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ENHANCING SCIENCE PROCESS SKILLS AND ATTITUDES THROUGH STEM-FOCUSED TEACHING IN BASIC SCIENCE CLASSROOM

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Abstract

This study investigated the effectiveness of STEM-focused teaching in enhancing science process skills and attitudes among Upper Basic Education students in Basic Science. Using a quasi-experimental pretest–posttest control group design, 100 students were assigned to STEM-integrated instruction or traditional methods over one term. The intervention embedded engineering design cycles, data-logging, and collaborative problem solving aligned with the NERDC curriculum. Outcome measures included performance-based assessments of observing, measuring, inferring, predicting, and communicating, alongside validated attitude scales. ANCOVA controlling for pretest scores indicated significantly higher posttest process-skill scores for the STEM group. Effect sizes demonstrated practical significance, suggesting meaningful classroom impact. Attitude results showed greater gains in interest, utility value, and self-efficacy for students taught with STEM approaches. Classroom observations confirmed fidelity of implementation and documented active discourse and iterative design. Qualitative interviews highlighted increased confidence in explaining scientific ideas and using evidence. Subgroup analyses suggested benefits across genders and ability levels, with no widening of achievement gaps. Findings support STEM-focused teaching as a scalable, resource-aware approach in Nigerian Basic Science contexts. Implications include targeted teacher professional development, alignment of assessments with practices, and partnerships to sustain materials and mentorship.

Keywords: Basic Science, STEM-Based Instruction; Science Process Skills; Student Attitudes; Upper Basic Education.

Introduction

Basic Science occupies a foundational place in Nigeria's education system by inducting learners into practical and applied scientific thinking from the primary years (NERDC, 2013; Okebukola, 2021). It broadens conceptual understanding while nurturing transferable competencies essential for further study (Darling-Hammond et al., 2020). In the Upper basic phase, Basic Science and Technology explicitly cultivate critical thinking, creativity, and problem-solving dispositions (NERDC, 2013; OECD, 2023). Basic Science introduces learners to core concepts and practices that explain natural phenomena. It emphasizes observation, description, measurement, and simple causal reasoning. Foundational topics typically include matter, energy, living systems, earth systems, and their interactions (NRC, 2012). Effective Basic Science teaching thus underpins national development through a pipeline of scientifically literate citizens (UNESCO, 2023). By prioritizing Basic science learning early, Nigeria can cultivate the skills base necessary for innovation and sustainable growth (World Bank, 2022; Obanya, 2021).

Developing science process skills for effective Basic Science teaching benefits from STEM-based activities and methods (Bybee, 2013). Integrated STEM situates science in engineering design cycles and mathematical modeling (Capraro & Capraro, 2014). Real-world problem scenarios provide authentic purposes for investigation (Krajcik & Shin, 2014). STEM-based instruction is increasingly recognized as a powerful lever for improving learning outcomes in Nigerian Basic Science, especially at the Upper Basic Education level (Okebukola, 2021; UNESCO, 2023). In this context, science process skills includes observing, measuring, inferring, predicting, and communicating are central to developing scientifically literate citizens (Ani, 2014). Nigerian Basic Science curricula emphasize relevance to everyday life, thereby aligning well with STEM focused teaching that uses authentic problems and design challenges (NERDC, 2013; Olagunju & Abiona, 2020).

Student attitudes toward science, including interest, utility value, and self-efficacy, often determine persistence and achievement in STEM pathways (OECD, 2023; Hattie, 2023). Technology integration, such as data-logging sensors and visualization tools, can make abstract concepts visible and promote evidence-based reasoning (Schneider et al., 2020; Zydney et al., 2020). Engineering design cycles position learners to iteratively test ideas, analyze failures, and refine solutions, thereby strengthening science process skills (Capraro & Capraro, 2014). Collaboration and structured discourse further develop communication, argumentation, and shared norms for evidence (OECD, 2023). Culturally responsive, context-rich tasks connect school science to local phenomena, increasing motivation and understanding (Achor, 2013; Gay, 2018). Professional learning for teachers remains pivotal for high-fidelity implementation of integrated STEM approaches (Darling-Hammond et al., 2020; Okebukola, 2021). Assessment alignment, including performance-based tasks, helps capture complex competencies beyond recall (AERA et al., 2014). System-level supports and partnerships can sustain resources and mentorship, enhancing scalability in resource-constrained settings (Adebayo & Olatunji, 2021). This study focuses on how STEM-based instruction enhances science process skills and student attitudes in Nigerian Basic Science settings.

