SCIENCE EDUCATION

Effects of Concept Mapping and Guided Inquiry on Pre-Service Teachers' Achievement in Ecology in Selected Private Colleges of Education in Ogun State

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Abstract

Persistently low achievement in Ecology among pre-service Biology teachers has been linked to lecture-dominated instruction, yet few studies have tested learner-centred alternatives in Nigerian Colleges of Education. This study examined the effects of concept mapping and guided inquiry, relative to traditional lecture instruction, on first-year Biology Education students' achievement in Ecology. A pretest–post-test, non-equivalent control group quasi-experimental design was used. Through multistage sampling, three private Colleges of Education, one from each senatorial district of Ogun State, were selected, and one intact BIO 112 (Ecology) class per college was assigned to concept mapping (n = 44), guided inquiry (n = 40) or traditional instruction (n = 43). The treatments lasted four weeks and followed structured instructional guides. Achievement was measured with the Ecology Achievement Test (KR-20 = .76) and analysed with analysis of covariance, using pretest scores as the covariate. Instructional strategy had a significant effect on post-test achievement, $F(2, 123) = 174.34$, $p < .001$, partial $\eta^2 = .739$. Adjusted post-test means were 26.85 for guided inquiry, 26.22 for concept mapping and 18.17 for traditional instruction; the two learner-centred groups differed little from each other. Because each strategy was implemented in a different college, the results are best read as strong quasi-experimental evidence rather than proof of causation. The findings support integrating both strategies into Ecology instruction in teacher education.

Keywords: concept mapping; guided inquiry; Ecology; academic achievement; pre-service Biology teachers; Colleges of Education

1 Introduction

Ecology is a core branch of Biology concerned with the interactions among organisms and between organisms and their physical environment. Its concepts, which include energy flow, nutrient cycling, population dynamics and ecosystem interdependence, underpin conservation, environmental management and education for sustainable development (Babalola and Olawuyi, 2021). For prospective teachers in Nigeria's Colleges of Education, Ecology (BIO 112) is a foundational first-year course, and how they learn it matters twice: they must master the content for themselves, and they will later teach it to secondary school pupils.

Ecology is also a demanding subject to learn. It requires students to hold several interacting ideas in mind at once and to think in networks and cycles rather than straight lines, and learners commonly carry alternative conceptions about ecosystems into the classroom (Yeo et al., 2022). Reviews of Ecology education point to continuing challenges in how the subject is taught and learned (Cooke et al., 2021; Nwachukwu et al., 2024), and work in Nigerian Colleges of Education has linked weak achievement in Ecology to instructional approaches that leave students as passive recipients of notes (Emeka

and Yusuf, 2021). Large classes and limited laboratory resources make lecturing the path of least resistance, even though it often encourages rote memorisation over conceptual understanding.

Concept mapping and guided inquiry are two learner-centred strategies that suit the structure of Ecology. Concept mapping asks students to organise concepts hierarchically and connect them with labelled links, which makes relationships such as those among producers, consumers and decomposers explicit. Guided inquiry gives students a problem and data and supports them, through questions and scaffolding, as they reason their way to the underlying principle. Both can be implemented with modest materials, which matters in resource-constrained colleges.

Most of the supporting evidence, however, comes from secondary schools. Studies in tertiary teacher-education settings are scarce, those that exist have usually addressed topics other than Ecology (for example et al., 2025, on Cell Biology), and few compare the two strategies with traditional instruction in a single design. This study addresses that gap. It reports one objective of a larger investigation: to determine the effect of instructional strategy (concept mapping, guided inquiry or traditional teaching) on first-year Biology Education students' achievement in Ecology in private Colleges of Education in Ogun State. The null hypothesis tested was that there is no significant main effect of instructional strategy on students' achievement in Ecology.

2 Theoretical framework and literature review

2.1 Theoretical framework

Two complementary frameworks guided the study. Ausubel's (1968) theory of meaningful learning holds that the most important influence on learning is what the learner already knows, and that new material is learned meaningfully when it is deliberately related to relevant concepts in the learner's cognitive structure rather than memorised arbitrarily. Concept maps, developed by Novak and Gowin (1984) from this theory, externalise that structure: general concepts sit above more specific ones, and labelled links form propositions that can be inspected and revised. Ecology, with its nested levels of organisation and its food chains, webs and cycles, is a natural candidate for this kind of representation.

