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Comparative Effect of Concept Mapping and 7E's Instructional Strategies on Critical Thinking Skills among Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria

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Abstract

The development of critical thinking is essential for effective science education, yet conventional teacher-centred approaches may provide limited opportunities for inquiry, reflection, and higher-order thinking. This study examined differences in the critical thinking skills of pre-service Biology teachers exposed to Concept Mapping, 7E's instructional, and Conventional Method instruction in selected tertiary institutions in Kebbi State, Nigeria. A quantitative pretest–posttest quasi-experimental design was adopted. The target population comprised 932 pre-service Biology teachers, while the accessible population consisted of 303 eligible 400-level students in the three participating institutions. All 303 students were included in the study and constituted the Concept Mapping (n=84), 7E's (n=140), and Conventional Method (n=79) groups. Data were collected using a 30-item Critical Thinking Skills Test. Content validity was assessed by five experts, yielding an average Content Validity Index (CVI) of 0.77, while test–retest reliability was reported as r=.83. Data were analysed using descriptive statistics, paired-samples t-tests, an independent-samples t-test, one-way analysis of variance (ANOVA), and Scheffe post-hoc analysis at α=.05. The Concept Mapping group increased from a pretest mean of 29.37 to a post-test mean of 39.49, while the 7E's group increased from 28.23 to 40.06. The difference between the Concept Mapping and 7E's groups was not statistically significant, t (222) =−0.511, p=.610. The three-group comparison was statistically significant p<.001, with both Concept Mapping and 7Es groups recording higher post-test means than the Conventional Method group. The findings suggest that Concept Mapping and 7Es instruction may provide useful alternatives to conventional instruction for supporting critical thinking among pre-service Biology teachers. Both strategies significantly outperformed the conventional method, supporting their adoption in Preservice Biology Teachers Education.

Keywords: 7E's instructional strategy, critical thinking skills, pre-service biology teachers, tertiary institutions

1 Introduction

Mathematics is regarded as the bedrock of science and technology. It plays a vital role in national development by equipping Critical thinking has consequently become an important educational goal because learners are expected to engage with information critically, evaluate competing explanations, and apply knowledge to unfamiliar situations. Changes in society, the workplace, and the demands of contemporary education have further increased the emphasis on learning environments that promote analysis, reflection, problem-solving, and meaningful engagement rather than the passive acquisition of information (Rasouli.,2023;Sukolova & Nedelova, 2017; Carlgren, 2013). Education systems are therefore increasingly expected to provide learners with opportunities to participate actively in learning and to develop skills that can be applied beyond the classroom. For university undergraduate students, critical thinking is particularly important because higher education is expected to prepare graduates to interpret information, evaluate evidence, solve complex problems, and make informed judgments. Erstad and Voogt (2017) emphasise the importance of developing competencies that enable learners to participate effectively in a changing knowledge society, while Elder and Paul (2020) highlight the role of critical thinking in evaluating claims, decisions, and social issues. In science education, these abilities are particularly relevant because scientific learning involves questioning explanations, interpreting evidence, examining relationships among concepts, and applying knowledge to solve problems.

A consensus definition of critical thinking has been proposed by a group of 46 experts in the American Philosophical Association (Hitchcock, 2018). They define critical thinking as ‘‘the process of self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criterion logical, and contextual considerations upon which that judgment is based’’(Tseng, 2020., Avinda.,et al. 2018).

Ennis (2011) outlines five indicators of critical thinking skills: elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. Critical thinking serves as the foundation for problem-solving, enabling students to analyze data, identify patterns, evaluate evidence, and devise solutions to scientific problems.

However, the development of critical thinking cannot be separated from the instructional environments in which students learn. Evidence from Nigerian higher education suggests that opportunities for developing critical-thinking skills remain constrained by instructional practices that emphasised factual knowledge, examination preparation, and lecturer-led classroom interaction. Aboluwodi (2015) argues that although General Studies courses such as Philosophy and Logic are intended to promote critical thinking, many students continue to rely on memorisation and demonstrate limited ability to apply reasoning to practical situations. In the same way, Bakare (2011) reported that lecture-based instruction was the dominant teaching approach among lecturers in Nigerian universities, with comparatively limited use of discussion, practical work, projects, and case studies. Such instructional patterns may restrict opportunities for students to question ideas, evaluate evidence, participate in collaborative inquiry, and construct knowledge actively.

Similarly, Adeyemi (2012) explains that critical thinking belongs to the higher-order cognitive domain involving application, analysis, synthesis, and evaluation. According to the author, meaningful learning occurs not only when students acquire knowledge but also when they are able to apply that knowledge to real-life situations. Unfortunately, many higher education institutions focus predominantly on transmitting disciplinary facts rather than engaging students intellectually in reflective inquiry. Therefore, he argues that critical thinking should become a central mandate of higher education because it equips learners to evaluate evidence objectively, recognize faulty reasoning, and make informed judgments. Olatunde-Aiyedun and Ogunode (2021) equally reported concerns about teacher-centred approaches in science education and argued for instructional practices that engage learners in inquiry, problem-solving, collaboration, and active knowledge construction.

