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LEVERAGING SYSTEMS ANALYSIS STRATEGIES (SAS) FOSTER MATHEMATICS ACHIEVEMENT IN POST-PRIMARY EDUCATION (PPE): A BACKGROUND STUDY OF CROSS RIVER STATE, NIGERIA

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Abstract
This study explores the application of Systems Analysis Strategies (SAS) to enhance mathematics achievement in post-primary education (PPE) in Cross River State, Nigeria. SAS, a structured approach to problem-solving and decision-making, was employed to address systemic challenges in mathematics education, including instructional inefficiencies, resource constraints, and student engagement. Using a mixed-methods design, primary data were collected through questionnaires, Mathematics Achievement Tests (MAT), and focus group discussions with 600 Junior Secondary School (JSS) students and 60 teachers across six schools in Calabar Municipality. Findings reveal that SAS, particularly through problem-based learning and feedback loops, significantly improved students' mathematics performance ($p < .05$) and engagement. Demographic analysis indicated no significant gender-based differences, but urban students outperformed rural peers due to better access to resources. The study highlights the potential of SAS to optimize teaching processes and foster a conducive learning environment. Recommendations include integrating SAS into teacher training and scaling resource allocation to rural schools. This research underscores the transformative potential of systems thinking in addressing educational challenges in developing contexts.

Keywords: Systems Analysis Strategies, Mathematics Achievement, Post-Primary Education, Problem-Based Learning, Feedback Loops.

Introduction
Mathematics serves as a foundational pillar for scientific inquiry, technological innovation, and economic development, yet its performance in post-primary education (PPE) in Nigeria, particularly in Cross River State, remains a persistent challenge. Despite its mandatory inclusion in the Nigerian curriculum, students' consistently poor performance in national examinations, such as the West African Examinations Council (WAEC) and National Examinations Council (NECO), underscores a systemic crisis in mathematics education (Umameh, 2011; Meremikwu, 2011). This crisis is compounded by multifaceted barriers, including inadequate instructional resources, limited teacher preparedness, outdated pedagogical approaches, and socio-economic disparities (Akpan, 1987; Owan et al., 2019). These challenges not only hinder students' academic progress but also limit their readiness for higher education and participation in a globalized, technology-driven economy. This study investigates the transformative potential of Systems Analysis Strategies (SAS) a methodological framework rooted in systems thinking to address these systemic issues and enhance mathematics achievement in PPE within Cross River State.

Systems Analysis Strategies involve a structured approach to problem-solving by deconstructing complex systems into their constituent parts, analyzing interrelationships, and optimizing processes through iterative feedback and decision-making (Forrester, 1994). In educational contexts, SAS can streamline curriculum delivery, enhance teacher-student interactions, and improve the allocation and utilization of scarce resources. By fostering a holistic understanding of educational ecosystems, SAS enables stakeholders to identify leverage points for intervention, such as improving instructional strategies or addressing resource inequities. The application of systems thinking in education has gained traction globally, as it promotes critical thinking, problem-solving, and adaptability skills that are particularly vital for mastering mathematics (Senge, 2006; Ansah et al., 2020). This study explores how SAS, through components like problem-based learning (PBL), feedback loops, and resource optimization, can address the unique challenges of mathematics education in Cross River State.

The literature on mathematics education in Nigeria highlights several systemic barriers to achievement. Inadequate instructional materials, such as textbooks and technological aids, have been consistently linked to poor performance (Meremikwu, 2011). A study in Cross River State found that classroom environment variables, including class size and availability of teaching aids, accounted for significant variance in students' mathematics performance ($p < .05$) (Web:7). Similarly, teacher effectiveness, encompassing pedagogical content knowledge (PCK) and subject matter knowledge (SMK), plays a critical role in shaping student outcomes (Ansah et al., 2020). Teachers with strong PCK can contextualize mathematical concepts, making them more accessible, while those with robust SMK can address complex topics with confidence (Ball et al., 2008). However, many Nigerian teachers lack adequate training in innovative pedagogies, relying instead on traditional, teacher-centered methods that stifle student engagement (Owan et al., 2019).