Constructivist theory supplies the rationale for guided inquiry. Learners are viewed as active builders of understanding who interpret new experience through existing ideas, and social interaction and expert support are central to that process (Vygotsky, 1978). In guided inquiry the lecturer frames the question and supplies data or materials, then withdraws support gradually as students reason toward an explanation, a form of scaffolding described by Wood et al. (1976). Together, the two frameworks predict that strategies that make students organise, connect and investigate ecological ideas should yield higher achievement than strategies that transmit them.

2.2 Empirical literature

Evidence for concept mapping is substantial. A meta-analysis of concept-map interventions in science education found a positive overall effect on student achievement (Anastasiou et al., 2024), and concept mapping has also been associated with higher motivation and achievement (Almulla and Alamri, 2021). In Nigerian secondary schools, Ahmed et al. (2021) reported that concept mapping improved Biology achievement and retention in Lagos State without a gender difference, and Ugwoke and Ude (2022) found that Enugu students taught Biology with concept mapping outperformed those taught by lecture. Closer to the present topic et al. (2023) reported significant achievement

differences when concept maps were used to teach ecological concepts to 267 senior secondary students in Ogbomoso, and Ogundare et al. (2020) found that concept mapping remediated about 62% of the Ecology misconceptions held by 114 senior secondary students. At the tertiary level et al. (2025) studied 240 first-year Biology students in Federal Colleges of Education in southwest Nigeria and found that concept mapping significantly improved Cell Biology achievement.

Inquiry-based approaches show a similar pattern. Dogo (2017) found that Biology students taught through inquiry-based instruction in Jigawa State achieved and retained more than a control group, and Mwenda and Ndayambaje (2021) reported higher Biology achievement among Tanzanian students taught through inquiry than among conventionally taught peers. At the undergraduate level, Shittu et al. (2023) found that inquiry outperformed lecture among Biology students in Zaria, and Tamari and Ho (2019) reported that guided inquiry-based activities improved learning in community college courses. Chengere et al. (2025) showed that guided inquiry-based laboratory activities strengthened secondary students' science process skills in Biology.

Two limitations of this literature motivate the present study. First, the evidence on Ecology specifically, and on pre-service teachers, is thin: the Ecology studies cited above were conducted with secondary school students. Second, concept mapping and guided inquiry are usually evaluated separately, each against a lecture control, so little is known about how they perform side by side with the same students, topic and test.

3 Methodology

3.1 Research design

A pretest–posttest, non-equivalent control group quasi-experimental design with three groups was used: two experimental groups (concept mapping and guided inquiry) and one control group (traditional lecture). Instructional strategy was the independent variable and achievement in Ecology the dependent variable. Intact classes were used to avoid disrupting the colleges' timetables.

3.2 Population, sampling and participants

The population comprised all first-year Biology Education students offering BIO 112 (Ecology) in the six private Colleges of Education in Ogun State during the 2025/2026 session (N = 1,184), distributed across the three senatorial districts. A multistage procedure was used. First, colleges were stratified by senatorial district. Ogun East has only one such college, which was included automatically; one college each was then drawn from Ogun Central and Ogun West by balloting. Second, one intact BIO 112 class was taken from each of the three selected colleges. Third, the three classes were allocated to the treatment conditions by balloting. This yielded N = 127 participants (59 male, 68 female): 44 in the concept mapping group (Ogun Central), 40 in the guided inquiry group (Ogun East) and 43 in the traditional teaching group (Ogun West; Table 1). Each condition was therefore delivered in a different college, a feature that bears on interpretation and is taken up in the Discussion.

Table 1. Distribution of participants by instructional strategy and gender.

Instructional strategy	Male	Female	Total
Concept mapping	20	24	44
Guided inquiry	19	21	40

Instructional strategy	Male	Female	Total
Traditional teaching	20	23	43
Total	**59**	**68**	**127**

Note. Each strategy was delivered to one intact class in a separate private College of Education.

