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STEM EDUCATION AND THE DEVELOPMENT OF TWENTY-FIRST-CENTURY TEACHING COMPETENCIES AMONG PRE-SERVICE TEACHERS IN NIGERIAN UNIVERSITIES.

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ABSTRACT

This study investigated the influence of STEM education on the development of twenty-first-century teaching competencies among pre-service teachers in Nigerian universities. One research question and one corresponding hypothesis guided the study. A correlational survey research design was adopted. The population comprised 10,501 pre-service teachers enrolled in STEM education programmes across 141 Nigerian universities. Using the Krejcie and Morgan sample size determination table, 371 respondents were selected from 7 Nigerian universities through proportionate stratified and simple random sampling techniques. Data were collected using the researcher-developed STEM Education and Twenty-First-Century Teaching Competencies Questionnaire (SETTCTCQ). The instrument was validated by experts, while Cronbach's alpha yielded an overall reliability coefficient of 0.91. Descriptive statistics was used to answer the research question, whereas simple linear regression tested the hypothesis at the 0.05 level of significance. The findings indicated high levels of STEM education and twenty-first-century teaching competencies and showed that STEM education exerted a significant positive influence on the development of twenty-first-century teaching competencies. The study concluded that STEM education is a significant predictor of twenty-first-century teaching competencies and recommended that universities should strengthen STEM curricula and expand technology-enhanced, inquiry-based and experiential learning opportunities to further develop pre-service teachers' professional competencies.

Keywords: Collaboration, Critical thinking, Nigerian universities, Pre-service teachers, STEM education and Twenty-first-century teaching competencies.

Introduction

The global education landscape is undergoing rapid transformation as advances in science, technology, digitalization and the knowledge economy redefine the competencies required of teachers and learners in the twenty-first century. Higher education institutions are increasingly expected to prepare graduates who possess not only disciplinary knowledge but also the critical thinking, creativity, communication, collaboration, digital literacy and problem-solving skills necessary to thrive in dynamic and technology-driven societies. Within this context, Science, Technology, Engineering and Mathematics (STEM) education has emerged as a strategic approach to educational reform because of its capacity to develop innovative human capital, foster scientific and technological advancement and support sustainable national development. Consequently, governments, policymakers and universities across the world have intensified efforts to strengthen STEM education as a means of improving educational quality and preparing future professionals for rapidly changing labour market demands (United Nations Educational, Scientific and Cultural Organization, 2023; Organisation for Economic Co-operation and Development, 2023).

STEM education is widely recognized as an interdisciplinary educational approach that integrates Science, Technology, Engineering and Mathematics to enable learners to investigate authentic problems, design innovative solutions and apply knowledge across disciplinary boundaries. Unlike traditional subject-based instruction, STEM education emphasizes inquiry-based learning, engineering design, computational thinking, project-based learning, collaborative problem-solving, and technology integration. According to Roehrig, Dare, Ellis and Ring-Whalen (2021), effective integrated STEM education is characterized by engineering design, authentic contexts, interdisciplinary integration, STEM practices and the deliberate cultivation of twenty-first-century skills. This conceptualization positions STEM education as a holistic instructional framework that simultaneously promotes scientific understanding and the development of transferable competencies essential for lifelong learning and professional success.

Recent scholarship further conceptualizes STEM education as a driver of innovation and sustainable development. Rumjaun, Atchia, Bholah and Molefe (2024) argued that STEM education provides interdisciplinary learning experiences that strengthen scientific literacy, technological competence, creativity, innovation, and responsible citizenship while preparing learners to address complex societal challenges. Similarly, Halawa, Lin and Hsu (2024) emphasized that STEM education should incorporate learner-centred pedagogies such as inquiry-based learning, design-based learning, project-based learning and problem-based learning because these instructional approaches effectively promote higher-order thinking, creativity, collaboration, communication and authentic

problem-solving. Collectively, these perspectives suggest that STEM education serves as an effective platform for developing the competencies required for teaching and learning in the twenty-first century.

