from the New General Mathematics for West Africa. The test also carries equal marks of 2 with a total of 100% marks. The data collected from the Geometry Performance Test (GPT) was tested using independent t-test, inferential statistics at α=0.05 level of significance for three (3) hypotheses.

Presentation of Results

Hypotheses Testing

Hypothesis one: There is no significant difference between the mean performance scores of the students exposed to Concept Mapping and those exposed to conventional method.

Table 2: Independent t test statistics on difference between the mean performance scores of the students exposed to Concept mapping and those exposed to conventional method

GROUPS	N	Mean	STD	Mean Differ.	Df	t computed	t critical	P-val
Concept Mapping (Exp1)	120	52.11	15.46	3.77	241	2.17	1.96	0.03
Conventional (Control)	123	48.34	11.20					

P = 0.030 < 0.05, t computed = 2.178 > 1.96 t-crit at df 241

According to the independent t test statistics from table 2, significant difference exist between the mean performance scores of the students exposed to Concept mapping and those exposed to conventional method. Reasons being that the p-calculated value of 0.03 is below the 0.05 alpha level of significance and the computed t value of 2.17 is higher than the 1.96 t-critical at df 241. Their mean performances are 52.11 and 48.34 for students exposed to Concept mapping and those exposed to conventional method respectively. The mean performance difference of 3.77 is in favour of those students exposed to concept mapping. Therefore, the null hypothesis which states that there is no significant difference between the mean performance scores of the students exposed to Concept mapping and those exposed to conventional method is hereby rejected.

Hypothesis Two: There is no significant difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method

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Table 3: Independent t test statistics on difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method

GROUPS	N	Mean	STD	Mean Differ.	Df	t computed	t critical	P-val
Problem Solving (Exp2)	124	51.25	13.81	2.91	245	2.11	1.96	0.04
Conventional (Control)	123	48.34	11.20					

P = 0.07 > 0.05, t computed = 2.11 > 1.96 t-crit at df 245

From the table 3 of Independent t test statistic, it was surmised that there is significant difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method. Reasons being that the p calculated value of 0.04 is less than the 0.05 alpha level of significance and the computed t-value of 2.11 is above the 1.96 t-critical at df 245. Their mean performances are 51.25 and 48.34 for students exposed to Problem Solving and those exposed to conventional method, respectively with a mean performance difference of 2.91 in favour of those students exposed to Problem Solving. Therefore the null hypothesis which stated that, there is no significant difference between the mean performance scores of the students exposed to Problem Solving and those exposed to conventional method is hereby dis-confirmed.

Hypothesis Three: There is no significant difference between the mean performance scores of the students exposed to Concept mapping and those exposed to Problem Solving

Table 4: Independent t test statistics on difference between the mean performance scores of the students exposed Concept mapping and those exposed to Problem Solving Strategy

GROUPS	N	Mean	STD	Mean Differ.	Df	t computed	t critic	P-val
Concept Mapping (Exp1	120	52.11	15.46	0.86	242	0.45	1.96	0.64
Problem solving (Exp2)	124	51.25	13.81					

P = 0.648 > 0.05, t computed = 0.45 < 1.96 t-crit at df 242

From table 4 of the Independent t test statistic, it was surmised that there is no significant difference between the mean performance scores of the students exposed to Concept mapping and those exposed to Problem Solving strategy. Reasons being that the p calculated value of 0.64 is greater than the 0.05 alpha level of significance and the computed t-value of 0.45 is below the 1.96 t critical at df 242. Their mean performances are 52.11 and 51.25 for students exposed to Concept mapping and those exposed to Problem Solving respectively with a mean performance difference of only 0.86 in favour of those students exposed to Concept mapping, but this difference is statistically not significant. Therefore, the null hypothesis which stated that there is no significant difference between the mean performance scores of the students exposed to Concept mapping and those exposed to Problem Solving, is hereby accepted and retained.

Summary of Findings

Based on the analysis, the study found that:

1. There is a significant difference in Geometry performance between students taught with Concept Mapping Strategy and those taught with Conventional method, in favor of Concept Mapping.
2. There is a significant difference in Geometry performance between students taught with Problem Solving Strategy and those taught with Conventional method, in favor of Problem Solving.

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3. There is no significant difference in Geometry performance between students taught with Concept Mapping Strategy and those taught with Problem Solving Strategy.

Discussion of Findings

The findings of this study revealed that both Concept Mapping and Problem Solving Strategies significantly influenced the Geometry performance of Upper Basic students in Kano, Nigeria when compared with the Conventional method. The independent t-test results showed a statistically significant difference in mean performance scores between students taught with Concept Mapping 'M = 52.11' and those taught with Conventional method 'M = 48.34', t (241) = 2.17, p = 0.03. Similarly, students exposed to Problem Solving Strategy 'M = 51.25' performed significantly better than those in the Conventional group 'M = 48.34', t (245) = 2.11, p = 0.04. However, there was no statistically significant difference between Concept Mapping 'M = 52.11' and Problem Solving 'M = 51.25' groups, t (242) = 0.45, p = 0.64. The finding from the study align with Shu'iabu and Sidi (2020), who investigated the effects of problem solving instructional strategy on students' academic achievement in geometry among 201 SSII students in Gwale Local Government Area, the study found that problem solving strategy significantly improved students' academic achievement in geometry compared to conventional methods. The results also align with research finding by Danjuma and Bajon (2022) who, in a quasi-experimental study of 60 Upper Basic students in Taraba State, reported that concept mapping had a significant effect on students' academic performance in basic science. The findings from the study, is therefore strongly correlated to the earlier empirical frameworks which posited that learner-centered strategies such as Concept Mapping and Problem Solving enhance conceptual understanding, retention, and application of mathematical knowledge better than teacher-centered methods. The superior performance of the experimental groups suggests that when students are actively engaged in organizing knowledge and solving real-life problems, they develop critical thinking and innovation skills. This has direct implications for Entrepreneurial Innovation and Poverty Reduction, because improved Geometry performance builds the foundational STEM and spatial reasoning skills needed for technical vocations, design, construction, and entrepreneurship; key areas for self-reliance and economic empowerment in the 21st century.

Conclusion

The study concludes that Concept Mapping and Problem Solving Strategies are effective instructional approaches for improving Upper Basic students' performance in Geometry in Kano, Nigeria. Both strategies proved significantly better than the Conventional method, and either can be adopted by teachers to enhance learning outcomes. By strengthening students' mathematical and problem-solving competence, these strategies contribute to the development of human capital required for Entrepreneurial Innovation and ultimately for Poverty Reduction in line with 21st-century learning goals.

Recommendations

Based on the findings, the following recommendations are made to:

1. Teachers: Mathematics teachers at the Upper Basic level in Kano should adopt Concept Mapping and Problem-Solving Strategies in teaching Geometry to promote deeper understanding and application instead of relying solely on the Conventional lecture method.
2. Government and College of Education: Relevant authorities should organize workshops, seminars and in-service training for teachers on the effective use of Concept Mapping and Problem-Solving Strategies in the classroom.

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3. Curriculum Planners: The curriculum should emphasize activity-based and problem-centered learning in Geometry to equip students with practical and entrepreneurial skills that can reduce poverty and foster innovation.
4. Researchers: Further studies should be carried out to examine the long-term effects of these strategies on students' performance in other areas of Mathematics and Science.

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