3.3 Instruments

The main instrument was the Ecology Achievement Test (EAT), a multiple-choice test with four options per item and allocated score of one mark per correct answer. Items were drawn from BIO 112 and covered three content areas: ecosystem components and interactions, energy flow and nutrient cycling, and population ecology and adaptation, distributed across the knowledge, comprehension and application levels of Bloom's taxonomy through a table of specifications. The supervisor and two lecturers in the Department of Science and Technology Education, Lead City University, judged face, content and construct validity, and their comments were incorporated. Internal consistency was established by administering the test to a separate group from the same population in a private College of Education not included in the main study; the Kuder–Richardson Formula 20 coefficient was .76. Three instructional guides (concept mapping, guided inquiry and traditional teaching) standardised the lessons. Each specified objectives, materials, duration and teacher and student activities. In the sample lesson on energy flow, concept mapping students built labelled maps linking producers, consumers and decomposers and critiqued one another's arrow directions; guided inquiry students analysed energy-value data across trophic levels, calculated the percentage lost at each step and answered guiding questions to deduce why energy declines; and the traditional group copied dictated notes and a board diagram and answered oral recall questions.

3.4 Procedure

In week one, the lecturers who served as research assistants were trained in the objectives of the study, the BIO 112 content and the use of the guides, and each taught a trial lesson under supervision. In week two the EAT was administered as a pretest to all groups. The treatment ran for four weeks (weeks three to six) with one lesson period per week in each college, so instructional time was equal across groups. Table 2 summarises the three instructional conditions. The researcher monitored sessions periodically to check adherence to the guides. In week seven the EAT was re-administered as a post-test with its items reshuffled to reduce recall effects.

Table 2. Summary of the three instructional conditions (sample lesson on energy flow).

Condition	Lecturer's role	Students' activity	Materials
Concept mapping	Presented the core concepts, organised students into groups, set the mapping task and critiqued the direction of arrows on the maps	Brainstormed, listed organisms by trophic role, drew nodes and labelled links hierarchically from producers to top predators, and presented maps to the class	Cardboard, markers, sticky notes, whiteboard, sample concept maps
Guided inquiry	Posed a problem, supplied data sheets, asked guiding questions and scaffolded without giving answers	Offered hypotheses, analysed energy data in pairs, calculated percentage differences between levels, deduced the cause of energy loss and predicted the effects of removing organisms	Data charts of energy values, worksheets with guiding questions

Condition	Lecturer's role	Students' activity	Materials
Traditional teaching	Dictated notes, drew and labelled a standard diagram, explained and asked oral questions	Listened, copied notes and the diagram, asked for clarification and answered oral recall questions	Chalkboard, textbook, lesson note

Note. Each lesson lasted 60 minutes and was delivered from the corresponding instructional guide.

3.5 Data analysis

Data were analysed with one-way analysis of covariance (ANCOVA), with posttest scores as the dependent variable, instructional strategy as the fixed factor and pretest scores as the covariate, at the .05 level of significance. Effect size is reported as partial η^2, interpreted against Cohen's (1988) benchmarks of .01 (small), .06 (medium) and .14 (large). Adjusted marginal means and 95% confidence intervals describe group performance after controlling for pretest.

4 Results

Table 3 presents the ANCOVA for the effect of instructional strategy on posttest achievement. After adjustment for the pretest, instructional strategy had a significant effect on achievement, $F(2, 123) = 174.34$, $p < .001$, partial $\eta^2 = .739$. By Cohen's benchmarks this is a very large effect: instructional strategy accounted for roughly three-quarters of the variance in adjusted posttest scores. The pretest covariate was not a significant predictor in the model, $F(1, 123) = 0.03$, $p = .859$. The null hypothesis of no main effect of instructional strategy was therefore rejected.

Table 3. Analysis of covariance for the effect of instructional strategy on posttest achievement in Ecology.

Source	SS	df	MS	F	p	Partial η^2
Pretest (covariate)	0.17	1	0.17	0.03	.859	.000
Instructional strategy	1895.07	2	947.54	174.34	< .001	.739
Error	668.52	123	5.44			
Corrected total	2665.02	126				

Note. Dependent variable: posttest score. $R^2 = .749$ (adjusted $R^2 = .743$).