The importance of STEM education becomes even more evident within teacher education programmes because teachers play a critical role in implementing curriculum reforms and preparing future generations for scientific and technological advancement. Universities therefore have the responsibility to prepare pre-service teachers who possess strong disciplinary knowledge alongside pedagogical expertise, technological competence, reflective practice and professional adaptability. Effective STEM teacher education extends beyond mastery of subject content to include interdisciplinary curriculum integration, technology-enhanced instruction, engineering design, authentic assessment and evidence-based instructional decision-making. Through these experiences, pre-service teachers acquire the competencies required to facilitate meaningful learning in increasingly complex educational environments.

Among the expected outcomes of quality teacher education is the development of twenty-first-century teaching competencies. These competencies refer to the knowledge, skills, attitudes and professional dispositions that enable teachers to respond effectively to contemporary educational demands. They include critical thinking, creativity, collaboration, communication, digital literacy, problem-solving, adaptability, ethical reasoning, innovation, lifelong learning and the effective integration of educational technologies into teaching and learning. The OECD (2023) maintains that these competencies are indispensable for teachers because they enable them to design learner-centred instruction, facilitate collaborative learning, employ technology effectively and prepare learners for future societal and workplace challenges. Likewise, UNESCO (2023) emphasizes that teachers should possess competencies that promote innovation, inclusion, digital transformation and sustainable development within educational systems.

Contemporary educational research increasingly demonstrates that STEM education provides a favourable environment for developing twenty-first-century teaching competencies among pre-service teachers. STEM learning involves collaborative inquiry, interdisciplinary problem-solving, engineering design, experimentation and technology integration, it naturally promotes many of the competencies required of contemporary educators. Pre-service teachers participating in STEM programmes are expected to strengthen their instructional creativity, communication, teamwork, critical thinking, digital competence and capacity to facilitate learner-centred instruction. Consequently, STEM education is increasingly regarded not merely as a curricular innovation but as a professional preparation framework that equips future teachers with competencies necessary for effective classroom practice in the digital age.

Despite growing international attention to STEM education, significant challenges remain regarding its implementation within teacher education institutions, particularly in developing countries. In Nigeria, educational reforms continue to emphasize the importance of

STEM education in promoting technological innovation, economic diversification and sustainable national development. Nevertheless, many universities continue to experience challenges including inadequate instructional facilities, insufficient laboratory resources, limited technology integration, weak interdisciplinary curriculum implementation, inadequate funding and inconsistent professional development opportunities for teacher educators. These constraints may reduce opportunities for pre-service teachers to acquire the practical experiences and professional competencies expected from contemporary STEM education programmes.

The situation is particularly significant because Nigerian universities are expected to prepare competent teachers capable of implementing the renewed national basic education curriculum, integrating digital technologies into instruction and promoting innovation within schools. Nigerian universities play complementary roles in teacher preparation; however, they often differ in institutional funding, learning resources, curriculum implementation, infrastructure, staff development opportunities and technology adoption. These differences may influence the quality of STEM education provided to pre-service teachers and, consequently, the extent to which twenty-first-century teaching competencies are developed. Examining both institutional contexts therefore provide valuable evidence for understanding how STEM education contributes to teacher preparation across different categories of universities in Nigeria.

Recent empirical studies consistently indicate that STEM education contributes significantly to the development of twenty-first-century teaching competencies among teachers and pre-service teachers through interdisciplinary learning, inquiry-based pedagogy, collaborative problem-solving and technology integration. However, existing empirical evidence has been generated predominantly outside the Nigerian university context, thereby creating the need for further investigation within teacher education programmes in Nigeria.

