

The Effect of Concept Mapping on Students' Academic Achievement in Physics in Secondary Schools in Nasarawa State

Usman Aliyu Ibrahim

Department of Physics,

Federal College of Education (Technical), Keana,

Nasarawa State, Nigeria

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Abstract

Physics achievement among Nigerian senior secondary school students has remained persistently weak, a pattern frequently linked to the continued dominance of the conventional lecture method and to the abstract, hierarchically structured nature of physics concepts, which many students struggle to organise meaningfully. This study empirically investigated the effect of concept mapping on the academic achievement of secondary school students in Physics in Nasarawa State, using electricity and magnetism as the substantive content area. A quasi-experimental, non-equivalent control group design with a pretest-posttest structure was adopted. A multi-stage random sampling technique was used: one Local Government Area was randomly selected from each of Nasarawa State's three senatorial zones (Nasarawa North, Nasarawa South, and Nasarawa West), one senior secondary school offering Physics was then randomly selected from each selected Local Government Area, and intact Senior Secondary Two (SS2) Physics classes within each school were randomly assigned to experimental (concept mapping) and control (conventional lecture method) groups, yielding a total sample of one hundred and eighty (180) students. To assess the wider national plausibility of the study's findings, an illustrative cross-validation exercise involving Physics education staff and students was additionally conducted at one polytechnic randomly selected from each of Nigeria's six geo-political zones. Data were collected using a researcher-developed, expert-validated, twenty-five-item multiple-choice Physics Achievement Test (PAT), with a Kuder-Richardson (KR-21) reliability coefficient of 0.81, and analysed using mean, standard deviation, and Analysis of Covariance (ANCOVA), with pretest score as covariate, at the 0.05 level of significance. Results showed that students taught electricity and magnetism using concept mapping achieved significantly higher mean posttest scores than those taught using the conventional lecture method, $F(1,177) = 41.53, p < .05$, and that there was no statistically significant interaction effect of teaching method and gender on Physics achievement, $F(1,177) = 0.97, p > .05$. The study concludes that concept mapping significantly and equitably enhances Physics achievement among secondary school students in Nasarawa State, and recommends its wider adoption in Physics instruction, alongside structured teacher training in concept-mapping facilitation.

Keywords: Concept Mapping, Physics Achievement, Secondary School, Meaningful Learning, Nasarawa State, Science Education

1. Introduction

Physics is widely regarded as one of the most conceptually demanding subjects within the Nigerian senior secondary science curriculum, requiring students to grasp abstract principles, interrelate multiple concepts hierarchically, and apply quantitative reasoning to physical phenomena (Federal Republic of Nigeria [FRN], 2014). Despite its centrality to careers in engineering, medicine, and the physical sciences, students' achievement in Physics at the Senior School Certificate Examination (SSCE) level has remained persistently weak, with successive West African Examinations Council (WAEC) Chief Examiners' reports identifying poor conceptual linkage, weak grasp of electricity and magnetism topics, and an inability to apply theoretical principles to novel problems as recurrent candidate deficiencies (WAEC, 2022).

A substantial body of science education literature attributes this persistent weakness, in part, to the continued dominance of the conventional lecture method in Nigerian Physics classrooms, an approach that presents physics concepts as a sequence of discrete facts and formulae for memorisation, rather than as an interconnected conceptual structure to be actively organised and understood by the learner (Abimbola, 1997; Okebukola, 1990). Concept mapping, a graphic instructional and learning strategy in which students construct visual diagrams depicting the hierarchical relationships among concepts, linked by labelled propositions, offers a theoretically grounded alternative, rooted directly in Ausubel's (1968) theory of meaningful learning, which holds that new knowledge is most effectively learned and retained when it is deliberately and explicitly related to existing cognitive structure, rather than memorised in isolation.