Table 4 and Figure 1 show the adjusted means, evaluated at the grand pretest mean of 12.66. Students taught with guided inquiry obtained the highest adjusted posttest mean ($M = 26.85$, $SE = 0.37$), followed by those taught with concept mapping ($M = 26.22$, $SE = 0.35$), while the traditional teaching group scored far lower ($M = 18.17$, $SE = 0.36$). The adjusted advantage over traditional teaching was 8.67 points for guided inquiry and 8.05 points for concept mapping. The 95% confidence interval for the traditional group (17.46 to 18.89) did not overlap with the interval for either learner-centred group, whereas the intervals for concept mapping (25.52 to 26.92) and guided inquiry (26.12 to 27.58) overlapped. The 0.63-point difference between the two learner-centred strategies was therefore small relative to their shared advantage over traditional teaching.

Table 4. Adjusted posttest means in Ecology by instructional strategy.

Instructional strategy	N	Adjusted M	SE	95% CI
Concept mapping	44	26.22	0.35	[25.52, 26.92]

Instructional strategy	N	Adjusted M	SE	95% CI
Guided inquiry	40	26.85	0.37	[26.12, 27.58]
Traditional teaching	43	18.17	0.36	[17.46, 18.89]

Note. Means are evaluated at the grand pretest mean of 12.66. CI = confidence interval.

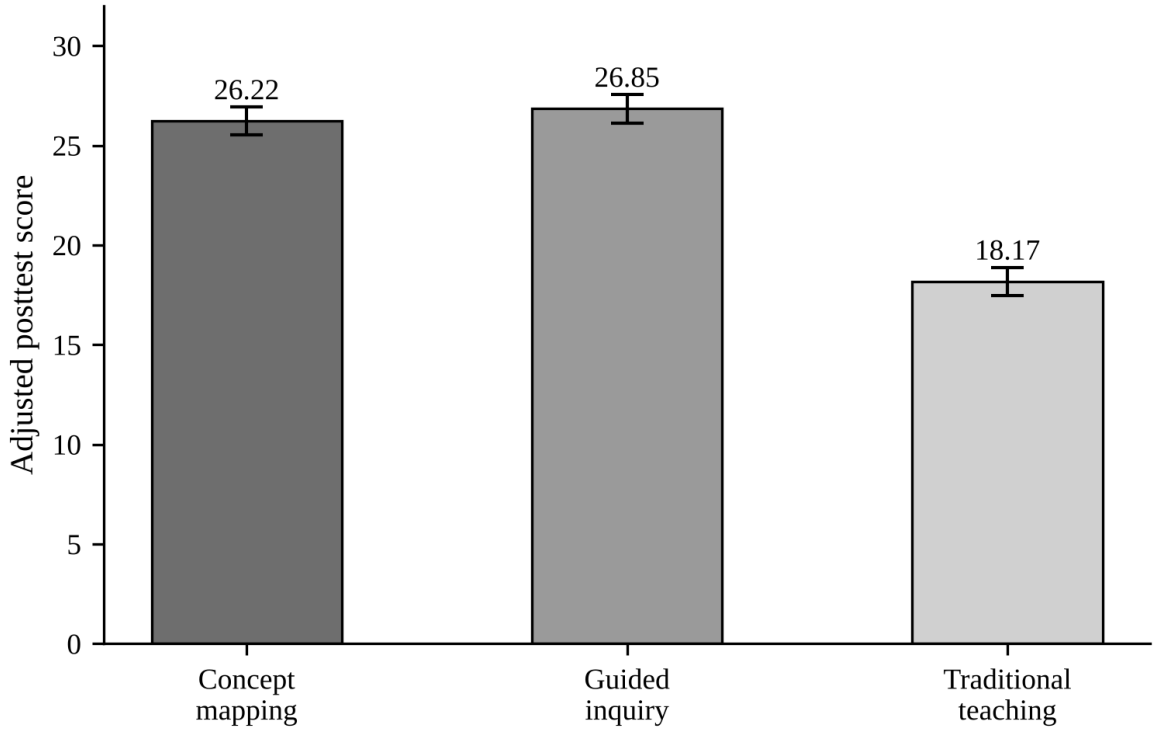

Figure 1. Adjusted posttest means in Ecology by instructional strategy. Error bars show 95% confidence intervals.