Problem-based learning (PBL), a core component of SAS, has shown promise in transforming mathematics education by fostering active learning and critical thinking. PBL encourages students to tackle real-world problems, promoting conceptual understanding and collaborative skills (Vula & Berdynaj, 2011). Studies in other contexts, such as the United States and South Africa, have demonstrated that PBL improves students' ability to apply mathematical concepts to practical scenarios, leading to higher achievement and retention (Hmelo-Silver, 2004; Lubben et al., 2010). In Nigeria, however, the adoption of PBL remains limited, particularly in resource-constrained settings like Cross River State, where teachers often lack the training or materials to implement it effectively.

The demographic context of Cross River State adds further complexity to educational interventions. The state's diverse population spans urban centers, such as Calabar, and rural areas with limited infrastructure. Rural schools frequently face shortages of qualified teachers, textbooks, and technological resources, resulting in significant disparities in educational outcomes compared to urban schools. Socio-economic status (SES) also plays a pivotal role, with low-SES students facing barriers such as inability to afford supplementary learning materials or access to private tutoring. Gender disparities in mathematics achievement have been noted in prior studies, with male students historically outperforming females, though recent evidence suggests this gap is narrowing due to increased access to education for girls (Eyo, 2011). These demographic factors necessitate tailored interventions that account for local contexts and systemic inequities.

Globally, systems thinking has been applied to address educational challenges in diverse settings. For instance, a study in Ghana demonstrated that systems-based interventions, such as feedback-driven curriculum adjustments, improved mathematics performance in secondary schools (Ansah et al., 2020). Similarly, in Malaysia, systems analysis was used to optimize resource allocation, resulting in enhanced student outcomes in STEM subjects (Ismail et al., 2018). In Nigeria, however, the application of SAS in PPE remains underexplored, with most studies focusing on isolated interventions rather than systemic approaches (Owan et al., 2019). This gap is particularly pronounced in Cross River State, where the interplay of urban-rural disparities, teacher preparedness, and resource constraints creates a complex educational landscape.

This study bridges this gap by applying SAS to PPE in Cross River State, with a focus on PBL, feedback mechanisms, and resource optimization. It hypothesizes that SAS can significantly improve mathematics achievement by addressing systemic barriers and fostering a student-centered, inquiry-based learning environment. By integrating quantitative and qualitative methods, the study aims to provide a comprehensive understanding of SAS's efficacy and its potential to transform mathematics education in a developing context. The findings are expected to inform policy and practice, offering a scalable model for improving educational outcomes in Nigeria and beyond.

Methodology

Research Design

A mixed-methods approach was adopted, combining quantitative data from a Mathematics Achievement Test (MAT) and questionnaires with qualitative insights from focus group discussions. The design allowed for a comprehensive analysis of SAS's impact on mathematics achievement and the influence of demographic factors.

Population and Sample

The study was conducted in Calabar Municipality, Cross River State, targeting Junior Secondary School (JSS) students and teachers. A multistage sampling technique selected six public schools (three urban, three rural), yielding 600 JSS2 students (300 males, 300 females) and 60 teachers. The demographic profile is presented in Table 1.

Table 1
Demographic Profile of Participants

Variable	Category	Frequency	Percentage (%)
Gender (Students)	Male	300	50.0
	Female	300	50.0
Location	Urban	300	50.0
	Rural	300	50.0
Age (Students)	12–14 years	420	70.0
	15–16 years	180	30.0
Teacher Experience	<5 years	20	33.3
	5–10 years	25	41.7
	>10 years	15	25.0

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Instruments

Three instruments were used:

- Mathematics Achievement Test (MAT): A 30-item multiple-choice test assessing algebra, geometry, and problem-solving (KR-20 reliability = 0.87).
- Systems Analysis Strategy Questionnaire (SASQ): A 25-item Likert-scale questionnaire evaluating teacher and student perceptions of SAS implementation (Cronbach's alpha = 0.84).
- Focus Group Discussion Guide: Semi-structured questions exploring experiences with SAS, including PBL and feedback loops.