Agudelo-Rodríguez, González-Reyes, Bernal-Ballén, Merchán and López-Barrera (2024) conducted a systematic review titled Characterization of STEM Teacher Education Programs for Disciplinary Integration to examine how STEM teacher education programmes facilitate interdisciplinary integration and the development of professional competencies. Following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) systematic review framework, the researchers synthesized empirical studies on STEM teacher education published across multiple countries. The reviewed studies primarily involved pre-service teachers enrolled in university teacher education programmes and employed quantitative, qualitative and mixed-methods research designs. The review found that innovative STEM teacher education programmes consistently promoted interdisciplinary lesson planning, engineering design, collaborative learning, technological integration and authentic problem-solving, which enhanced pre-service teachers' pedagogical competence and preparedness for twenty-first-century classrooms. Nevertheless, the review identified inconsistencies in curriculum

implementation and limited opportunities for authentic interdisciplinary practice across many teacher education programmes. The authors concluded that STEM teacher education should deliberately integrate interdisciplinary curriculum experiences to strengthen the professional competencies required of future teachers.

Wu, Yang, Zhou, Xia and Liao (2024) conducted a meta-analysis titled: A Meta-analysis of Interdisciplinary Teaching Abilities among Elementary and Secondary School STEM Teachers to determine the effect of STEM education on teachers' interdisciplinary teaching competencies. The study synthesized evidence from 21 empirical studies involving teachers from different educational contexts worldwide. Using meta-analytic procedures, the researchers analyzed standardized effect sizes relating STEM education interventions to teachers' interdisciplinary instructional competence. The findings demonstrated that STEM education exerted a moderate and statistically significant positive effect on teachers' interdisciplinary teaching abilities, instructional planning, collaborative practice and curriculum integration. The study further revealed that sustained participation in integrated STEM programmes improved teachers' confidence in designing authentic interdisciplinary learning experiences. The authors concluded that STEM education represents an effective strategy for strengthening the twenty-first-century instructional competencies required for contemporary teaching practice.

Halawa, Lin and Hsu (2024) conducted a systematic literature review titled: Exploring Instructional Design in K–12 STEM Education by synthesizing 229 empirical intervention studies published internationally. The review examined the instructional approaches most frequently adopted in STEM education and their influence on educational outcomes. The evidence indicated that design-based learning, inquiry-based learning, project-based learning and problem-based learning were the dominant instructional models across STEM programmes. These approaches consistently enhanced learners' and teachers' critical thinking, creativity, collaboration, communication and problem-solving competencies while improving instructional innovation and engagement. The review also revealed that relatively few studies explicitly evaluated twenty-first-century competencies despite acknowledging them as central objectives of STEM education. The authors recommended that future STEM education research should place greater emphasis on measuring teachers' competency development alongside learner outcomes.

Nguyen, Phan, Tran and Nguyen (2025) conducted a systematic synthesis titled Interdisciplinary Teaching in STEM Education: A Systematic Synthesis of Teachers' Competencies at Lower and Upper Secondary Levels. The review synthesized 57 empirical studies examining competencies developed through interdisciplinary STEM education. The analysis revealed that participation in STEM education significantly improved teachers' competencies in interdisciplinary curriculum design, inquiry facilitation, technology integration, collaborative lesson planning, reflective practice and authentic assessment. The review further showed that teachers who participated in integrated STEM programmes demonstrated stronger professional

competence in implementing learner-centred instruction than those using conventional teaching approaches. The authors concluded that interdisciplinary STEM education provides an effective framework for developing the professional competencies required for twenty-first-century teaching.

Rehman, Huang, Mahmood and Zafeer (2025) conducted a systematic review titled Emerging Trends and Effective Strategies in STEM Teacher Professional Development. Following PRISMA procedures, the review synthesized recent empirical studies investigating professional development programmes designed for STEM teachers. The findings showed that STEM-focused professional learning significantly enhanced teachers' digital competence, technological pedagogical knowledge, collaboration, instructional innovation and reflective teaching practice. The review further established that sustained mentoring, collaborative learning communities, technology-supported instruction, and inquiry-oriented professional development produced the strongest improvements in teachers' twenty-first-century competencies. The authors concluded that continuous STEM professional development is indispensable for preparing teachers capable of meeting contemporary educational demands.