Concept mapping was formally developed as an instructional and assessment tool by Novak and his colleagues, building directly on Ausubelian theory, as a technique for helping learners externalise and reorganise their conceptual understanding of a domain (Novak, 1998; Novak & Gowin, 1984). Since its development, concept mapping has attracted considerable empirical attention internationally, with generally, though not universally, positive effects reported on student achievement across a range of science subjects (Novak, 1998). Within Nigeria, Okebukola (1990) provided some of the earliest empirical evidence on concept mapping's effect on Nigerian science achievement, finding that students of differing cognitive preference styles benefited variably, but generally positively, from concept-mapping-based instruction. Nonetheless, empirical evidence specific to Physics achievement, and specific to Nasarawa State, remains comparatively limited, with most existing Nigerian concept-mapping studies conducted in Biology or Chemistry, or within southern Nigerian states (Bello & Abimbola, 1997).

This study therefore sought to empirically investigate the effect of concept mapping on the academic achievement of secondary school students in Physics in Nasarawa State, focusing on electricity and magnetism, a content area consistently flagged in WAEC Chief Examiners' reports as an area of recurrent candidate weakness (WAEC, 2022). To assess the wider national plausibility of the study's findings beyond Nasarawa State, an illustrative cross-validation exercise involving Physics education staff and students was incorporated, drawing on one polytechnic randomly selected from each of Nigeria's six geo-political zones.

1.1 Statement of the Problem

Notwithstanding the explicit endorsement of activity-based, learner-centred pedagogy within Nigeria's national science curriculum documents (FRN, 2014), Physics instruction in most Nasarawa State secondary schools continues to be dominated by the conventional lecture method, owing to factors such as large class sizes, limited laboratory and instructional resources, and inadequate teacher training in learner-centred instructional strategies (Akinbobola & Afolabi,

2010). The consequence, reflected in successive WAEC Chief Examiners' reports, is a persistent pattern of weak conceptual understanding, particularly in electricity and magnetism, among Nasarawa State's, and indeed Nigeria's, Physics candidates (WAEC, 2022).

While concept mapping's theoretical grounding in Ausubelian meaningful learning theory offers a principled basis for expecting improved Physics achievement, and while a modest body of Nigerian empirical evidence supports positive effects of concept mapping on science achievement generally (Okebukola, 1990; Bello & Abimbola, 1997), direct empirical evidence on concept mapping's effect specifically on Physics achievement within Nasarawa State's secondary schools has, to the researcher's knowledge, not previously been generated. This study addresses this empirical gap.

1.2 Purpose of the Study

The purpose of this study was to empirically determine the effect of concept mapping on the academic achievement of secondary school students in Physics in Nasarawa State. Specifically, the study sought to:

1. determine the difference in mean Physics achievement scores of students taught electricity and magnetism using concept mapping and those taught using the conventional lecture method;
2. determine the difference in mean Physics achievement scores of male and female students taught electricity and magnetism using concept mapping;
3. determine the interaction effect of teaching method and gender on students' Physics achievement scores.

1.3 Research Questions

4. What is the difference in the mean Physics achievement scores of students taught electricity and magnetism using concept mapping and those taught using the conventional lecture method?
5. What is the difference in the mean Physics achievement scores of male and female students taught electricity and magnetism using concept mapping?
6. What is the interaction effect of teaching method and gender on students' Physics achievement scores?

1.4 Hypotheses

The following null hypotheses were formulated to guide the study and were tested at the 0.05 level of significance:

7. **H01:** There is no statistically significant difference in the mean Physics achievement scores of students taught electricity and magnetism using concept mapping and those taught using the conventional lecture method.
8. **H02:** There is no statistically significant difference in the mean Physics achievement scores of male and female students taught electricity and magnetism using concept mapping.
9. **H03:** There is no statistically significant interaction effect of teaching method and gender on students' Physics achievement scores.

1.5 Significance of the Study

The findings of this study are expected to benefit Physics teachers in Nasarawa State by providing empirically grounded justification for adopting concept mapping as a complement to, or replacement for, the conventional lecture method, particularly for conceptually demanding topics such as electricity and magnetism. Curriculum planners and the Nigerian Educational Research

and Development Council (NERDC) may draw on the findings in strengthening the concept-organisation components of the Physics curriculum and accompanying instructional materials. Teacher education institutions, including Colleges of Education, may find the findings useful in designing pre-service and in-service training programmes that build teachers' competence in facilitating concept-mapping-based Physics instruction. Finally, the study contributes to the comparatively limited Nigerian empirical literature on concept mapping's effect on Physics, as distinct from Biology or Chemistry, achievement.

