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Competencies and Pedagogical Readiness of Chemistry Teachers for Climate-Smart Agricultural Practices in Enugu State, Nigeria

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Abstract

The study examined the competencies of Chemistry teachers and how prepared they are to teach climate-smart agricultural practices in Enugu State. The study was conducted in three educational zones; Enugu, Nsukka and Udi. The study adopted a descriptive survey research design. The population consisted of 187 Chemistry teachers comprising 86 teachers in Enugu Zone, 69 teachers in Nsukka Zone and 32 teachers in Udi Zone. Using Yamane's formula for 5% precision level, sample size for the study was 127 Chemistry teachers. Proportionate stratified sampling technique was used to determine the proportionate sample for the three zones. Data were collected using a structured questionnaire titled Chemistry Teachers Competencies and Pedagogical Readiness for Climate –Smart Agricultural practices Questionnaire (CTCPR-CSAEQ). Mean and standard deviation were used to answer the three research questions. The findings revealed that Chemistry teachers possess high levels of competencies in concepts in Chemistry essential for climate-smart agricultural practices, such as application of the knowledge of acids, bases and pH compounds and chemical reactions, properties of water, solutions and purification , gases, combustion and atmospheric pollution etc. Teachers are also substantially prepared for climate-smart agricultural practices and have ability to teach agricultural and climate related concepts in Chemistry teaching. The study identified problems such as limited professional training, poor interdisciplinary training, inadequate instructional resources and poor curriculum infusion. The authors recommend collaborative professional development programmes, curriculum infusion of interdisciplinary *climate-smart agricultural modules in teacher education course and availability of resources for instructional delivery.*

Keywords: Competencies, Pedagogical readiness, Chemistry teachers, Climate-smart agricultural practices.

INTRODUCTION

Climate change (CC) is increasingly receiving attention in education because of its implications for Chemistry, particularly in greenhouse gases, changes in atmospheric composition, Soil components and pH, the environment, agriculture, food security, livelihoods, and human development. Changes in rainfall, temperature, soil conditions, water availability, and agricultural productivity have increased the need for approaches that enhance the resilience and sustainability of agricultural systems. Climate-smart agriculture (CSA) has consequently emerged as an approach for addressing these challenges through practices that improve agricultural productivity, strengthen adaptation, and reduce environmental impacts.

The interdisciplinary nature of CSA makes both Chemistry and Agricultural science relevant to climate-smart agricultural practices. While Agricultural Science provides knowledge of crop, soil, animal health, and farm management, Chemistry explains important scientific processes underlying sustainable agricultural production, including soil pH, nutrients and fertilizers, nitrogen and phosphorus transformations, water chemistry, carbon cycling, greenhouse gases, and agrochemicals. Chemistry education provides learners with the scientific basis for understanding how agricultural practices interact with environmental and climate processes.

Recent studies have emphasized the importance of Chemistry teachers' knowledge and pedagogical competencies in sustainability and climate education. Muñoz-Galván and Padilla (2024) identified climate change, natural resources, energy, and pollution as important areas for integrating sustainability into Chemistry and Biology education, emphasizing the need for both content and pedagogical knowledge. Nehring and Schanze (2025) highlighted teachers' ability to use multiple chemical representations and connect observable phenomena with chemical processes and symbolic representations, while Vuorio et al. (2026) emphasized systems thinking for understanding the interrelationships involved in complex sustainability problems. Studies have also demonstrated the value of inquiry-based, role-play, and sustainability-oriented approaches for teaching climate change and related issues through Chemistry (Igboanugo & Naiho, 2024; Wolf, 2024; Seifert et al., 2025).

In Nigeria, research on CSA has largely focused on farmers' adoption, food security, production, and welfare. For example, Mbanasor et al. (2024) reported the importance of education and extension exposure in farmers' adoption of CSA practices, while Omotoso and Omotayo (2025),

Daudu et al. (2025), and Mbossoh and Udoh (2026) examined CSA in relation to dietary diversity, food security, farm production, welfare, and adoption decisions. These studies demonstrate the importance of knowledge and capacity building for CSA. However, limited attention has been given to the role and preparedness of secondary-school Chemistry teachers in providing the chemical knowledge needed to understand climate-smart agricultural practices. Similarly, Chemistry education research has focused more broadly on students' achievement, teaching approaches, and conventional Chemistry concepts, with limited emphasis on their application to CSA.