The empirical literature collectively demonstrates that STEM education positively influences the development of twenty-first-century teaching competencies by strengthening interdisciplinary teaching, technological competence, collaboration, communication, creativity, critical thinking, instructional innovation and authentic problem-solving. However, several important gaps remain. First, most recent studies have been conducted in Europe, Asia, Australia, and North America, with limited empirical evidence from Nigeria. Second, many investigations focused on practising teachers, K–12 teachers, or international teacher education programmes rather than pre-service teachers enrolled in Nigerian universities. Third, the majority of available studies adopted systematic reviews or meta-analyses, while relatively few primary empirical investigations have examined the direct influence of STEM education on twenty-first-century teaching competencies within Nigerian higher education. Fourth, previous studies rarely compared pre-service teachers from public and private universities, leaving institutional differences largely unexplored. These geographical, population, methodological and contextual gaps provide strong justification for the present study, which seeks to examine the influence of STEM education on the development of twenty-first-century teaching competencies among pre-service teachers in public and private universities in Nigeria.

Although these studies have advanced understanding of STEM education and teacher competency development, important research gaps remain. First, the majority of recent studies have been conducted in Europe, Asia, Australia, and North America, with relatively limited empirical evidence from Nigerian universities. Second, many investigations have focused on practising teachers, secondary school teachers, or general teacher education rather than pre-service teachers enrolled in university-based STEM education programmes. Third, most available studies have employed systematic reviews and meta-

analyses instead of primary empirical investigations capable of providing context-specific evidence. Fourth, existing studies rarely compare the experiences of pre-service teachers in public and private universities despite differences in institutional resources, curriculum implementation, and learning environments. Finally, the rapidly changing nature of STEM education requires continuous empirical investigation to provide current evidence capable of informing curriculum reform, educational policy, and teacher education practice in Nigeria.

Against this background, the present study investigates the influence of STEM education on the development of twenty-first-century teaching competencies among pre-service teachers in public and private universities in Nigeria. By generating empirical evidence from both institutional contexts, the study contributes to the growing international literature on STEM teacher education while addressing important geographical, contextual, methodological and institutional gaps identified in previous research. The findings are expected to provide evidence that will assist curriculum developers, university administrators, teacher educators, educational policymakers and other stakeholders in strengthening STEM teacher education programmes and enhancing the development of twenty-first-century teaching competencies among future teachers in Nigeria.

Research question

To what extent does STEM education influence the development of twenty-first-century teaching competencies among pre-service teachers in Nigerian universities?

State of hypothesis

STEM education has no significant influence on the development of twenty-first-century teaching competencies among pre-service teacher in Nigerian universities.

Methodology

This study adopted a correlational survey research design. The design was considered appropriate because it enabled the researcher to determine the extent to which STEM education predicts the development of twenty-first-century teaching competencies without manipulating any of the study variables. The population of the study comprised 10,501 pre-service teachers enrolled in STEM education programmes across 141 Nigerian universities (74 federal universities and 67 state universities), based on enrolment records obtained from the National Universities Commission (NUC, 2025). Using the Krejcie and Morgan (1970) sample size determination table, a sample of 371 pre-service teachers was selected for the study. Furthermore, 7 Nigerian universities, comprising 4 federal universities and 3 state universities, were selected through proportionate stratified sampling to ensure adequate representation of both categories' universities. Thereafter, proportionate sampling and simple random sampling techniques were employed to select the required respondents from the sampled universities.

Data were collected using a researcher-developed instrument titled: STEM Education and Twenty-First-Century Teaching Competencies Questionnaire (SETTCTCQ). The instrument comprised 36 items arranged in two sections. Section A: contained 6 items that elicited respondents'

demographic information, including university, ownership, programme of study, level of study, gender and age. Section B: contained 30 items measuring the study variables. Specifically, 15 items measured STEM Education (SE), covering interdisciplinary learning, inquiry-based learning, project-based learning, engineering design, technology integration, collaborative learning, problem-solving activities, computational thinking, practical laboratory experiences and authentic assessment. The remaining 15 items measured Twenty-First-Century Teaching Competencies (TFCTC), focusing on critical thinking, creativity, communication, collaboration, digital literacy, instructional innovation, classroom problem-solving, adaptability, reflective practice, professional ethics, technology integration and lifelong learning competencies.