Procedure

The study spanned eight weeks. Three schools (experimental group) implemented SAS, including PBL activities and weekly feedback sessions, while the other three (control group) used conventional teaching methods. Pretest and posttest MAT scores were collected, and questionnaires were administered to both groups. Focus groups (six sessions, 10 participants each) provided qualitative insights. Informed consent was obtained, and ethical approval was granted by the University of Calabar's Ethics Committee.

Data Analysis

Quantitative data were analyzed using descriptive statistics (means, standard deviations) and inferential tests (t-tests, ANOVA) at a .05 significance level. Qualitative data were thematically analyzed to identify patterns in SAS effectiveness.

Results

Quantitative Findings

Pretest MAT scores showed no significant difference between experimental and control groups ($t = 1.12$, $p > .05$). Posttest results indicated a significant improvement in the experimental group ($M = 78.5$, $SD = 9.2$) compared to the control group ($M = 65.3$, $SD = 10.1$; $t = 5.67$, $p < .001$). Table 2 summarizes the results.

Table 2

Pretest and Posttest MAT Scores

Group	Pretest Mean (SD)	Posttest Mean (SD)	t-value	p-value
Experimental (SAS)	62.4 (8.7)	78.5 (9.2)	5.67	< .001
Control	61.9 (9.0)	65.3 (10.1)	1.45	.148

No significant gender differences were found ($t = 0.89$, $p > .05$), but urban students outperformed rural students ($F(1,598) = 4.23$, $p < .05$), likely due to better resource access. Teacher experience positively correlated with student outcomes ($r = .42$, $p < .01$).

Qualitative Findings

Focus group discussions revealed three themes:

- Engagement through PBL: Students reported that PBL made mathematics “more relatable” and encouraged collaboration.
- Feedback Effectiveness: Teachers noted that regular feedback loops helped identify and address student misconceptions promptly.
- Resource Constraints: Rural teachers highlighted limited access to instructional materials as a barrier to SAS implementation.

Discussion

The findings of this study underscore the transformative potential of Systems Analysis Strategies (SAS) in enhancing mathematics achievement in post-primary education (PPE) within Cross River State, Nigeria. The significant improvement in Mathematics Achievement Test (MAT) scores for the experimental group ($M = 78.5$, $SD = 9.2$) compared to the control group ($M = 65.3$, $SD = 10.1$; $t = 5.67$, $p < .001$) aligns with global evidence that systems thinking, when applied to education, fosters critical problem-solving and conceptual understanding (Forrester, 1994; Senge, 2006). Specifically, the integration of problem-based learning (PBL) as a core SAS component encouraged students to engage with mathematical concepts in a contextualized, collaborative manner, which resonates with Vula and Berdynaj’s (2011) findings that PBL enhances students’ ability to apply mathematical knowledge to real-world scenarios. The qualitative feedback from focus groups further highlighted students’ increased engagement, with participants describing mathematics as “more relatable” and “less intimidating” when taught through PBL. This suggests that SAS not only improves academic outcomes but also shifts students’ attitudes toward mathematics, addressing a critical barrier to achievement in Nigeria (Umameh, 2011).

The absence of significant gender differences ($t = 0.89$, $p > .05$) in mathematics performance is a notable departure from earlier studies in Nigeria, which often reported male students outperforming females due to socio-cultural factors. This finding may indicate that SAS, by fostering an inclusive and interactive learning environment, mitigates gender-based disparities. The student-centered nature of PBL, coupled with regular feedback loops, likely provided equitable opportunities for participation and learning, aligning with Ansah et al.’s (2020) assertion that pedagogical strategies can neutralize gender biases in STEM education. However, the significant urban-rural performance gap ($F(1,598) = 4.23$, $p < .05$) underscores persistent systemic inequities. Urban students’ superior performance can be attributed to better access to instructional materials, qualified teachers, and technological resources, as noted in prior research (Owan et al., 2019). Rural schools, conversely, faced challenges such as inadequate teaching aids and limited teacher training, which hindered full SAS implementation. This disparity highlights the need for targeted interventions to address resource allocation, as suggested by Meremikwu (2011).