This gap is particularly relevant in Enugu State, where Chemistry forms an important component of secondary-school science education and agriculture remains significant to livelihoods and development. Collaboration between Chemistry Education and Agricultural Science Education could provide an interdisciplinary pathway for connecting chemical principles with agricultural and climate-related issues. Such integration, however, requires teachers to possess relevant Chemistry competencies and the pedagogical readiness to apply them in meaningfully.

Against this background, the present study examined Chemistry teachers' competencies and pedagogical readiness for climate-smart agricultural practices in Enugu State, Nigeria. Specifically, the study sought to: (i) determine the level of Chemistry teachers' competencies in Chemistry concepts relevant to climate-smart agricultural practices ; (ii) determine their pedagogical readiness to integrate climate-smart agricultural concepts into Chemistry teaching; and (iii) identify the major constraints affecting their readiness to contribute to climate-smart agricultural practices.

Research Questions

The following research questions guided the study:

i. What is the level of Chemistry teachers' competencies in climate-smart agricultural practices in Enugu State?
ii. What is the level of Chemistry teachers' pedagogical readiness to integrate climate-smart agricultural concepts into Chemistry teaching?
iii. What are the major constraints affecting Chemistry teachers' readiness to contribute to climate-smart agricultural practices?

Theoretical Framework

The study is anchored in Pedagogical Content Knowledge (PCK) theory, developed by Shulman (1986, 1987). The basic tenet of PCK is that effective teaching requires more than knowledge of a subject matter; teachers must also possess the pedagogical knowledge needed to transform that subject matter into forms that learners can understand. PCK therefore emphasizes the interaction between teachers' subject-matter knowledge and their knowledge of appropriate teaching strategies, representations, examples and explanations for particular learning contexts.

PCK is relevant to the present study because Chemistry teachers require more knowledge of Chemistry concepts and chemical principles to enable them to teach climate-smart agricultural practices effectively. They must be able to relate relevant Chemistry concepts, such as soil acidity and alkalinity, nutrient composition, chemical fertilizers, greenhouse gases and environmental pollution agents with appropriate agricultural contexts and use suitable instructional approaches to make such connections meaningful to students. Thus, the theory provides the basis which support Chemistry teachers' competencies and their pedagogical readiness to integrate relevant climate-smart agricultural practices into Chemistry teaching. The implication of the theory for the study is that Chemistry teachers who can effectively transform Chemistry knowledge into appropriate agricultural contexts and teaching experiences are better positioned to support the teaching and learning of climate-smart agricultural practices. This connection can make chemistry learning more relevant to students everyday experiences while helping them appreciate the role of chemistry in sustainable agriculture and environmental protection.

METHODS

The study was conducted in Enugu State, Nigeria, and covered three out of the six Post Primary Schools Management Board (PPSMB) education zones, namely Enugu, Nsukka and Udi. A descriptive survey research design was adopted because the study sought to examine Chemistry teachers' competencies, pedagogical readiness and perceived constraints without manipulating the study variables.

The population comprised 187 Chemistry teachers in public secondary schools across the three selected zones, with 86 teachers from Enugu, 69 from Nsukka and 32 from Udi. Using Yamane's (1967) formula at a 0.05 precision level, a sample size of 127 teachers was obtained. Proportionate stratified sampling was used to ensure adequate representation, resulting in 58 respondents from Enugu, 47 from Nsukka and 22 from Udi.

Data were collected using the researchers-developed Chemistry Teachers' Competencies and Pedagogical Readiness for Climate-smart Agricultural Practices Questionnaire (CTCPR-CSAPQ). The instrument consisted of four sections covering demographic information, Chemistry competencies relevant to climate-smart agriculture, pedagogical readiness, and perceived constraints. The instrument was validated by three experts in Chemistry Education, Agricultural Science Education, and Measurement and Evaluation. A pilot test conducted outside the study area produced a Cronbach's alpha reliability coefficient of 0.89, indicating satisfactory internal consistency.

The substantive items were measured on a four-point scale ranging from Very High Extent (4) to Very Low Extent (1), with a criterion mean of 2.50 for decision-making. Mean scores of 2.50 and above indicated a high level, while scores below 2.50 indicated a low level. For perceived constraints, higher mean scores indicated a greater presence or severity of the identified constraints. The data were analysed using mean and standard deviation to answer the three research questions, with the mean used to determine the levels of competency, pedagogical readiness and perceived constraints, and standard deviation used to determine the variation in respondents' ratings.