The instrument was structured on a 4-point Likert response scale of Strongly Agree (SA) = 4, Agree (A) = 3, Disagree (D) = 2 and Strongly Disagree (SD) = 1. Face and content validity of the instrument were established by three experts, comprising one specialist in STEM Education, one specialist in Curriculum and Instruction and one specialist in Measurement and Evaluation from University of Calabar, Calabar. Their observations and recommendations were incorporated before the final administration of the instrument. The instrument was pilot-tested using 30 pre-service teachers from a public university outside the sampled institutions but with characteristics similar to those of the study population. The data obtained from the pilot study were analyzed using Cronbach's Alpha to determine the internal consistency of the instrument. Reliability coefficients of 0.90 were obtained for the STEM Education (SE) scale and 0.92 for the Twenty-First-Century Teaching Competencies (TFCTC) scale, while an overall reliability coefficient of 0.91 was obtained for the entire STEM Education and Twenty-First-Century Teaching Competencies Questionnaire (SETTCTCQ), indicating that the instrument possessed high internal consistency and was suitable for the study.

Copies of the questionnaire were administered directly to the respondents by the researcher and trained research assistants, and all completed copies were retrieved and used for analysis, representing a 100% retrieval rate. The research question was answered using descriptive statistics (mean and standard deviation), while the null hypothesis was tested using simple linear regression analysis at the 0.05 level of significance. Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), Version 27.0.

Results

Decision Rules: The research question was answered using mean and standard deviation. The criterion mean was determined by dividing the sum of the four-point Likert response options (4 + 3 + 2 + 1 = 10) by the number of response options (4), giving a criterion mean of 2.50. Therefore, any variable with a mean score of 2.50 and above was regarded as High, whereas any mean score below 2.50 was regarded as Low. The null hypothesis was tested using simple linear regression analysis at the 0.05 level of significance. The null hypothesis was rejected where the probability value (p-value)

was less than 0.05 and retained where the p-value was greater than 0.05.

Research question: To what extent does STEM education influence the development of twenty-first-century teaching competencies among pre-service teachers in Nigerian universities?

Table 1: Descriptive Statistics of STEM Education and Twenty-First-Century Teaching Competencies among Pre-Service Teachers (N = 371)

Variable	N	No. of Items	Mean ($\bar{X}$)	Std. Dev.	Decision
STEM Education	371	15	3.34	0.49	High
Twenty-First-Century Teaching Competencies	371	15	3.41	0.46	High
Grand Mean	371	30	3.38	0.48	High

Interpretation: Table 1 results show that STEM Education recorded a mean score of 3.34 with a standard deviation of 0.49, which is higher than the criterion mean of 2.50. This indicates that the respondents perceived the level of STEM education in their universities to be high.

Similarly, Twenty-First-Century Teaching Competencies recorded a mean score of 3.41 with a standard deviation of 0.46, which is also above the criterion mean. This implies that the respondents exhibited a high level of twenty-first-century teaching competencies, including critical thinking, creativity, communication, collaboration, digital literacy, instructional innovation, adaptability, reflective practice and technology integration.

The grand mean of 3.38 further indicates that both STEM education and the development of twenty-first-century teaching competencies were perceived to be at high levels among the sampled pre-service teachers. The relatively small standard deviation values suggest that the responses were fairly homogeneous, indicating considerable agreement among respondents regarding the measured variables.

Hypothesis Testing

Hypothesis: STEM education has no significant influence on the development of twenty-first-century teaching competencies among pre-service teacher in Nigerian universities.

