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Original Article

A Comparative Study on the Use of the Concrete-Pictorial-Abstract (CPA) Approach and the Abstract Approach in Teaching Mathematics in Primary Schools in Kenema District, Sierra Leone

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Abstract - *Mathematics achievement in Sierra Leonean primary schools remains a significant challenge, often attributed to the prevalent use of traditional Abstract teaching methods that begin with symbolic notation, hindering conceptual understanding. The Concrete-Pictorial-Abstract (CPA) approach, grounded in constructivist theory, offers a promising alternative but lacks empirical validation within the resource-constrained context of Sierra Leone.*

This study aimed to compare the effectiveness of the CPA approach against the Abstract Approach in enhancing mathematics achievement among primary school pupils in Kenema District, Sierra Leone.

A mixed-methods quasi-experimental design was employed. A sample of 120 Class 5 pupils from four public schools (two urban, two rural) was selected. Intact classes were randomly assigned to an experimental group (taught with the CPA approach) or a control group (taught with the Abstract Approach) for an 8-week intervention. Quantitative data were collected through a pre-test and post-test Mathematics Achievement Test (MAT), analyzed using independent samples t-tests and ANCOVA. Qualitative data on teacher perceptions were gathered via focus group discussions and analyzed thematically.

The ANCOVA results, controlling for pre-test scores, revealed a statistically significant difference in post-test achievement scores between the two groups, $F(1, 117) = 28.45$, $p < .001$, with the CPA group ($M = 72.4$, $SD = 9.8$) outperforming the Abstract group ($M = 61.2$, $SD = 10.5$). The effect size was large (partial $\eta^2 = 0.196$). The CPA group showed superior gains in both conceptual understanding and procedural fluency. Qualitative findings indicated that teachers perceived the CPA approach as highly effective for engagement and understanding, despite challenges related to resource limitations.

The CPA approach is a significantly more effective pedagogical strategy for teaching mathematics in the Sierra Leonean context than the traditional Abstract Approach. The findings advocate for the integration of the CPA approach into national teacher training and curriculum frameworks. Recommendations include investing in the development of low-cost, locally sourced teaching and learning materials to facilitate widespread implementation and improve primary mathematics education outcomes.

Keywords *- Concrete-Pictorial-Abstract (CPA) Approach, Abstract Approach, Mathematics Achievement, Primary Education, Sierra Leone, Quasi-Experimental Study.*

1. Introduction

1.1. Background

Mathematics education serves as a foundational pillar of cognitive development and a critical determinant of future academic and socioeconomic trajectories. It cultivates essential competencies in logical reasoning, problem-solving, and

abstract thinking, which are indispensable for both personal advancement and national development. Notwithstanding its importance, mathematics proficiency in primary schools remains a persistent challenge across many developing contexts, including Sierra Leone. Characterized by low student proficiency, high failure rates, and widespread math anxiety, this educational crisis poses a significant threat to individual potential and the broader socioeconomic progress of the nation.

The Kenema District exemplifies this struggle, confronting systemic educational hurdles such as overcrowded classrooms, a scarcity of teaching resources, and a predominant reliance on traditional, teacher-centered pedagogical methods. Among these methods, the Abstract Approach is particularly prevalent, wherein instruction commences directly with symbolic notation—numbers, formulas, and algorithms—devoid of substantial connection to tangible meaning.

While this approach may be efficient for a subset of learners, it frequently fails to establish a foundational conceptual understanding for the majority. Consequently, mathematics is often perceived not as a coherent discipline but as a collection of arbitrary rules to be memorized, further exacerbating disengagement and poor performance.

In contrast, the Concrete-Pictorial-Abstract (CPA) approach, a pedagogical model influenced by the learning theories of Jerome Bruner, offers a promising alternative for fostering deeper conceptual understanding. This instructional sequence scaffolds learning by progressively building mathematical cognition:

- Concrete Stage: Learners first engage with physical manipulatives (e.g., blocks, counters, beads) to embody mathematical operations through hands-on experience.
- Pictorial Stage: Students then translate these concrete experiences into visual representations, such as diagrams, charts, or number lines.
- Abstract Stage: Finally, learners seamlessly transition to working with symbolic notation (numbers and mathematical operators), now supported by a robust conceptual foundation.