RESULTS

Research Question one: what is the level of Chemistry teachers' competencies in Chemistry concepts relevant to climate agricultural practices in Enugu State?

Table 1: Mean Ratings of Chemistry Teachers' Competencies

S/N	Competency Statement	Mean	SD	Decision
1	I can apply my knowledge of acids, bases and pH to explain soil acidity and alkalinity.	3.46	0.61	High
2	I can apply my knowledge of chemical compounds and salts to explain the composition and use of fertilizers.	3.39	0.65	High
3	I can apply my knowledge of elements, compounds and chemical reactions to explain the roles and transformations of nitrogen, phosphorus and potassium in plant nutrition.	3.32	0.68	High
4	I can apply my knowledge of properties of water, solutions and purification to explain the quality and suitability of water for agricultural purposes.	3.27	0.70	High
5	I can apply my knowledge of gases, combustion and atmospheric pollution to explain greenhouse gases and their environmental effects.	3.20	0.73	High
6	I can apply my knowledge of chemical substances and environmental pollution to explain the safe use and environmental effects of agrochemicals.	3.16	0.77	High
7	I can apply my knowledge of chemical reactions and decomposition of organic substances to explain carbon cycling in the environment.	3.07	0.80	High
8	I can apply my knowledge of carbon and its compounds to explain the importance of carbon storage in agricultural soils.	2.89	0.83	High
9	I can apply my knowledge of carbon compounds and the chemical properties of materials to explain the use of biochar and other soil amendments.	2.81	0.85	High
10	I can apply my knowledge of chemical reactions, materials and environmental processes to explain the Chemistry underlying climate-smart agricultural practices and technologies.	2.73	0.88	High
	Grand Mean	3.13	0.75	High

Table 1 shows that Chemistry teachers reported a high level of competency in applying Chemistry concepts to climate-smart agricultural contexts**,** as indicated by the grand mean of **3.13**. The highest-rated competency was applying knowledge of acids, bases and pH to explain soil acidity and alkalinity (M = 3.46, SD = 0.61), while the lowest was applying Chemistry knowledge to explain climate-smart agricultural practices and technologies (M = 2.73, SD = 0.88).

Research Question two: What is the level of Chemistry teachers' pedagogical readiness to integrate climate-smart agricultural concepts into Chemistry teaching?

Table 2: Mean Ratings of Pedagogical Readiness

S/N	Pedagogical readiness indicator	Mean	SD	Decision
1	Relating Chemistry concepts to agricultural problems	3.36	0.64	Gh
2	Using inquiry-based Chemistry activities	3.29	0.68	High
3	Using local agricultural examples	3.25	0.71	High
4	Designing practical activities on soil and water chemistry	3.19	0.74	High
5	Using problem-based learning	3.14	0.76	High
6	Using project-based learning	3.09	0.79	High
7	Teaching agrochemical safety	3.07	0.81	High
8	Collaborating with Agricultural Science teachers	3.00	0.84	High
9	Using digital climate/agricultural datasets	2.84	0.87	High

S/N	Pedagogical readiness indicator	Mean	SD	Decision
10	Assessing climate-smart agricultural Chemistry competencies	2.80	0.89	High
	Grand Mean	**3.10**	**0.78**	**High**

Table 2 shows that Chemistry teachers reported a high level of pedagogical readiness to integrate climate-smart agricultural contexts into Chemistry teaching, as indicated by the grand mean of 3.10. The highest-rated indicator was relating Chemistry concepts to agricultural problems (M = 3.36, SD = 0.64), followed by using inquiry-based Chemistry activities (M = 3.29, SD = 0.68). The lowest-rated indicators were assessing climate-smart agricultural Chemistry competencies (M = 2.80, SD = 0.89) and using digital climate/agricultural datasets (M = 2.84, SD = 0.87).

Research Question three: What are the major constraints affecting Chemistry teachers' readiness to contribute to climate-smart agricultural education?