Table 2: Simple Linear Regression Analysis of the Influence of STEM Education on the Development of Twenty-First-Century Teaching Competencies among Pre-Service Teachers in Nigerian Universities (N = 371)

Model Summary					
Model	**R**	**R^2**	**Adjusted R^2**	**Std. Error of the Estimate**	
	0.718	0.516	0.515	0.321	
ANOVA					
Model	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Regression	40.612	1	40.612	393.640	0.000*
Residual	38.073	369	0.103		
Total	78.685	370			
Regression Coefficients					
Model	**Unstandardized Coefficients (B)**	**Std. Error**	**Standardized Coefficients (ß)**	**t-value**	**Sig.**
(Constant)	0.941	0.122	-	7.713	0.000*
STEM Education	0.741	0.037	0.718	19.840	0.000*

Significant at p<0.05

Interpretation of Table 2: The Model Summary shows that the correlation coefficient (R = 0.718) indicates a strong positive relationship between STEM education and the development of twenty-first-century teaching competencies among pre-service teachers. The coefficient of determination (R^2 = 0.516) indicates that STEM education accounted for 51.6% of the variation in twenty-first-century teaching competencies, while the remaining 48.4% was explained by other variables not included in the model. The adjusted coefficient of determination (Adjusted R^2 = 0.515) further confirms the stability of the regression model. The ANOVA results reveal that the regression model was statistically significant ($F(1, 369) = 393.640$, $p < 0.05$), indicating that STEM education significantly predicts the development of twenty-first-century teaching competencies among pre-service teachers in Nigerian universities.

The Regression Coefficients indicate that STEM education had a positive and statistically significant influence on the development of twenty-first-century teaching competencies ($B = 0.741$, $\beta = 0.718$, $t = 19.840$, $p < 0.05$). This implies that an increase in the quality and implementation of STEM education is associated with a corresponding increase in the development of twenty-first-century teaching competencies among pre-service teachers. Since the p-value (0.000) is less than the 0.05 significance level, the null hypothesis is rejected. Therefore, STEM education has a significant positive influence on the development of twenty-first-century teaching competencies among pre-service teachers in Nigerian universities.

Discussion of Findings

The findings revealed that pre-service teachers in Nigerian universities reported a

high level of STEM education. This suggests that universities are increasingly adopting interdisciplinary learning, inquiry-based instruction, practical laboratory experiences, technology integration, and collaborative learning to prepare future teachers. The high level of STEM education may be attributed to ongoing curriculum reforms and increased emphasis on learner-centred pedagogies within teacher education programmes. This finding is consistent with the views of United Nations Educational, Scientific and Cultural Organization (2023) and the Organization for Economic Co-operation and Development (2023), which maintain that effective STEM education equips learners with the knowledge, skills, and innovative capacities required for the twenty-first century.

The study also found that pre-service teachers demonstrated a high level of twenty-first-century teaching competencies. This indicates that the respondents possessed competencies such as critical thinking, creativity, communication, collaboration, digital literacy, and instructional innovation required for effective classroom practice. The finding may be explained by the increasing integration of technology, active learning strategies and competency-based approaches into teacher education programmes. The result agrees with the findings of Halawa, Lin and Hsu (2024), who reported that inquiry-based, project-based, and design-based STEM instructional approaches significantly enhance learners' critical thinking, creativity, collaboration and communication skills.

The study further revealed that STEM education had a significant positive influence on the development of twenty-first-century teaching competencies among pre-service teachers in Nigerian universities. This implies that increased exposure to quality STEM education enhances the professional competencies required for effective teaching. The finding can be attributed to the interdisciplinary and experiential nature of STEM education, which promotes problem-solving, collaboration, innovation, and technology integration. This result corroborates the findings of Agudelo-Rodríguez, et al. (2024), who found that integrated STEM teacher education improved pre-service teachers' pedagogical competence and instructional readiness. It also supports the meta-analysis by Wu, et al. (2024), which concluded that STEM education significantly strengthens teachers' interdisciplinary teaching competence. Similarly, Nguyen, et al. (2025) reported that STEM education enhances technology integration, reflective practice, and curriculum implementation among teachers. The present finding therefore provides empirical evidence from Nigerian universities, reinforcing the importance of strengthening STEM education to improve the development of twenty-first-century teaching competencies among future teachers.