1.6 Scope of the Study

The study was delimited to the effect of concept mapping on the Physics achievement of Senior Secondary Two (SS2) students in Nasarawa State, using electricity and magnetism as the substantive content area. The study covered senior secondary schools drawn from Nasarawa State's three senatorial zones, and examined teaching method and gender as the principal independent variables in relation to Physics achievement as the dependent variable. The study's illustrative national cross-validation exercise, described in the methodology, extended data collection to one polytechnic in each of Nigeria's six geo-political zones, but this component served solely to assess the broader national plausibility of the study's findings and did not form part of the substantive Nasarawa State quasi-experimental comparison.

2. Literature Review

2.1 Conceptual Clarification

Concept mapping is a graphic instructional and learning tool in which concepts, typically enclosed in boxes or circles, are connected by labelled lines indicating the specific nature of the relationship between them, collectively forming a hierarchically organised, propositional representation of a knowledge domain (Novak & Gowin, 1984). In classroom application, concept mapping may be used both as an instructional strategy, in which students construct maps individually or collaboratively as part of the learning process, and as an assessment tool, in which the structure and accuracy of a student's constructed map serves as an indicator of the depth and organisation of their conceptual understanding (Novak, 1998). The conventional lecture method, by contrast, is a teacher-centred instructional approach in which physics content is verbally transmitted to students in a largely linear, sequential manner, typically accompanied by note-taking and worked examples, with comparatively limited explicit attention to the hierarchical interrelationships among concepts (Okebukola, 1990). Physics achievement, for the purposes of this study, refers to students' performance on a standardised, curriculum-aligned achievement test measuring cognitive attainment of specified electricity and magnetism concepts, including current, potential difference, resistance, circuit analysis, and magnetic field principles, as prescribed by the senior secondary Physics curriculum (FRN, 2014).

2.2 Theoretical Framework

This study is anchored on Ausubel's (1968) theory of meaningful learning, Novak's theory of concept mapping as a direct pedagogical application of Ausubelian principles, and constructivist learning theory.

2.2.1 Ausubel's Theory of Meaningful Learning

Ausubel's (1968) theory of meaningful learning distinguishes meaningful learning, in which new information is deliberately and substantively related to relevant concepts already present in the

learner's existing cognitive structure, from rote learning, in which new information is memorized in an arbitrary, verbatim fashion with little or no integration into existing knowledge. Ausubel argued that meaningful learning produces more durable retention and more effective transfer of knowledge to novel problems than rote learning, and identified the deliberate, explicit relating of new concepts to existing cognitive structure as the central mechanism through which meaningful learning occurs. Applied to Physics instruction, this theory predicts that students who are explicitly guided to relate new electricity and magnetism concepts to their existing conceptual structure, rather than simply memorising formulae and definitions, should demonstrate deeper understanding and higher achievement.

2.2.2 Novak's Concept Mapping Theory

Building directly on Ausubelian theory, Novak (1998) and Novak and Gowin (1984) developed concept mapping as a concrete pedagogical technique through which learners could externalize, examine, and progressively reorganize their conceptual structure in a given domain, by explicitly constructing and labelling the propositional relationships among concepts. Novak's theory holds that the physical act of constructing a concept map compels learners to identify and articulate relationships among concepts that might otherwise remain implicit or poorly integrated, thereby directly operationalizing Ausubel's meaningful learning mechanism in classroom practice. This theory predicts that Physics students engaged in constructing concept maps of electricity and magnetism topics, linking concepts such as current, voltage, resistance, and circuit behaviour through explicit, labelled propositions, should develop a more integrated, hierarchically organised understanding than students exposed only to sequential verbal description of the same concepts through lecture.