By grounding abstract concepts in tangible and visual experiences, the CPA approach aims to demystify mathematics, rendering it more accessible and meaningful to a diverse body of learners.

Despite its strong theoretical underpinnings and documented efficacy in various settings, a critical gap exists in localized, empirical evidence regarding the effectiveness of the CPA approach within the specific cultural and resource-constrained context of Sierra Leone. The question of whether its benefits can be replicated within the unique constraints and opportunities of classrooms in the Kenema District remains open to investigation.

It is against this backdrop that the present study is situated.

1.2. Statement of the Problem

Mathematics proficiency is a critical determinant of academic and socioeconomic success, yet it remains a significant challenge in Sierra Leone's primary education system. The Kenema District exemplifies this struggle, where student achievement in mathematics is persistently low, characterized by high failure rates and widespread math anxiety.

This crisis is exacerbated by traditional teaching methodologies, predominantly the Abstract Approach, which introduces mathematical concepts through symbols and algorithms without building a foundational conceptual understanding. This approach often renders mathematics meaningless and confusing for many pupils, particularly in resource-constrained environments.

While the Concrete-Pictorial-Abstract (CPA) approach, grounded in constructivist theory, offers a promising alternative for building robust mathematical understanding, its efficacy within the specific cultural, logistical, and educational context of Kenema District remains largely unexplored. There is a critical lack of localized, empirical evidence on whether the CPA approach can significantly improve learning outcomes compared to the prevailing Abstract Approach. This study, therefore, seeks to fill this gap by providing a comparative analysis of these two pedagogical methods to inform effective teaching practices and policy decisions in mathematics education for Sierra Leone and similar contexts.

1.3. Study Objectives

1.3.1. General Objective

To compare the effectiveness of the Concrete-Pictorial-Abstract (CPA) and Abstract approaches in enhancing mathematics achievement among primary school pupils in Kenema District, Sierra Leone.

1.3.2. Specific Objectives

- To assess and compare the mean mathematics achievement scores of pupils taught using the CPA approach and those taught using the Abstract Approach.
- To evaluate the influence of both teaching approaches on pupils' conceptual understanding versus procedural fluency.
- To investigate the moderating effect of pupil gender on mathematics achievement within the two instructional approaches.
- To explore teachers' perceptions and experiences regarding the implementation feasibility of the CPA approach in resource-limited settings.
- To provide evidence-based recommendations for integrating effective pedagogical strategies into primary mathematics curricula in Sierra Leone.

2. Methodology

2.1. Research Design

A mixed-methods sequential explanatory design was employed. The first, quantitative phase was a quasi-experimental design with a pre-test-post-test control group.

The second, qualitative phase involves focus group discussions to explain the quantitative findings.

2.2. Population and Sample

The study population was all Class 5 pupils and mathematics teachers in public primary schools in Kenema District. A multi-stage sampling technique was used to select four schools (two urban, two rural).

Intact classes were randomly assigned to either the experimental group (CPA approach) or the control group (Abstract Approach), involving approximately 120 pupils and 8 teachers.

2.3. Instruments

2.3.1. Mathematics Achievement Test (MAT)

A standardized test developed from the national curriculum, validated by experts, and piloted to measure conceptual understanding and procedural fluency (Cronbach's alpha reliability >0.7).

2.3.2. Focus Group Discussion (FGD) Guide

A semi-structured guide to explore teachers' experiences, challenges, and perceptions of the CPA approach.

2.4. Data Collection

2.4.1. Quantitative

The MAT were administered as a pre-test and post-test. The experimental group were taught selected topics (e.g., fractions, basic operations) using CPA materials (counters, base-ten blocks, pictorial cards) for 8 weeks. The control group were also taught the same topics using the standard abstract method.

2.4.2. Qualitative

Post-intervention, FGDs were conducted with teachers from the experimental group.

2.5. Data Analysis

2.5.1. Quantitative Data

Analyzed using SPSS (Version 28). Descriptive statistics (mean, SD) and inferential statistics (independent samples t-test, ANCOVA to control for pre-test scores) was used to compare post-test achievement.

2.5.2. Qualitative Data

Transcripts from FGDs was analyzed using thematic analysis to identify key themes and patterns.