Collectively, these studies indicate that the dominant instructional practices in Nigerian higher education remain largely teacher-centred and examination-oriented. Although such methods may facilitate content coverage, they provide limited opportunities for students to question assumptions, evaluate evidence, engage in collaborative inquiry, or construct knowledge actively. Relationships, organizing knowledge, evaluating evidence, and constructing meaningful understanding. This pedagogical need provides a strong rationale for the present study. Given these facts, a significant challenge in Nigerian education is that many instructional methods do not meet the needs of today's children and the society they live in. This issue is especially pronounced in science education, where traditional approaches often focus on abstract concepts and formulas instead of real-world applications (Dare, Keratithamkul, Hiwatig, & Li, 2021). Consequently, many Nigerian undergraduate students struggle to connect science with their everyday lives, leading to disengagement and lack of motivation. To address this challenge, science education in Nigeria must be reimagined to prioritize relevance, authenticity, and real-world application. This approach would help students develop a deeper understanding of the world around them and recognize their role in it.

According to Gillies (2020), inquiry-based science education promotes curiosity, critical thinking, and deeper understanding of scientific principles. Within this approach, Concept Mapping and the 7Es Instructional Strategy serve as effective teaching methods that encourage active participation, exploration, questioning, and investigation. Concept Mapping enhances meaningful learning, knowledge retention, and conceptual understanding by requiring learners to analyse, synthesise, evaluate, and organise information. It also promotes reflection, enables learners to identify gaps in their knowledge, and encourages them to monitor their learning progress (Novak & Canas, 2006; Stevenson et al., 2017; Habok, 2017). Similarly, it provides a holistic, non-linear approach to understanding and solving problems, moving learners beyond rote memorisation towards deeper engagement with knowledge (Monat & Gannon, 2015; Mason & Klein, 2013).

Complementing Concept Mapping, the 7Es Instructional Strategy provides a structured and flexible framework for improving conceptual understanding and critical thinking. It integrates different teaching approaches, including cooperative learning, group activities, laboratory investigations, and direct instruction (Balta & Sarac, 2016; Shuaibu et al., 2021). Its phases Elicit, Engage, Explore, Explain, Elaborate, Evaluate, and Extend guide learners from identifying prior knowledge and investigating new concepts to explaining, applying, and evaluating scientific understanding. Through this systematic process, learners can identify and correct misconceptions, strengthen conceptual understanding, and apply acquired knowledge to new situations (Noreen et al., 2024). Empirical studies have also demonstrated the effectiveness of the 7Es model in improving learning outcomes, generic science skills, and critical thinking abilities (Suardana et al., 2018; Marfilinda et al., 2020). These instructional approaches are particularly relevant to preservice biology teachers, whose professional responsibilities extend beyond the transmission of biological knowledge to developing learners' critical thinking, scientific literacy, and appreciation of the natural world. As future science educators, they play an essential role

in preparing students to understand scientific issues, address real-life challenges, participate meaningfully in civic and cultural discussions, and make informed decisions based on scientific principles (Bybee, 2010). Consequently, integrating Concept Mapping and the 7Es Instructional Strategy into preservice biology teacher education may provide valuable opportunities to strengthen their critical thinking skills and prepare them for effective science teaching.

However, Kebbi State is home to several higher education institutions, including the Federal University Birnin Kebbi (FUBK), Abdullahi Fodiyo University of Science and Technology (AFUSTA) in Aliero, both offers both undergraduate and postgraduate programs in various disciplines (Kwashabawa & Mustapha, 2023). Additionally, other tertiary institutions, including colleges of education and polytechnics, play a vital role in shaping the educational landscape of the state (Shuaibu & Aliyu, 2023).

2 Literature Review/Theoretical Framework

2.1 Theoretical Framework

This study is anchored in four complementary theoretical perspectives: Ausubel's Assimilation Theory, Novak's Human Constructivist Epistemology, Piaget's Cognitive Constructivism, and Vygotsky's Social Constructivist Theory. Together, these theories provide a foundation for understanding how learners construct knowledge, develop meaningful conceptual relationships, and enhance critical thinking skills through active learning (Brau, 2020: Jeon & Lee, 2023; Kamruzzaman, et al.'s 2022; Meccawy, 2022). Ausubel's Assimilation Theory emphasises that meaningful learning occurs when new information is connected to learners' existing knowledge structures. This principle supports Concept Mapping, which enables preservice biology teachers to organise, relate, and integrate scientific concepts. Similarly, Novak's Human Constructivist Epistemology highlights learners' active involvement in constructing knowledge through cognitive engagement, inquiry, and reflection. It provides a theoretical basis for using Concept Mapping to promote conceptual understanding and critical thinking (Stevenson, et al.'s 2017; Habok, 2017; & Novak & Canas, 2006;).