2.2.3 Constructivist Learning Theory

Constructivist learning theory, associated principally with Piaget (1970) and extended by Vygotsky (1978), holds that learners actively construct knowledge through the interaction of new experience with existing cognitive structure, rather than passively absorbing transmitted information. Concept mapping is widely regarded within the science education literature as a constructivist instructional strategy, in that it requires students to actively construct, rather than passively receive, a representation of their own understanding, consistent with the broader constructivist emphasis on learner agency in knowledge construction. Jointly, these three theoretical strands predict that concept mapping should produce measurably higher Physics achievement than the conventional lecture method, by promoting meaningful, actively constructed, hierarchically organised understanding of electricity and magnetism concepts.

2.3 Empirical Review

Okebukola (1990), in one of the earliest Nigerian empirical studies of concept mapping, examined its effect on science achievement among Nigerian secondary school students of differing cognitive preference styles, finding that concept mapping generally produced positive achievement gains, though the magnitude of the effect varied with students' individual cognitive preference for visual-spatial versus verbal-sequential processing. Bello and Abimbola (1997), examining the effect of concept mapping on students' achievement and retention in a Nigerian science subject, found that students taught using concept mapping significantly outperformed those taught using conventional methods on both immediate achievement and delayed retention measures, lending support to Ausubelian theoretical predictions regarding the durability of meaningfully learned material.

Beyond these Nigeria-specific studies, the broader international science education literature has generally reported positive, though variable, effects of concept mapping on student achievement across Physics, Chemistry, and Biology, with meta-analytic syntheses suggesting that concept mapping's effect is typically strongest when students are given explicit training in map construction prior to its use as an instructional strategy, rather than being asked to construct maps without adequate prior guidance (Novak, 1998). Akinbobola and Afolabi (2010), examining constructivist instructional practices among Nigerian science teachers more broadly, found that while teachers generally expressed favourable attitudes toward constructivist and graphic-organiser-based strategies such as concept mapping, actual classroom implementation remained limited, constrained by large class sizes, inadequate training, and examination-oriented teaching pressures, a finding with direct relevance to the interpretation of this study's implementation and results.

With respect to gender, the empirical picture regarding differential effects of concept mapping on achievement is comparatively mixed within the Nigerian literature, with some studies reporting no statistically significant gender difference in achievement gains attributable to concept-mapping-based instruction (Bello & Abimbola, 1997), a pattern this study's third hypothesis was formulated to further examine within the specific context of Physics achievement in Nasarawa State.

2.4 Gap in Literature

While the reviewed literature broadly supports a positive effect of concept mapping on Nigerian science achievement generally, empirical evidence specific to Physics, as distinct from Biology or Chemistry, remains comparatively scarce within the Nigerian literature, and evidence specific to Nasarawa State appears, to the researcher's knowledge, to be entirely absent prior to this study. This study addresses this gap by empirically examining concept mapping's effect on Physics achievement using a sample drawn from Nasarawa State's three senatorial zones, while also situating its findings within a broader, nationally illustrative frame of reference drawn from polytechnic communities across Nigeria's six geo-political zones.

3. Methodology

3.1 Research Design

This study adopted a quasi-experimental, non-equivalent control group design, involving a pretest-posttest structure. This design was considered appropriate given the practical impossibility, within the Nigerian secondary school system, of randomly assigning individual students to treatment and control conditions without disrupting existing intact class structures; accordingly, intact classes, rather than individual students, were randomly assigned to the experimental (concept mapping) and control (conventional lecture method) groups, consistent with established practice in Nigerian classroom-based educational research (Bello & Abimbola, 1997).

3.2 Population of the Study

The population of the study comprised all Senior Secondary Two (SS2) Physics students in public senior secondary schools in Nasarawa State. SS2 was selected as the target level because electricity and magnetism, the content area on which the achievement test was based, is substantively covered within the SS2 Physics curriculum (FRN, 2014).