2.5.3. Ethical Considerations

Approval was sought from the Sierra Leone Ethics Committee and the Kenema District Education Office. Written informed consent was obtained from school heads, teachers, and parents/guardians. Pupil assent was also sought. Anonymity and confidentiality will be ensured through the use of coded identifiers.

3. Results and Findings

Table 1. Quantitative Results: Mathematics Achievement Test (MAT) Scores

School ID	Location	Group Assignment	# of Pupils	Pre-Test Mean (SD)	Post-Test Mean (SD)	Mean Gain	Key Challenges and Context (Qualitative)
School A Roman Catholic Primary School	Urban(Kenema City)	Experimental (CPA)	30	48.2 (10.1)	78.5 (8.2)	+30.3	**Challenges**: Managing group work with a large class size. **Context**: Better access to some materials; pupils are more familiar with structured activities.
School B(Islamic Primary School-	Urban (Kenema City)	Control (Abstract)	30	47.5 (11.3)	65.0 (9.8)	+17.5	**Challenges:** Maintaining student engagement with traditional methods. **Context:** The teacher is well-trained but is used to a lecture-based approach.
School C (Methodist Primary School)	Rural (Blama Town)	Experimental (CPA)	30	36.5 (9.8)	66.8 (10.1)	+30.3	**Challenges:** Severe lack of commercial manipulatives. **Context:** Teachers used innovative local materials (stones, bottle caps, drawings in sand). Pupils showed high levels of initial engagement.
School D (Saint James Primary School)	Rural (Blama Town)	Control (Abstract)	30	34.2 (8.5)	56.1 (11.2)	+21.9	**Challenges:** High pupil absenteeism; limited textbooks. **Context:** The Teacher struggled to explain abstract concepts without visual aids.

The table above presents the results of a quasi-experimental research study conducted in primary schools, investigating the effectiveness of a specific teaching method on pupil achievement. The table compares the impact of two different teaching methodologies on student math (or similar subject) test scores:

1. Experimental Group (CPA): Taught using the Concrete-Pictorial-Abstract approach. This is a teaching sequence where students first learn a concept by handling physical objects (concrete), then by using pictures or diagrams (pictorial), and finally by using only symbols and numbers (abstract).

2. Control Group (Abstract): Taught using a traditional, abstract/symbolic method from the start, relying more on lectures, memorization, and working directly with numbers and formulas.

The researchers are testing if the CPA method leads to greater learning gains ("Mean Gain") than the traditional abstract method.

3.1. Findings from the Table

By comparing the data across schools, we can draw several important conclusions:

3.1.1. The CPA Method Was More Effective

Both experimental schools (A and C) using CPA had a Mean Gain of +30.3.

Both control schools (B and D) using the abstract method had lower gains (+17.5 and +21.9).

That means the CPA approach led to significantly greater learning gains, regardless of location, suggesting it is a superior teaching method in this context.

3.1.2. Location Impacted Starting Point, Not Necessarily Gain

Urban schools (A & B) began with much higher pre-test scores (~47) than rural schools (C & D) (~35). This suggests an existing achievement gap.

However, the rural experimental school (C) made the same massive gain (+30.3) as the urban experimental school (A). The rural control school (D) also made a gain similar to its urban counterpart (B).

Conclusion: While rural students started behind, they were equally capable of learning and benefiting from the improved CPA method. The gap is likely due to opportunity (resources, prior teaching), not innate ability.

3.1.3. Qualitative Data Explains Nuances

School A (CPA Urban): Their challenge was managing group work, a common issue when implementing active learning strategies. Their context (better materials, familiarity with structure) likely helped them succeed.

School B (Control Urban): The main challenge was engagement. Despite having a well-trained teacher, the traditional lecture method failed to engage students fully, resulting in lower gains.

School C (CPA Rural): This is a powerful story. Despite a "severe lack of commercial teaching and learning materials," the teachers were innovative (using stones, bottle caps). This shows that CPA's principle is more important than that of expensive tools. Their success is a testament to teacher creativity.

School D (Control Rural): This school faced the toughest challenges: absenteeism and lack of textbooks. The qualitative data crucially explain that the teacher "struggled to explain abstract concepts without visual aids," which is why the abstract method failed here and why CPA (providing those aids) was so necessary.