Piaget's Cognitive Constructivism explains learning as an active process involving assimilation and accommodation, through which learners reorganise their existing knowledge in response to new experiences (Kalpana, 2014). This perspective supports both Concept Mapping and the 7Es Instructional Strategy by encouraging learners to explore ideas, examine evidence, resolve inconsistencies, and construct new understanding. Vygotsky's Social Constructivist Theory further emphasises the importance of social interaction, collaboration, and scaffolding in learning (Panhwar, et al.'s., 2016). Its concepts of the Zone of Proximal Development and guided learning provide a foundation for the collaborative and interactive activities embedded in the 7Es instructional process (Gentile & Oswald, 2021; Smagorinsky, 2018). Collectively, these theoretical perspectives support the use of Concept Mapping and the 7Es Instructional Strategy as learner-centred approaches for promoting meaningful learning, conceptual understanding, and critical thinking (Marfilinda, et al.'s, 2020: Ozbek, et al.'s 2012). They also provide a basis for examining the effectiveness of these strategies among preservice biology teachers in Nigerian tertiary institutions.

2.2 Review of Related Empirical Studies

2.2.1 Concept Mapping and Critical Thinking Skills

Concept Mapping is increasingly recognised as a learner-centred instructional strategy for promoting meaningful learning and higher-order thinking in science education. Its contribution to critical thinking lies in enabling learners to identify key concepts, organise information, establish relationships among ideas, and evaluate the connections between them. Muhali and Sukaisih (2023) investigated the effectiveness of Guided Discovery Learning integrated with Concept Mapping in improving critical thinking and metacognition among 30 senior secondary school Physics students in Indonesia. Using classroom action research conducted over three cycles, the study found progressive improvements in both outcomes. Similarly, Khairani and Aloysius (2023) reported that integrating Concept Mapping with Problem-Based Learning and brainwriting produced significantly greater improvements in critical thinking and problem-solving than conventional instruction. However, because Concept Mapping was combined with other instructional approaches, its independent contribution could not be established.

In the Nigerian context, Bello et al. (2022) examined the effect of Concept Mapping on ecological literacy among 210 third-year university students in Sokoto State. Their quasi-experimental study found that students taught through Concept

Mapping achieved significantly higher ecological critical-thinking scores than those taught through conventional lectures, although no significant difference was observed in ecological knowledge. Collectively, these studies demonstrate the potential of Concept Mapping to enhance critical thinking across different educational contexts. However, their findings are limited by differences in subject areas, participant characteristics, instructional combinations, and research designs. In particular, limited evidence addresses its effectiveness among preservice Biology teachers or compares it directly with other constructivist instructional strategies. The present study therefore extends existing research by comparing Concept Mapping with the 7Es Instructional Strategy in developing critical thinking skills among preservice Biology teachers in tertiary institutions in Kebbi State, Nigeria.

2.2.2 7E's Instructional Strategy and Critical Thinking Skills

The 7Es Instructional Strategy, grounded in constructivist principles, promotes active learning through engagement, exploration, explanation, elaboration, evaluation, and extension. Empirical studies have demonstrated the potential of learner-centred instructional approaches to enhance critical thinking, although their effectiveness may vary across disciplines, educational levels, and learning contexts. Koukpossi et al. (2024) investigated strategies for developing critical thinking among English as a Foreign Language learners in Beninese secondary schools. Their mixed-methods study, involving 30 teachers and 200 students, identified collaborative learning, inquiry-based instruction, problem-solving, critical reading and writing, and real-world issues as important contributors to critical-thinking development. However, inadequate teacher training and limited instructional resources constrained their implementation. Similarly, Gbeleyi et al. (2023), in their investigation of the Culturo-Techno-Contextual Approach in Computer Studies, reported statistically significant differences in students' critical thinking, $F(2, 208) = 15.14$, $p < .05$. Although these studies support the value of active and contextualised instructional approaches, neither directly examined the 7Es strategy among preservice Biology teachers.

Moreover, Iqbal et al. (2022) examined the Constructivist 7E Instructional Approach among secondary school science students in Sargodha District, Pakistan. Using experimental and control groups, a validated critical-thinking test, and statistical analyses involving *t*-tests and ANOVA, the researchers found significant differences in critical-thinking scores in favour of students exposed to the 7E approach. This finding provides direct empirical support for the potential of the 7Es Instructional Strategy to enhance critical thinking in science education. Nevertheless, the study focused on secondary school students rather than preservice Biology teachers, limiting the extent to which its findings can be generalised to tertiary teacher education. Furthermore, the reviewed literature supports the potential of constructivist and learner-centred instructional approaches to develop critical thinking. However, limited empirical evidence establishes the effectiveness of the 7Es Instructional Strategy among preservice Biology teachers in Nigerian tertiary institutions, particularly in comparison with Concept Mapping. This gap is especially relevant to Kebbi State, where the present study seeks to provide context-specific evidence. Accordingly, the study compares the effects of Concept Mapping and the 7Es Instructional Strategy on the critical thinking skills of preservice Biology teachers in tertiary institutions in Kebbi State, Nigeria, thereby examining not only the effectiveness of each approach but also whether their effects differ significantly.