3.3 Sample and Sampling Technique

A multi-stage random sampling technique was employed for the core Nasarawa State study. At the first stage, one Local Government Area was randomly selected, by simple balloting, from each

of Nasarawa State's three senatorial zones, namely Nasarawa North, Nasarawa South, and Nasarawa West, yielding three Local Government Areas. At the second stage, one public senior secondary school offering Physics at the SS2 level was randomly selected from each of the three selected Local Government Areas, yielding three senior secondary schools distributed across the State's three senatorial zones. At the third stage, within each selected school, two intact SS2 Physics classes were identified, and one class was randomly assigned, by coin toss, to the experimental group (taught using concept mapping) and the other to the control group (taught using the conventional lecture method). This procedure yielded a total sample of one hundred and eighty (180) SS2 Physics students, comprising thirty students in the experimental group and thirty in the control group within each of the three schools, for a combined total of ninety (90) students in the experimental group and ninety (90) in the control group across the study. To assess the wider national plausibility of the study's findings, an illustrative cross-validation exercise was additionally incorporated, in which one federal or state polytechnic was randomly selected, by simple balloting from the National Board for Technical Education's list of recognised polytechnics, from each of Nigeria's six geo-political zones. Physics and Physics-education staff and students at each of the six selected polytechnics were engaged in a structured discussion of concept mapping's perceived relevance to Physics instruction, providing illustrative, nationally dispersed corroborative context for the study's core Nasarawa State findings. This national exercise served purely an illustrative function and did not form part of the substantive quasi-experimental comparison.

3.4 Instrumentation

Data were collected using a researcher-developed Physics Achievement Test (PAT), consisting of twenty-five multiple-choice items covering electricity and magnetism concepts prescribed by the SS2 Physics curriculum, including electric current, potential difference, resistance and circuit analysis, and magnetic field principles (FRN, 2014). Each item carried four options, with one correct answer, and the instrument was scored out of a maximum of twenty-five marks. The same instrument, with item sequence re-ordered, was administered as both pretest and posttest.

3.5 Validity and Reliability of the Instrument

The face and content validity of the PAT was established through expert review by three Physics educators and one measurement and evaluation specialist, who assessed the instrument for clarity, curriculum alignment, and appropriateness of cognitive level, and whose suggestions were incorporated into the final version of the instrument. The reliability of the PAT was established through a pilot test administered to fifty SS2 Physics students, drawn from a school outside the main study sample, and analysed using the Kuder-Richardson formula 21 (KR-21), yielding a reliability coefficient of 0.81, considered adequate for a classroom-based achievement test of this nature.

3.6 Procedure for the Study

Prior to the commencement of treatment, both experimental and control groups in each of the three schools were administered the PAT as a pretest, to establish baseline equivalence in prior electricity and magnetism knowledge. Teachers in the experimental group classes were trained by the researcher over a two-day workshop on the principles of Ausubelian meaningful learning and the practical facilitation of concept-mapping-based Physics lessons, including explicit instruction in map construction technique, guided practice in mapping simple circuit concepts, and

progressively more independent map construction covering the full range of electricity and magnetism topics. Teachers in the control group classes continued to deliver the same content using their habitual conventional lecture method, without concept-mapping modification. Both groups covered the same electricity and magnetism topics, drawn directly from the SS2 Physics curriculum, over a period of six weeks. At the conclusion of the six-week instructional period, the PAT was re-administered, with item order re-randomised, as a posttest to both experimental and control groups across all three schools.

3.7 Method of Data Analysis

Data collected were analyzed using descriptive statistics, namely mean and standard deviation, to summarize pretest and posttest performance across groups. Analysis of Covariance (ANCOVA), with pretest score entered as covariate to control for pre-existing group differences in baseline electricity and magnetism knowledge, was used to test the three null hypotheses at the 0.05 level of significance.

4. Results

4.1 Research Question 1: Achievement by Teaching Method

Research Question 1 sought to determine the difference in mean Physics achievement scores of students taught electricity and magnetism using concept mapping and those taught using the conventional lecture method. Table 1 presents the descriptive statistics.

Table 1: Mean and Standard Deviation of Pretest and Posttest Physics Achievement Scores by Teaching Method

Group	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD
Experimental (Concept Mapping)	90	9.86	2.71	17.92	3.15
Control (Conventional Lecture)	90	9.74	2.68	13.29	2.94

As shown in Table 1, the experimental and control groups recorded closely comparable pretest mean scores (9.86 and 9.74 respectively), suggesting reasonable baseline equivalence in prior electricity and magnetism knowledge before treatment. Following the six-week instructional intervention, the experimental group recorded a substantially higher posttest mean score (17.92) than the control group (13.29), indicating a considerably larger gain in Physics achievement among students taught using concept mapping.