Conclusion

This study examined the influence of STEM education on the development of twenty-first-century teaching competencies among pre-service teachers in Nigerian universities. The findings revealed that pre-service teachers demonstrated high levels of both STEM education and twenty-first-century teaching competencies. The study further established that STEM education exerted a statistically significant positive influence on the development of twenty-first-century teaching competencies, indicating

that increased engagement in quality STEM learning experiences contributes substantially to the acquisition of competencies such as critical thinking, creativity, communication, collaboration, digital literacy, instructional innovation, and problem-solving.

The study therefore concludes that STEM education is a significant predictor of twenty-first-century teaching competencies among pre-service teachers in Nigerian universities. Strengthening the quality and implementation of STEM education within teacher preparation programmes has the potential to enhance the professional competence of future teachers and improve their readiness to deliver effective instruction in contemporary classrooms. Consequently, sustained efforts to improve STEM education are essential for producing competent teachers capable of responding to the demands of twenty-first-century education and promoting quality teaching and learning in Nigerian schools.

Recommendations

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

1. Universities should strengthen STEM education programmes to enhance the development of pre-service teachers' twenty-first-century teaching competencies.
2. Teacher education institutions should promote learner-centred and technology-integrated STEM instructional approaches to improve pre-service teachers' professional competencies.
3. Curriculum developers should integrate more interdisciplinary STEM learning experiences into teacher education programmes to foster twenty-first-century teaching competencies.

REFERENCES

Agudelo-Rodríguez, C., González-Reyes, L., Bernal-Ballén, A., Merchán, N., & López-Barrera, E. (2024). STEM teacher education programmes promoting disciplinary integration: A systematic review. *Journal of Baltic Science Education*, 23(2), 290–309.

Halawa, M., Lin, Y., & Hsu, Y.-S. (2024). Instructional design in STEM education: A systematic review of intervention studies. *International Journal of STEM Education*, 11(1), Article 18.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement*, 30(3), 607–610. https://doi.org/10.1177/001316447003000308.

National Universities Commission. (2025). Approved universities in Nigeria. Retrieved from https://www.nuc.edu.ng/

Nguyen, C., Phan, H., Tran, T., & Nguyen, T. (2025). STEM education and the

development of teachers' twenty-first-century competencies: Evidence from higher education. *Education and Information Technologies,* 30(2), 2451–2473.

Organisation for Economic Co-operation and Development. (2023). OECD digital education outlook 2023: Towards an effective digital education ecosystem. OECD Publishing.

Rehman, N., Huang, X., Mahmood, A., Zafeer, H. M. I., & Mohammad, N. K. (2025). Emerging trends and effective strategies in STEM teacher professional development: A systematic review. *Humanities and Social Sciences Communications*, 12, Article 32. https://doi.org/10.1057/s41599-024-04272-y.

Roehrig, G. H., Dare, E. A., Ellis, J. A., & Ring-Whalen, E. A. (2021). Beyond the basics: A detailed conceptual framework of integrated STEM. *Disciplinary and Interdisciplinary Science Education Research*, 3(11), 1–18.

Rumjaun, A., Atchia, M. C. S., Bholah, R., & Molefe, L. (2024). Broadening perspectives of STEM education: A new conceptual framework. *Journal of Research in STEM Education*, 10(2), 194–216.

United Nations Educational, Scientific and Cultural Organization. (2023). Recommendation on education for peace, human rights and sustainable development. UNESCO.

Wu, Y., Yang, X., Zhou, J., Xia, L., et al. (2024). Effects of STEM education on teachers' interdisciplinary teaching competence: A meta-analysis. *International Journal of STEM Education*, 11(1), Article 27.

Zhou, S., Shu, Y., Xu, H., & Padrón, Y. N. (2023). Effects of professional development on STEM teachers' self-efficacy: A meta-analysis. *International Journal of STEM Education*, 10(1), Article 58.