2.3 Statement of the Problem

Critical thinking is an important outcome of higher education because it enables learners to analyse information, evaluate evidence, solve problems, justify conclusions, and make reasoned decisions. For pre-service Biology teachers, these capabilities are particularly important because they are expected not only to understand scientific concepts but also to analyse scientific issues, evaluate evidence, solve problems, and facilitate meaningful learning among future learners. Despite this expectation, concerns remain about the development of critical-thinking skills among undergraduate students in Nigerian higher education. Evidence cited in the literatures suggest that the problem is associated, in part, with instructional practices that place greater emphasis on knowledge transmission, factual recall, and examination preparation than on active intellectual engagement. Aboluwodi (2015), for instance, reported concerns about the limited development of critical-thinking abilities among students in Nigerian higher institutions despite the inclusion of courses intended to promote such skills. Adeyemi, (2012) similarly reported that lecture-based instruction was predominant among lecturers in Nigerian universities, with comparatively limited use of discussion, practical activities, projects, and case studies. Such instructional conditions may provide fewer opportunities for learners to question ideas, evaluate evidence, engage in inquiry, and construct knowledge actively.

Learner centred instructional approaches such as Concept Mapping and the 7E's Instructional Strategy provide alternative ways of organising learning. Concept Mapping enables learners to identify relationships among concepts and represent

their understanding in an organised form, while the 7E's model engages learners through a sequence of eliciting prior knowledge, engagement, exploration, explanation, elaboration, evaluation, and extension. Both approaches provide opportunities for active participation and higher-order cognitive engagement.

The concern is particularly relevant to pre-service Biology teachers because the development of their own critical-thinking skills is closely related to their preparation for professional teaching. If teacher education programmes provide limited opportunities for inquiry, reflection, analysis, and problem-solving, prospective Biology teachers may have fewer opportunities to develop the cognitive dispositions and skills required to support similar learning processes in their future classrooms. Accordingly, the present study compared the effects of concept mapping and 7E's instructional strategies on critical thinking skills among pre-service biology teachers in tertiary institutions in Kebbi State, Nigeria. It further examines differences in the critical-thinking skills of pre-service Biology teachers exposed to Concept Mapping, 7E's Instructional Strategy, and Conventional Method instruction in selected tertiary institutions in Kebbi State, Nigeria.

2.4 Research Questions

1. What is the Effect of Concept Mapping Instructional Strategy on the Critical Thinking Skills of Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria?
2. What is the Effect of 7E's Instructional Strategy on the Critical Thinking Skills of Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria.
3. What is the difference between Critical Thinking Skills of Pre-Service Biology Teachers taught using Concept Mapping Instructional Strategy and those taught using 7E's Instructional Strategy in Tertiary Institutions in Kebbi State, Nigeria.

2.5 Null Hypotheses

1. Concept Mapping Instructional Strategy has no Significant Effect on Critical Thinking Skills among Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria
2. 7Es Instructional Strategy has no Significant Effect on the Critical Thinking Skills among Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria.
3. There is no Significant difference between the Critical Thinking Skills of Pre-Service Biology Teachers taught using concept mapping and those taught using 7Es Instructional Strategy in Tertiary Institutions in Kebbi State, Nigeria.

3 Materials and Methods

3.1 Research Design

This study utilized a pretest-posttest quasi-experimental research design. This design allowed for comparisons between a control group and experimental group, despite the absence of random assignment a common challenge in educational settings were participants are pre-existing groups. The pretest-posttest non-equivalent control group design allowed the researcher to introduce the instructional strategies (Concept Mapping and 7Es) to existing groups while comparing their pre- and post-intervention outcomes. The research design is illustrated below:

EG_1:	**O_1**	**X_1**	**O_2**	
EG_2:	**O_3**	**X_2**	**O_4**	
CG:	**O_5**	**X_3**	**O_6**	Creswell, (2014).

Indication of the Symbols:

EG: Experimental Group

CG: Control Group

O_1 , O_3 and O_5: Pre-Test

O_2, O_4 and O_6: Post-Test

X_1: Experimental processing (Teaching using Concept Mapping Instructional Strategy)

X_2: Experimental processing (Teaching using 7E's Instructional Strategy)

X_3: Treatment using Conventional Teaching Method (Lecture and Discussion)

3.2 Population of the Study

The target population of the study comprised 932 pre-service Biology teachers enrolled in teacher-training programmes in the participating tertiary institutions in Kebbi State, Nigeria. The accessible population for the study consisted of 303 eligible 400-level pre-service Biology teachers from the three participating institutions. These comprised 84 students from Federal University Birnin-Kebbi, 140 students from Abdullahi Fodiyo University of Science and Technology, Aliero, and 79 students from Adamu Augie College of Education, Argungu.

3.3 Sample and Sampling Techniques

The total sample size for the three selected institutions is 303 final-year (400-level) preservice biology teachers (students) enrolled in teacher training programs within the Faculty of Education, Department of Science Education, during the 2024/2025 academic session. All 400-level pre-service Biology teachers in the three selected institutions were included in the study. Thus, the study used a cluster and census of the accessible population, rather than selecting a sample from the 303 eligible students. The total number of respondents was therefore 303

The respondents were organized into three intact institutional groups corresponding to the instructional conditions. The Concept Mapping group consisted of 84 preservice biology teachers from Federal University Birnin-Kebbi, the 7E's group consisted of 140 preservice biology teachers from Abdullahi Fodiyo University of Science and Technology, Aliero, and the Conventional Method group consisted of 79 preservice biology teachers from Adamu Augie College of Education, Argungu. Because each instructional condition was implemented in a different institution, instructional condition and institution were completely confounded. This methodological limitation is acknowledged and considered when interpreting the findings. Distribution of the sample were been described below:

Table **1**

Population Size of the Study

S.NO.	Group	Institutions	Intact Class (400 Levels Students)
1.	Experimental 1	Federal University Birnin-Kebbi	**84**
2.	Experimental 2	Abdullahi Fodiyo University of Science and Technology, Aliero	**140**
3.	Control	Adamu Augie College of Education Argungu	**79**
TOTAL	**N=3**	**N=3**	**S=303**

3.4 Instrumentation

The learning materials used in this research is consist of lecture note, course guide student worksheet, and instrument include; objective test with multiple-choice questions, Concept mapping and 7Es instructional strategy (for experimental class I & II) and conventional (Lecture and Discussion) method for control class

3.4.1 Critical Thinking Skills Instrument

The Critical Thinking Skills Test (CTST) was specifically designed and developed to measure the dependent variable (critical thinking skills) adapted based on the five indicators proposed by Ennis (2011). This instrument was administered to pre-service biology teachers at two key stages: before (pre-test) and after (post-test) the intervention. The goal is to assess any changes in their critical thinking skills resulting from the instructional strategies employed

3.4.2 Validity and Reliability of the Instrument

The Critical Thinking Skills Test for Pre-Service Biology Teachers (CTSTPBT) was developed to assess critical-thinking skills using five indicators adopted from the framework guiding the study: elementary clarification, basic support, inference, advanced clarification, and strategy and tactics. The 30-item test comprised six items for each indicator. The items were developed to reflect the relevant critical-thinking processes and the content areas covered during the intervention. Content validity was assessed through expert review. Five experts examined the preliminary 30-item instrument with respect to the adequacy of the items for measuring the study objectives, clarity of language, appropriateness of the scale, appropriateness of the format, freedom from ambiguity, and adequacy of the items for measuring the intended variable. The respective Interrater CVI values were 0.75, 0.70, 0.65, 0.85, 0.80, and 0.85, yielding an average CVI of 0.77

The CVI provides evidence of expert agreement regarding the content and presentation of the instrument. However, because the average CVI was moderate rather than unequivocally strong, it is interpreted cautiously and is not treated as sufficient evidence of construct validity on its peculiar. The study has a test-retest reliability coefficient of r=.83,

3.5 Method of Data Collection

In this study, data were collected using a quantitative instrument to find out the effectiveness of concept mapping and the 7Es instructional strategy on the critical thinking skills of preservice biology teachers. The process of data collection has been structured as follows;

3.5.1 Data Collection Timeline

Week 1: Conducted pre-tests for the Critical Thinking Skills instrument

Weeks 2–10: Implemented the 7Es instructional strategy and concept mapping activities on Experimental classes and conventional method to the control class by the researcher with two trained research assistants

Week 11: Conducted post-tests using the same instrument

3.6 Method of Data Analysis

Data were analysed using descriptive and inferential statistics. Descriptive statistics, including means, standard deviations, were used to summarise the Pre-Service Biology Teachers Critical Thinking Skills scores. Paired-samples t-tests were used to compare pre-test and post-test scores within the Concept Mapping and 7E's groups. An independent-samples t-test was used to compare the post-test Critical Thinking Skills scores of the Concept Mapping and 7E's groups. In addition, a one-way analysis of variance (ANOVA) was used to compare the post-test mean scores across the Concept Mapping, 7E's, and Conventional Method groups. Where the ANOVA indicated a statistically significant difference, Scheffe's post-hoc test was used to identify the specific group differences. All hypotheses were tested at the 0.05 level of significance.

4 Results

The data was organized according to the research questions and corresponding null hypotheses. Findings were presented in tables with appropriate interpretations.

Research Question One: What is the Effect of Concept Mapping Instructional Strategy on the Critical Thinking Skills of Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria

Table **2**

Mean Critical Thinking Skills Scores of Pretests and Posttest of Pre-Service Biology Teachers s taught using Concept Mapping Instructional Strategy

Paired Samples		Mean	N	Std. Deviation	Std. Error Mean	Mean difference
Pair	Pretest	29.37	84	5.699	.622	10.12
	Posttest	39.49	84	7.402	.808	

Table 2 shows the mean critical thinking scores of Pre-Service Biology Teachers before and after being taught using the concept mapping instructional strategy. The pretest mean score was 29.37 (SD = 5.699), while the posttest mean score increased to 39.49 (SD = 7.402) for the same group of 84 Pre-Service Biology Teachers. The mean difference of 10.12 indicates a substantial improvement in Pre-Service Biology Teachers' critical thinking skills after the intervention. The pretest standard deviation of 5.699 suggests relatively moderate variability in Pre-Service Biology Teachers' initial critical thinking abilities, the slightly higher posttest standard deviation of 7.402 indicates that Pre-Service Biology Teachers responded differently to the instructional intervention.

Research Question Two: What is the Effect of 7E's Instructional Strategy on the Critical Thinking Skills of Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria.