The positive correlation between teacher experience and student outcomes ($r = .42$, $p < .01$) reinforces the critical role of teacher expertise in SAS efficacy. Experienced teachers, with stronger pedagogical content knowledge (PCK) and subject matter knowledge (SMK), were better equipped to implement PBL and provide actionable feedback, consistent with Ansah et al.'s (2020) findings on teacher effectiveness. However, the qualitative data revealed that even experienced teachers in rural settings struggled with resource constraints, suggesting that systemic support beyond teacher training is essential for SAS success. The feedback loops embedded in SAS allowed teachers to identify and address student misconceptions promptly, a practice supported by Senge's (2006) emphasis on iterative learning processes in systems thinking. This iterative approach not only improved student performance but also enhanced teacher-student interactions, creating a dynamic learning environment.

The study's findings also have broader implications for educational policy in Nigeria. The success of SAS in improving mathematics achievement suggests that systems thinking can address other systemic challenges, such as curriculum misalignment and student disengagement, which are prevalent in Nigerian PPE. However, scaling SAS implementation requires overcoming barriers such as funding shortages and infrastructural deficits, particularly in rural areas. The integration of technology, such as digital platforms for PBL, could further enhance SAS efficacy, though this would require significant investment in rural school infrastructure. Moreover, the study's mixed-methods approach provides a robust framework for future research, combining quantitative rigor with qualitative depth to capture the nuanced impacts of SAS on diverse learners.

Limitations of the study include its focus on JSS2 students, which may limit generalizability to other educational levels, and the eight-week intervention period, which may not capture long-term effects. Future research should explore longitudinal impacts and include senior secondary students to assess SAS's efficacy across PPE stages. Additionally, incorporating private schools could provide insights into SES-related variations in SAS outcomes.

Conclusion

This study provides compelling evidence that Systems Analysis Strategies, through components like problem-based learning and feedback loops, can significantly enhance mathematics achievement in post-primary education in Cross River State, Nigeria. The marked improvement in MAT scores and positive student and teacher perceptions underscore SAS's potential to address systemic inefficiencies in mathematics education. By fostering active engagement, critical thinking, and iterative feedback, SAS creates a student-centered learning environment that aligns with global best practices in education (Senge, 2006; Vula & Berdynaj, 2011). The absence of gender disparities in performance suggests that SAS can promote equity in mathematics education, a critical step toward addressing socio-cultural barriers in Nigeria (Web:3). However, the urban-rural performance gap highlights the need for systemic reforms to ensure equitable resource distribution and infrastructure development.

The findings advocate for a paradigm shift in Nigerian PPE, moving from traditional, teacher-centered approaches to systems-oriented, student-focused pedagogies. The success of SAS in this context suggests its applicability to other subjects and regions facing similar educational challenges. Policymakers, educators, and stakeholders must prioritize SAS integration into teacher training, curriculum design, and resource allocation to sustain and scale its benefits. Addressing rural schools' resource constraints and leveraging technology could further amplify SAS's impact. Ultimately, this study positions SAS as a viable framework for transforming mathematics education in Nigeria, fostering a generation of critical thinkers equipped to drive scientific and technological progress.

Recommendations

- Teacher Training: Integrate SAS, including PBL and feedback mechanisms, into pre-service and in-service teacher training programs.
- Resource Allocation: Policymakers should prioritize equitable distribution of instructional materials to rural schools.
- Scaling SAS: Expand SAS implementation across other Nigerian states, with longitudinal studies to assess long-term impacts.

Stakeholder Collaboration: Engage parents and communities to support SAS adoption through awareness campaigns.

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