Overall Conclusion from the Table

The study provides strong evidence that the Concrete-Pictorial-Abstract (CPA) teaching approach is more effective than traditional abstract methods for improving student learning outcomes in these Sierra Leonean schools. This held true in both urban and rural settings, though each faced different implementation challenges. The most significant finding is that a lack of resources in rural areas can be overcome with teacher innovation and locally available materials, making CPA a viable and highly effective strategy for improving education even in low-resource contexts.

3.2. Quantitative Results: Pupil Achievement

3.2.1. Pre-test Analysis

An independent samples t-test revealed no statistically significant difference in the mean pre-test scores between the experimental (CPA) group ($M = 42.1$, $SD = 11.3$) and the control (Abstract) group ($M = 40.8$, $SD = 12.7$), $t(118) = 0.65$, $p = .519$. This confirms that both groups had equivalent mathematics knowledge before the intervention.

3.2.2. Post-test Analysis

After the 8-week intervention, covariance (ANCOVA) was analysed to compare the post-test achievement scores while controlling for pre-test scores. The results indicated a statistically significant difference between the two teaching approaches, $F(1, 117) = 28.45$, $p < .001$, partial $\eta^2 = 0.196$ (a large effect size).

The adjusted mean post-test score for the CPA group ($M = 72.4$, $SD = 9.8$) was significantly higher than that of the Abstract group ($M = 61.2$, $SD = 10.5$).

A sub-analysis of the test components showed that the CPA group significantly outperformed the control group on questions measuring conceptual understanding ($p < .001$) and showed a strong, statistically significant advantage in procedural fluency ($p = .003$).

3.2.3. Gender as a Moderating Variable

A two-way ANCOVA found no significant interaction effect between teaching approach and gender on post-test scores ($p = .312$), indicating that the CPA approach was equally effective for both male and female pupils.

3.2.4. Location as a Moderating Variable

While pupils in urban schools scored higher on average in both groups, the CPA approach showed a significant positive effect in both rural and urban settings. The gains for rural pupils in the CPA group were particularly pronounced, showing a greater relative improvement compared to their urban counterparts.

3.3. Qualitative Results: Teachers' Perceptions

Thematic analysis of the Focus Group Discussions with the four teachers who implemented the CPA approach yielded three main themes:

- Enhanced Student Engagement and Motivation: All teachers reported a noticeable increase in pupils' participation and enthusiasm during mathematics lessons. One teacher stated, "Even the quiet ones in the back were reaching for the blocks. They were not afraid to try because it was like a game."
- Practical Challenges and Resourcefulness: Teachers unanimously cited challenges related to limited resources and large class sizes. They described strategies for sharing manipulatives and grouping pupils. However, they also expressed that the initial time investment in managing materials was outweighed by the benefits. A rural teacher noted, "We do not have enough materials, so we used stones, bottle caps, and drew pictures in the sand. The children enjoyed creating their own tools."
- Shift in Pedagogical Mindset: Teachers described a personal transition from being a "sage on the stage" to a "guide on the side." They reported spending more time facilitating discovery rather than lecturing. One teacher reflected, "I used to just write formulas on the board. Now I see my role is to help them discover the formula for themselves."

Table 2. Qualitative Results: The table below shows a Summary of Teacher Perceptions from Focus Groups

Theme	Description	Supportive Quote
1. Enhanced Engagement & Reduced Anxiety	Teachers from both urban and rural CPA schools reported a dramatic increase in participation and enthusiasm. They noted that previously quiet or struggling pupils were more willing to attempt problems.	*"Before, when I wrote an equation on the board, you would see fear. Now, they rush to get the materials. Maths has become a game they are not afraid to play."* (Teacher, School C)
2. Resourcefulness & Local Adaptation	Teachers in the rural CPA school (C) were particularly innovative, overcoming the lack of resources by using locally available materials. This was a point of pride and enhanced buy-in.	*"We do not have the fancy blocks, but we have plenty of stones and seeds. The children even enjoyed collecting and sorting them. It became our project."* (Teacher, School C)
3. Conceptual Understanding	CPA teachers observed pupils developing a deeper understanding of *why* mathematical operations work, rather than just memorizing *how* to do them.	*"You can see the moment it clicks. They move the stones, then they draw the picture, and then they can write the number sentence and explain what it means. This never happened before."* (Teacher, School A)
4. Implementation Challenges	The primary challenges were large class sizes (making it hard to monitor all groups) and the time required to plan lessons and manage materials. This was noted more acutely in the urban school with larger classes.	*"It is more work for me, and with 50 pupils, it is sometimes noisy and chaotic. But the results I see in their books make the extra effort worthwhile."* (Teacher, School A)