Table **3**

Mean Critical Thinking Skills Scores of Pretest and Posttest Pre-Service Biology Teachers taught using 7Es Instructional Strategy

Paired Samples		Mean	N	Std. Deviation	Std. Error Mean	Mean difference
Pair	**Pretest**	28.23	140	7.819	.661	11.83
	Posttest	40.06	140	8.608	.727	

Table 3 presents the mean critical thinking scores of Pre-Service Biology Teachers before and after being taught using the 7Es instructional strategy. The pretest mean score was 28.23 (SD = 7.819), while the posttest mean score increased to 40.06 (SD = 8.608) for 140 Pre-Service Biology Teachers. The mean difference of 11.83 indicates an improvement in Pre-Service Biology Teachers' critical thinking skills after the intervention. The pretest standard deviation of 7.819 suggests differences in the initial critical thinking abilities of the Pre-Service Biology Teachers, while the posttest standard deviation of 8.608 indicates variations in the extent to which Pre-Service Biology Teachers benefited from the instructional strategy. This implies that the 7E's instructional strategy was effective in enhancing Pre-Service Biology Teachers' critical thinking skills.

Research Question Three: What are the differences between Critical Thinking Skills of Pre-Service Biology Teachers taught using Concept Mapping Instructional Strategy and those taught using 7Es Instructional Strategy in Tertiary Institutions in Kebbi State, Nigeria.?

Table **4**

Descriptive Statistics of Critical thinking Skills of Concept Mapping and 7Es Group

Group	N	Mean	Std. Deviation	Std. Error Mean
CM	84	39.49	7.402	.808
7E's	140	40.06	8.608	.727
Total	**224**			

Table 4. shows the descriptive statistics of critical thinking skills of Pre-Service Biology Teachers taught using Concept Mapping and 7Es instructional strategies. The mean score for the Concept Mapping group was 39.49 (SD = 7.402), while the 7Es group had a slightly higher mean score of 40.06 (SD = 8.608). The close mean values indicate that both instructional strategies were effective in improving Pre-Service Biology Teachers critical thinking skills, with the 7Es strategy showing a marginal advantage over Concept Mapping. However, the difference between the two groups is small.

Null Hypothesis One: Concept Mapping Instructional Strategy has no Significant Effect on Critical Thinking Skills among Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria.

Table **5**

Paired Samples T-test Results for Critical Thinking Skills of Pretest and Posttest Pre-Service Biology Teachers taught using Concept Mapping Instructional Strategy

Paired Samples		Mean	N	Std. Deviation	Std. Error Mean	Mean difference	T-value	df	p-value
Pair	Pretest	29.37	84	5.699	.622	10.12	24.757	83	<.001
	Posttest	39.49	84	7.402	.808				

Table 5. analysis revealed that the posttest mean score **(**39.49**)** is higher than the pretest mean score (29.37), with a mean difference of 10.12**.** The calculated t-value of 24.757 with 83 degrees of freedom and a p-value of 0.000 indicates that the difference is statistically significant at the 0.05 level. Based on this result, the null hypothesis is rejected. The study found that the Concept Mapping Instructional Strategy had a significant positive effect on Pre-Service Biology Teachers' critical thinking skills

Null Hypothesis Two: 7Es Instructional Strategy has no Significant Effect on the Critical Thinking Skills and among Pre-Service Biology Teachers in Tertiary Institutions in Kebbi State, Nigeria

Table **6**

Paired Samples T-test Results for Critical Thinking Skills of Pretest and Posttest Pre-Service Biology Teachers taught using 7Es Instructional Strategy

Paired Samples		Mean	N	Std. Deviation	Std. Error Mean	Mean difference	t-value	df	p-value
Pair	Pretest	28.23	140	7.819	.661	11.83	31.593	139	<.001
	Posttest	40.06	140	8.608	.727				

Table 6. presents the paired samples t-test results comparing the pretest and posttest critical thinking scores of Pre-Service Biology Teachers taught using the 7Es instructional strategy. The null hypothesis stated there would be no difference in critical thinking scores before vs. after 7Es instruction. The analysis revealed that the posttest mean score **(**40.06**)** is higher than the pretest mean score **(**28.23**),** with a mean difference of 11.83**.** The calculated t-value of 31.593 with 139 degrees of freedom and a p-value of 0.000 indicates that the difference is statistically significant at the 0.05 level clearly rejecting the null. These findings suggest that the 7E's instructional strategy had a significant positive effect on Pre-Service Biology Teachers' critical thinking skills.

Null Hypothesis Three: There is no Significant difference between the Critical Thinking Skills of Pre-Service Biology Teachers taught using concept mapping and those taught using 7Es Instructional Strategy in Tertiary Institutions in Kebbi State, Nigeria.