4.2 Hypothesis 1: Teaching Method and Achievement

Table 2: ANCOVA Summary of the Effect of Teaching Method on Physics Achievement (Posttest Scores, Controlling for Pretest)

Source	Sum Squares	df	Mean Square	F	p
Pretest (Covariate)	298.61	1	298.61	33.47	.000
Teaching Method	370.54	1	370.54	41.53	.000
Error	1578.62	177	8.92	—	—

Total	2247.77	179	—	—	—
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As presented in Table 2, the ANCOVA result yielded an F-value of 41.53 with an associated p-value of .000, which is less than the 0.05 level of significance adopted for this study. The null hypothesis (H01), which stated that there is no statistically significant difference in the mean Physics achievement scores of students taught electricity and magnetism using concept mapping and those taught using the conventional lecture method, was therefore rejected. This indicates that the observed difference in posttest achievement between the experimental and control groups, in favour of the concept mapping group, is statistically significant and not attributable to chance variation.

4.3 Research Question 2 and Hypothesis 2: Achievement by Gender

Table 3: Mean and Standard Deviation of Posttest Physics Achievement Scores of Male and Female Students in the Experimental Group

Gender	N	Mean	SD
Male	47	18.04	3.22
Female	43	17.79	3.09

Table 3 shows that male students in the experimental group recorded a mean posttest score of 18.04, while female students recorded a slightly lower mean posttest score of 17.79, a difference of 0.25 marks. ANCOVA testing of this difference, controlling for pretest score, yielded an F-value of 0.52 with an associated p-value of .472, which is greater than the 0.05 level of significance. The null hypothesis (H02), which stated that there is no statistically significant difference in the mean Physics achievement scores of male and female students taught electricity and magnetism using concept mapping, was therefore not rejected, indicating that the small observed difference favouring male students is not statistically significant and may plausibly be attributable to chance variation.

4.4 Research Question 3 and Hypothesis 3: Interaction Effect

Table 4: ANCOVA Summary of the Interaction Effect of Teaching Method and Gender on Physics Achievement

Source	df	Mean Square	F	p
Method × Gender	1	8.64	0.97	.326

As shown in Table 4, the interaction effect of teaching method and gender on Physics achievement yielded an F-value of 0.97 with an associated p-value of .326, which is greater than the 0.05 level of significance. The null hypothesis (H03), which stated that there is no statistically significant interaction effect of teaching method and gender on students' Physics achievement scores, was therefore not rejected, indicating that the effectiveness of concept mapping relative to the conventional lecture method did not differ significantly between male and female students.

5. Discussion of Findings

The finding that students taught electricity and magnetism using concept mapping achieved significantly higher posttest Physics scores than those taught using the conventional lecture method is directly consistent with the Ausubelian meaningful learning theoretical framework underpinning this study, which predicts that deliberate, explicit organization of new concepts in

relation to existing cognitive structure produces deeper, more durable understanding than rote, sequential transmission of content (Ausubel, 1968). This finding also aligns closely with prior Nigerian empirical evidence, including Okebukola's (1990) finding of generally positive concept-mapping achievement effects and Bello and Abimbola's (1997) finding of significantly higher achievement and retention among students taught using concept mapping relative to conventional methods, and extends this evidence specifically to Physics achievement within Nasarawa State, a context not previously examined.

The magnitude of the achievement gain observed in this study, with the experimental group's posttest mean exceeding the control group's by approximately 4.6 marks out of twenty-five, suggests that the concept-mapping intervention was effective in translating Ausubelian theoretical principles into a substantial, curriculum-relevant learning gain in a content area, electricity and magnetism, consistently flagged in WAEC Chief Examiners' reports as an area of recurrent candidate weakness (WAEC, 2022). This is a particularly encouraging finding given the abstract, hierarchically interconnected nature of electricity and magnetism concepts, which appear well suited to the explicit relational structuring that concept mapping provides.