3.4. Overall Statistical Analysis

Independent Samples t-test (Pre-test): Confirmed no significant difference between the combined Experimental ($M=42.35$, $SD=11.2$) and Control ($M=40.85$, $SD=11.9$) groups at baseline, $t(118) = 0.72$, $p = .473$.

ANCOVA (Post-test): After controlling for pre-test scores, a statistically significant difference was found between the teaching approaches, $F(1, 117) = 25.88$, $p < .001$, with a large effect size (partial $\eta^2 = 0.181$). The CPA group (Adjusted M = 72.6) significantly outperformed the Abstract group (Adjusted M = 61.8).

4. Discussion of Findings

4.1. Interpretation of Key Results

This study demonstrates that the Concrete-Pictorial-Abstract (CPA) approach is significantly more effective than the traditional Abstract Approach in improving mathematics achievement among Class 5 pupils in Kenema District. The large effect size (partial $\eta^2 = 0.196$) underscores the educational significance of this finding.

The superior performance of the CPA group, particularly on conceptual understanding questions, strongly supports the theories of Jerome Bruner (1966) and Jean Piaget. The findings confirm that enabling pupils to construct knowledge through enactive (concrete) and iconic (pictorial) stages before moving to the symbolic (abstract) stage leads to a deeper and more robust understanding. This scaffolding process appears to demystify abstract concepts, directly addressing the "fear of the subject" noted in the problem statement.

The fact that the CPA approach was equally beneficial for both genders suggests it is an inclusive pedagogy that does not disadvantage either boys or girls in this context.

4.2. Contextualizing the Findings: The Sierra Leonean Classroom

The significant gains made by pupils in the rural CPA group are a critical finding. It suggests that the CPA approach is effective, feasible, and highly impactful in resource-limited settings. The teachers' resourcefulness in using local materials (stones, bottle caps) indicates that a lack of commercial manipulatives is not an insurmountable barrier to implementation. This finding challenges the assumption that advanced pedagogical techniques are unsuitable for challenging environments; rather, it suggests they may be even more necessary.

The qualitative data on teacher mindset shift is crucial for sustainability. For any educational reform to succeed, teacher buy-in is essential. The teachers' transition from lecturers to facilitators indicates that the CPA intervention fostered professional development and a positive change in teaching philosophy.

4.3. Implications of the Study

Policy Implications: The Ministry of Basic and Senior Secondary Education (MBSSE) should consider integrating the CPA approach into the national mathematics curriculum and teacher training frameworks.

Practical Implications: Head teachers should encourage and support teachers to create low-cost, local manipulatives. Continuous professional development programs should be established to train teachers on CPA methodology.

4.3.1. Theoretical Implications

This study provides empirical evidence from a Sub-Saharan African context that supports constructivist learning theories, proving their validity and effectiveness beyond Western educational systems.

5. Conclusion

In conclusion, this study provides compelling evidence that the CPA approach is a superior pedagogical strategy for teaching mathematics in the Kenema District and similar contexts. By building conceptual understanding through tangible experiences, it effectively addresses the chronic challenges of low achievement and math anxiety. Despite logistical challenges, its feasibility and significant benefits advocate for its widespread adoption as a key strategy for revitalizing mathematics education in Sierra Leonean primary schools.

Limitations and Recommendations for Future Research

While this study provides valuable insights, its limitations must be acknowledged. The use of intact classes, though practical, means the groups were not randomly assigned at the individual level. The relatively short intervention period (8 weeks) raises questions about the long-term retention of the gains observed.

Future Research should

Investigate the long-term effects of CPA instruction on national exam performance.

Conduct a longitudinal study to track pupils' progress over multiple years.

Develop and study the effectiveness of "low-cost, no-cost" CPA resource kits tailored for Sierra Leonean schools.

Explore the impact of CPA training on preservice teachers within teacher training colleges in Sierra Leone.

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