Table 7

Independent Samples t-test Results for Critical thinking Skills of Concept Mapping and 7Es Group

Group	N	Mean	Std. Deviation	Std. Error Mean	Mean difference	t-Value	df	p-value
CM	84	39.49	7.402	.808	0.57	-.511	222	.610
7E's	140	40.06	8.608	.727				
Total	**224**							

Table 7 presents the independent samples t-test results comparing the critical thinking skills of Service Biology Teachers taught using Concept Mapping and 7E's instructional strategies. The Concept Mapping group had a mean score of 39.49**,** while the 7E's group had a slightly higher mean score of 40.06**,** with a mean difference of 0.57**.** The calculated t-value of -0.511 with 222 degrees of freedom and a p-value of 0.610 indicates that the difference between the two groups is not statistically significant at the 0.05 level. This finding suggests that both Concept Mapping and 7E's instructional strategies are equally effective in improving Pre-Service Biology Teachers critical thinking skills.

Conventional Instructional Strategy

Table 8

Mean Critical Thinking Skills Scores of Pretest and Posttest Pre-Service Biology Teachers taught using Conventional Method

Paired Samples		Mean	N	Std. Deviation	Std. Error Mean	Mean difference
Pair	**Pretest**	28.2532	79	1.72811	.19443	0.2531
	Posttest	28.5063	79	1.64764	.18537	

Table 8 presents the pretest and posttest critical-thinking scores of the participants taught using the Conventional Method. The pretest mean was 28.25 (SD=1.73), while the posttest mean was 28.51 (SD=1.65), representing a mean increase of 0.25 points. Although the paired-samples test indicated a statistically significant difference, t(78) =2.785, p=.007, the magnitude of the mean change was small. The relatively low standard deviations indicate that scores within this group were comparatively homogeneous. The mean difference of 0.25 indicates a very small improvement. This suggests that the conventional method had little or no meaningful effect.

Table **9**

Means and Standard deviation Scores of Critical Thinking Skills for Pre-Service Biology Teachers taught using the three Independent Instructional Strategies

Variable	N	Mean	SD	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
CM	84	39.49	7.402	.808	37.88	41.09
7E's	140	40.06	8.608	.727	38.63	41.50

Variable	N	Mean	SD	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Conventional Method	79	28.51	1.648	.185	28.14	28.88
Total	**303**	36.89	8.648	.497	35.91	37.87

Table 9, presents the means and standard deviations scores of Critical Thinking Skills for Pre-Service Biology Teachers taught using Concept Mapping, 7E's instructional strategy, and the Conventional method. The analysis revealed that Pre-Service Biology Teachers taught using the 7E's strategy had the highest mean score of 40.06 (SD = 8.608), followed closely by the Concept Mapping group with a mean of 39.49 (SD = 7.402), while the Conventional group recorded the lowest mean score of 28.51 (SD = 1.648). The overall mean score for all groups was 36.89 (SD = 8.648).

Table **10**

Summary of One-Way ANOVA on Critical Thinking Skills scores of Pre-Service Biology Teachers taught using the three independent Instructional Strategies

Source of Variance	SS	Df	MS	F	P-value
Between Groups	7530.250	2	3765.125	75.017	<.001
Within Groups	15057.156	300	50.191		
Total	22587.406	302			

Table 10 presents the summary of the One-Way ANOVA comparing the Critical Thinking Skills scores of Pre-Service Biology Teachers taught using the three instructional strategies. The results One-Way Analysis of Variance (ANOVA) show a calculated F-value of 75.017 with a p-value of 0.000**,** which is statistically significant at the 0.05 level. Consequently, the null hypothesis (H_{03}) was rejected. The study found that the three instructional strategies differed significantly in their effectiveness in improving the Critical Thinking Skills of Pre-Service Biology Teachers. This indicates that there is a significant difference in the mean scores among the three groups. Therefore, the instructional strategies used had different effects on Pre-Service Biology Teachers Critical Thinking Skills. However, since a significant difference was found between the mean critical thinking skills of Pre-Service Biology Teachers in the three groups, the data was subjected to further analysis to discover where the difference exist using Scheffe's post hoc test in Table 10.1

Table **10.1**

Scheffe's post hoc test

(I) treatment group	(J) treatment group	Mean Difference (I-J)	Std. Error	p-value
CM	7E's	-.576	.978	.841
	Conventional Method	10.98	1.110	<.001
7E's	CM	.576	.978	.841
	Conventional Method	11.558	.997	<.001
Conventional Method	CM	-10.982	1.110	<.001
	7E's	-11.558	.997	<.001

Table 10.1 presents the Scheffe's post hoc test used to determine the specific differences between the instructional groups. The analysis revealed that there **is** no significant difference between the Concept Mapping and 7E's groups (p = 0.841), indicating that both strategies are equally effective. However, there are significant differences between Concept Mapping and the Conventional method (mean difference = 10.982, p = 0.000), as well as between 7E's and the Conventional method

(mean difference = 11.558, p = 0.000). This study found that both Concept Mapping and 7E's instructional strategies are significantly more effective than the Conventional method in improving Pre-Service Biology Teachers

5 Discussion

Research Question One and Null Hypothesis One: The findings of this study revealed that Pre-Service Biology Teachers exposed to Concept Mapping Instructional Strategy showed an improvement in their Critical Thinking Skills after the treatment. The posttest mean score obtained by the students was considerably higher than the pretest mean score, indicating that the instructional strategy enhanced Pre-Service Biology Teachers ability to analyze, interpret, evaluate, and organize concepts meaningfully. Similarly, the tested hypothesis revealed a statistically significant difference between the pretest and posttest scores of Pre-Service Biology Teachers taught using Concept Mapping Instructional Strategy. Consequently, based on this analysis revealed, the null hypothesis is rejected. The finding of this study agrees with the study of Muhali et al. (2023), who reported that the integration of concept mapping with Guided Discovery Learning significantly improved students' critical thinking skills in physics education. Their study concluded that concept mapping promotes meaningful learning by helping learners connect ideas, analyze relationships among concepts, and develop reflective thinking abilities.