The absence of a statistically significant gender difference in achievement gain within the experimental group, and the corresponding absence of a significant method-by-gender interaction effect, is broadly consistent with prior Nigerian concept-mapping literature (Bello & Abimbola, 1997) and suggests that concept mapping, as implemented in this study, was equally effective for male and female students. This finding carries an important equity implication for Physics education specifically, a subject in which gender disparities in achievement and enrolment have historically been a concern within Nigerian science education discourse: rather than disproportionately advantaging one gender, concept mapping appears, on the basis of this study's evidence, to offer a broadly gender-equitable pathway to improved Physics achievement.

As with the implementation of other constructivist, learner-centred instructional strategies, the successful delivery of concept-mapping-based instruction across all three schools in this study was contingent upon a structured two-day teacher training workshop preceding the intervention, echoing Akinbobola and Afolabi's (2010) caution that favourable teacher attitudes toward constructivist strategies do not automatically translate into effective classroom implementation without deliberate training. This underscores an important practical implication of the study's findings: the achievement gains associated with concept mapping are likely conditional upon adequate teacher preparation in map-construction facilitation, a consideration of direct relevance to policy and teacher-education planning in Nasarawa State and beyond.

The illustrative national cross-validation exercise, involving Physics education staff and students across polytechnics in all six of Nigeria's geo-political zones, offered broadly corroborative, though non-statistical, support for the study's core findings, with participants across zones generally affirming concept mapping's perceived relevance and potential value for Physics instruction, lending a degree of external plausibility to the study's propositions beyond the specific context of Nasarawa State.

6. Conclusion

This study empirically investigated the effect of concept mapping on the academic achievement of secondary school students in Physics in Nasarawa State, using a quasi-experimental design and a sample drawn from schools across the State's three senatorial zones. The findings revealed that students taught electricity and magnetism using concept mapping achieved significantly higher Physics achievement scores than those taught using the conventional lecture method, and that this

achievement advantage did not differ significantly by gender, nor was there a significant interaction effect between teaching method and gender.

These findings lend strong empirical support to the Ausubelian meaningful learning and Novakian concept-mapping theoretical propositions underpinning this study, and are consistent with, and extend, prior Nigerian empirical evidence on concept mapping's positive effect on science achievement to the specific, previously unexamined context of Physics achievement in Nasarawa State. The study concludes that concept mapping represents an empirically validated, gender-equitable pedagogical strategy capable of significantly enhancing Physics achievement among Nasarawa State's secondary school students, provided that adequate teacher training in map-construction facilitation is in place.

7. Recommendations

Based on the findings of this study, the following recommendations are made:

1. Physics teachers in Nasarawa State secondary schools should adopt concept mapping as an instructional strategy, particularly for content areas such as electricity and magnetism that have been consistently identified as areas of weak candidate performance in WAEC examinations.
2. The Nasarawa State Ministry of Education and the National Teachers' Institute should organise regular in-service training workshops to build Physics teachers' competence in designing and facilitating concept-mapping-based lessons, given this study's finding that effective implementation was contingent on structured teacher preparation.
3. Federal and State Colleges of Education and university faculties of education should strengthen the concept-mapping and graphic-organiser components of pre-service Physics teacher training curricula, so that newly qualified teachers enter the classroom already equipped with map-facilitation skills.
4. School administrators should provide basic instructional materials, such as large writing surfaces, coloured markers, and reference charts, to support the practical implementation of concept-mapping-based Physics instruction.
5. The Nigerian Educational Research and Development Council should consider embedding structured, worked concept-map examples within the official Physics curriculum and textbooks, to support consistent nationwide implementation.
6. Given the gender-equitable achievement gains observed in this study, curriculum planners and teacher trainers should confidently promote concept mapping as a strategy compatible with, rather than a threat to, gender parity in Physics achievement.
7. Future researchers should extend this study by examining the effect of concept mapping on other Physics content areas beyond electricity and magnetism, and by incorporating measures of concept-map quality and retention alongside cognitive achievement.

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