5 Discussion

5.1 Effect of instructional strategy on achievement

The central finding is that students taught Ecology with either concept mapping or guided inquiry achieved substantially more than students taught by traditional lecture, after controlling for prior achievement. This agrees with the wider literature on both strategies (Agada-Adeleye and Sam-Kayode, 2025; Ahmed et al., 2021; Anastasiou et al., 2024; Dogo, 2017; Shittu et al., 2023) and with the two earlier studies that applied concept maps specifically to Ecology (Akintola and Odewumi, 2023; Ogundare et al., 2020). It extends that work in two ways: the participants were pre-service teachers rather than secondary school pupils, and both strategies were tested against a lecture control within the same topic area, test and population.

The theoretical frameworks offer a plausible account of why. In the concept mapping lessons, students had to decide which concepts were more general, choose the words that linked them and defend the direction of each energy arrow. That work forces explicit connections among ecological ideas, which Ausubel's (1968) theory identifies as the mechanism of meaningful learning. In the guided inquiry lessons, students worked from energy data and guiding questions to deduce why energy declines along a food chain, a pattern consistent with the constructivist emphasis on reasoning from evidence with calibrated support (Vygotsky, 1978; Wood et al., 1976). In the

traditional lessons, by contrast, students copied the 10% rule and a food-chain diagram and recalled them orally. Students in that condition could reproduce the facts but had little occasion to relate them to one another, which is the kind of rote learning Ausubel contrasted with meaningful learning.

5.2 Relative effectiveness of the learner-centred strategies

Although guided inquiry produced the numerically highest adjusted mean, the gap between it and concept mapping was under one point, the confidence intervals overlapped, and the difference should not be read as evidence that one strategy is superior. A cautious reading is that both strategies are about equally effective in this setting. This is also consistent with the view that they work through different but complementary routes: concept mapping by organising knowledge, and guided inquiry by building it from evidence. Whether combining the two yields additional gains remain an open question.

5.3 Interpreting the effect size and limitations

The size of the effect calls for careful interpretation. A partial η^2 of .739 is considerably larger than the moderate-to-large effects usually reported in syntheses of concept mapping and inquiry research, and several features of the design could have inflated it. Most importantly, each strategy was delivered in a single intact class in a different college, so treatment is confounded with college and with the lecturer who taught it. Differences in student intake, classroom climate or lecturer skill between colleges cannot be separated from the effect of the strategy, and with only three clusters the effective sample is far smaller than 127. The intervention was brief (four lessons), and novelty effects and closer alignment between the activities and the test items in the experimental conditions are possible. Using the same test, reshuffled, for pretest and posttest may also have contributed. The conclusion that both strategies are associated with markedly higher Ecology achievement is well supported; the precise magnitude is not.

Other limitations should be noted. Achievement was measured with a single researcher-developed multiple-choice test, which captures recall, comprehension and application on selected topics but not students' scientific reasoning or practical skills. Only immediate posttest performance was measured, so the durability of the gains is unknown. Implementation fidelity was monitored through periodic observation rather than systematically scored, so differences in how faithfully each lecturer followed the guide cannot be ruled out. Finally, participants came from private Colleges of Education in one state, and the results may not transfer to public colleges, universities or other Biology topics.

5.4 Implications for teacher education

The findings nonetheless have practical implications for teacher education. Both strategies were implemented with inexpensive materials such as marker pens, cardboard, worksheets and printed data tables, and neither required laboratory facilities, which makes them realistic where classes are large and resources scarce. Because pre-service teachers tend to teach as they were taught, experiencing these strategies as learners may also prepare them to use them in secondary school classrooms. Colleges of Education should therefore consider building concept mapping and guided inquiry into Ecology courses, supported by professional development for lecturers on designing concept-mapping tasks and guiding questions, and teacher-education curriculum developers should make explicit room for learner-centred strategies in Biology courses.

6 Conclusion

In summary, first-year Biology Education students taught Ecology through concept mapping or guided inquiry achieved significantly higher adjusted posttest scores than those taught by traditional lecture, and the two learner-centred strategies performed similarly. Given the quasi-experimental design, with treatment delivered at the college level, the results offer strong but not definitive evidence of effectiveness. They support the adoption of both strategies in Ecology instruction in Colleges of Education and justify larger, more tightly controlled replications.

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