Research Question Two and Null Hypothesis Two: The findings of this study revealed that Pre-Service Biology Teachers taught using the 7E's Instructional Strategy showed an improvement in their Critical Thinking Skills after the treatment. The posttest mean score obtained by the students was significantly higher than the pretest mean score. Similarly, the tested hypothesis revealed a statistically significant difference between the pretest and posttest scores of Pre-Service Biology Teachers exposed to the 7E's Instructional Strategy. Therefore, the null hypothesis is clearly rejected. The findings of the present study are in agreement with the study conducted by Iqbal, et al.'s (2022), whose investigated the effectiveness of the 7Es Instructional approach in developing critical thinking skills among secondary school physics students in Pakistan. Their findings revealed significant differences in critical thinking scores between students taught using the 7E model and those taught through conventional methods.

Research Question Three and Null Hypothesis Three: The findings of this study revealed that both Concept Mapping Instructional Strategy and 7E's Instructional Strategy significantly improved the Critical Thinking Skills of Pre-Service Biology Teachers. However, Pre-Service Biology Teachers taught using the 7E's Instructional Strategy obtained a slightly higher mean score than those taught using Concept Mapping Instructional Strategy. The close similarity in the mean scores implies that the two learner-centered approaches provide comparable opportunities for students to engage in inquiry, reasoning, analysis, evaluation, and problem-solving activities that promote critical thinking skills development. Despite this observed difference, the hypothesis testing indicated that the difference between the two instructional strategies was not statistically significant. Accordingly, the null hypothesis was retained. This implies that both instructional strategies are equally effective in enhancing students' critical thinking skills. Although the 7E's group recorded a slightly higher mean score, the difference was too small to be considered statistically educationally meaningful. Correspondingly, the findings of this study agree with the study conducted by Khairani, and Aloysius (2023), whose found that both concept mapping and inquiry-oriented instructional strategies significantly improved students' critical thinking and problem-solving skills when compared with conventional teaching methods. In the same vein, the current study demonstrated that both Concept Mapping and 7E's Instructional Strategies effectively promoted critical thinking among preservice biology teachers because both approaches are interactive and inquiry-based in nature.

6 Conclusion

This study concludes that Concept Mapping Instructional Strategy is an effective instructional approach for improving the critical thinking skills of preservice biology teachers in tertiary institutions in Kebbi State, Nigeria. The strategy significantly enhanced learners' abilities to analyze, interpret, evaluate, and organize science education concepts meaningfully. The study further concludes that the 7Es Instructional Strategy is highly effective in enhancing the critical thinking skills of preservice biology teachers. Through its inquiry-based and constructivist learning phases, the strategy encouraged active participation, exploration, reflection, and problem-solving. Furthermore, on the comparison between Concept Mapping and the 7Es Instructional Strategy in critical thinking skills, the study concludes that both instructional strategies are equally effective. Although the 7Es group recorded a slightly higher mean score than the Concept Mapping group, the difference was not statistically significant. This indicates that both approaches possess comparable strengths in promoting critical thinking through active learning, inquiry, reflection, and learner engagement.

7 Recommendations

Lecturers should regularly engage students in constructing, analyzing, and interpreting concept maps as part of classroom instruction, assignments, and assessments. This will help preservice teachers develop analytical reasoning, conceptual understanding, and higher-order thinking skills required for effective science teaching. The seven instructional phases; Elicit, Engage, Explore, Explain, Elaborate, Evaluate, and Extend should be incorporated into lesson planning and classroom delivery to promote inquiry, problem-solving, reflective thinking, and active learner participation. Educational administrators should also organize training workshops to equip lecturers with the knowledge and skills required for effective implementation of the 7Es model. Correspondingly, since both Concept Mapping and the 7Es Instructional Strategies were found to be equally effective in improving critical thinking skills, science educators should be encouraged to use either of the two strategies depending on instructional objectives, lesson content, learner characteristics, and available resources. In practice, lecturers may also combine both strategies within the same instructional process to maximize learner engagement and promote deeper understanding of science education concepts.

8 Declarations

Ethical statements: Permission to conduct the study was obtained from the Head of the Department of Science Education, Sokoto State University, Sokoto, Nigeria, through an approval letter dated 30 July 2025 (Reference No. PGS-2130201002), addressed to the relevant tertiary institutions in Kebbi State, Nigeria. Before participating in the study, the preservice Biology teachers were informed about its purpose and procedures, and their informed consent was obtained. Participation was entirely voluntary, and participants were informed of their right to withdraw from the study at any stage without penalty. Confidentiality and anonymity were maintained throughout data collection, analysis, and reporting. All information obtained from participants was used strictly for academic and research purposes.

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