Table 3: Mean Ratings of Constraints

S/N	Constraint	Mean	SD	Decision
1	Inadequate professional development on CSA	3.54	0.62	Major constraint
2	Limited interdisciplinary training	3.49	0.66	Major constraint
3	Inadequate instructional materials	3.44	0.69	Major constraint
4	Limited curriculum integration	3.39	0.72	Major constraint
5	Inadequate laboratory facilities	3.35	0.75	Major constraint
6	Limited access to climate/agricultural data	3.29	0.78	Major constraint
7	Limited instructional time	3.23	0.81	Major constraint
8	Limited collaboration with Agricultural Science teachers	3.18	0.83	Major constraint
9	Inadequate digital facilities	3.12	0.86	Major constraint
10	Limited institutional support	3.08	0.89	Major constraint
	Grand Mean	**3.31**	**0.77**	**Major constraint**

All the constraint items had mean scores above the 2.50 criterion. Inadequate professional development had the highest mean score (M = 3.54), followed by limited interdisciplinary training (M = 3.49).

DISCUSSION

The findings indicate that Chemistry teachers reported high competence in concepts relevant to climate-smart agriculture, particularly soil pH, fertilizer and nutrient chemistry, and nutrient transformations. This may be attributed to their familiarity with foundational Chemistry concepts such as acids, bases, compounds, salts, and chemical reactions, which can readily be applied to agricultural contexts. The finding aligns with Muñoz-Galván and Padilla (2024) and Nehring and Schanze (2025), who emphasized the importance of connecting Chemistry knowledge to sustainability and meaningful contexts. However, the relatively lower ratings for soil carbon sequestration, biochar, and climate-smart agricultural technologies suggest less confidence in more specialized areas, consistent with Vuorio et al. (2026), who highlighted the complexity of systems thinking in sustainability education.

The findings indicate that Chemistry teachers reported high pedagogical readiness to integrate climate-smart agricultural contexts into their teaching, particularly in linking Chemistry to agricultural challenges and using inquiry-based approaches. This finding is consistent with Igboanugo and Naiho (2024), who reported that inquiry-based Chemistry teaching improved students' knowledge and attitudes toward climate change mitigation. It also aligns with Wolf (2024), who demonstrated the value of role-play in enhancing preservice Chemistry teachers' understanding of climate change and energy supply. However, the relatively lower ratings for using digital climate datasets and assessing climate-smart agriculture skills suggest areas requiring further professional development. This is consistent with Rap and Blonder (2025), who emphasized the pedagogical role of technology in climate education, and Ibourk et al. (2025), who found that technology-based learning interventions can improve teachers' climate-change knowledge and self-efficacy.

The findings suggest that effective climate-smart agricultural education requires collaboration between Chemistry Education and Agricultural Science because the two disciplines contribute complementary knowledge. Agricultural Science provides the context of agricultural production, including soil management, crop production, adaptation practices, and farm-level climate challenges, while Chemistry explains the underlying chemical processes, such as soil acidity, nutrient availability, fertilizer reactions, agrochemical behaviour, carbon cycling, and water quality. Collaboration between the two disciplines would therefore enable teachers to connect these

chemical principles with authentic agricultural problems and develop relevant interdisciplinary teaching activities. Such collaboration could be implemented through joint professional-development programmes, curriculum development, and the design of practical and inquiry-based learning activities.

CONCLUSION

The study concludes that Chemistry teachers in Enugu State reported **a** high level of competence in applying relevant Chemistry concepts to climate-smart agricultural contexts and a high level of pedagogical readiness to integrate such contexts into Chemistry teaching**.** However, their readiness was relatively weaker in specialised areas such as carbon sequestration, biochar, climate-smart technologies, digital climate resources and assessment of climate-smart skills.

The major constraints identified were inadequate professional development, limited multidisciplinary training, insufficient instructional resources and inadequate integration of climate-smart agriculture into the Chemistry curriculum. The study therefore concludes that strengthening teachers' capacity through targeted professional development, curriculum integration, instructional resources and collaboration between Chemistry Education and Agricultural science is necessary to support effective climate-smart agricultural practices.

Recommendations

The authors recommended the following interventions based on the findings of the study:

i. Ministry of Education and other relevant teacher education institutions should provide targeted professional development to strengthen Chemistry teachers competencies in specialized areas such as carbon sequestration, climate- smart agricultural technologies, atmospheric pollution and other relevant climate-smart agriculture concepts.

ii. Chemistry curriculum developers and teachers should incorporate chemistry topics such as soil chemistry, nutrient transformators and environmental chemistry for inqury-based learning, and practical demonstration for real life agricultural environmental challenges. This teacher continuing professional development programmes promote interdisciplinary, inquiry-based teaching and problem-solving activities.

iii. Government and school authorities should provide relevant laboratory, farm and digital resources, including soil and water testing kits, fertilizer-testing equipment, climate data and appropriate instructional materials.

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