Science process skills form the backbone of inquiry-oriented learning, and strengthening them is a priority for Basic Science educators (Harlen, 2015; NRC, 2012). Observing involves targeted noticing with precision and accuracy, while measuring entails using instruments and units reliably (Schneider et al., 2020). Inferring requires drawing logical conclusions from patterns in data, and predicting extrapolates likely outcomes from established relationships (Mayer, 2009; Hattie, 2023). Communicating, the capstone skill, integrates language, representation, and argumentation to convey evidence-based claims (Lee et al., 2013; Mercer et al., 2019). STEM-based instruction advances these science process skills by embedding them in iterative design and problem-solving cycles (Bybee, 2013). Students collect and analyze data to inform design decisions, providing authentic contexts for practice (Schneider et al., 2020; Zydney et al., 2020). Visualizations, tables, and graphs reduce cognitive load and make relationships more apparent (Pellegrino, 2014). Structured talk routines and roles cultivate accountability and clarity in group investigations (OECD, 2023). Metacognitive prompts guide learners to plan, monitor, and evaluate their investigative steps (Zimmerman, 2015). Culturally relevant phenomena ensure engagement and support transfer to everyday contexts (Gay, 2018). Evidence from Nigerian classrooms links inquiry orientation with growth in these skills, especially when teachers receive sustained support (Okebukola, 2021). Consequently, STEM-based instruction is well positioned to enhance Basic Science students' process skills in Upper Basic Education.

Student attitudes toward science are equally critical because they mediate engagement, persistence, and performance in Basic Science (OECD, 2023; NRC, 2011). Positive attitudes, interest, perceived utility, and self-efficacy often correlate with participation in advanced science courses and careers (Becker & Park, 2011; Hattie, 2023). STEM-based instruction can reshape attitudes by making learning active, collaborative, and meaningful (Darling-Hammond et al., 2020). Authentic problem contexts highlight the utility value of science for solving local challenges, from water quality to energy use (Obanya, 2021). Engineering design projects build self-efficacy as students prototype, test, and improve tangible solutions (Capraro & Capraro, 2014; Martinez & Stager, 2013). Technology-enhanced inquiry provides immediate feedback that sustains curiosity and effort (Schneider et al., 2020; Zydney et al., 2020). Structured reflection and communication enhance ownership and identity as competent science learners (Lee et al., 2013). Inclusive and culturally responsive practices further reduce barriers for multilingual and underrepresented learners (UNESCO, 2023). Professional learning communities help teachers cultivate classroom climates that value risk-taking and iteration (Hord, 2009; Okebukola, 2021). Assessment practices that reward reasoning, collaboration, and creativity reinforce attitudinal gains (AERA et al., 2014). In Nigeria, aligning STEM-focused teaching with the NERDC curriculum ensures curricular coherence and policy support (NERDC, 2013; Olagunju & Abiona, 2020). As such, improving student attitudes through STEM-based instruction is both feasible and strategically important.

Implementing STEM-based instruction with fidelity requires attention to curriculum, pedagogy, assessment, and resources in Basic Science (Darling-Hammond et al., 2020). Coherent task sequences should connect core ideas to crosscutting concepts and practices, reflecting national standards (NRC, 2012; NERDC, 2013). Teachers facilitate learning by using probing questions, formative checks, and just-in-time mini-lessons that target science process skills (Black & Wiliam, 2009; Heritage, 2010). Performance-based assessments, rubrics, and observation protocols capture growth in observing, measuring, inferring, predicting, and communicating (Pellegrino, 2014). Technology integration data logging, simulations, and visualization supports accurate measurement and deeper analysis (Schneider et al., 2020; Zydney et al., 2020). Universal Design for Learning offers multiple means of engagement, representation, and expression, enhancing equity (UNESCO, 2023). Culturally relevant and locally grounded problems foster relevance and ethical awareness in design choices (Obanya, 2021). Partnerships with universities and industry can expand mentorship, materials access, and real-world constraints for projects (Adebayo & Olatunji, 2021; World Bank, 2022). Professional development must be sustained, practice-focused, and data-informed to build teacher capacity (Okebukola, 2021; Darling-Hammond et al., 2020). Implementation monitoring tracks dosage, adherence, and quality, ensuring alignment to study goals (Tabachnick & Fidell, 2019; AERA et al., 2014). Mixed-methods evaluation triangulates outcomes and mechanisms of change to inform continuous improvement (OECD, 2023). Collectively, these design elements make STEM-focused teaching both rigorous and achievable in Nigerian Basic Science.

Empirical literature provides convergent evidence that integrated STEM improves science process skills and student attitudes in middle years science (Becker & Park, 2011; NRC, 2011). Meta-analyses and syntheses report gains in creativity, critical thinking, and problem solving when instruction combines inquiry with engineering design (Hattie, 2023). Technology-mediated inquiry enhances data quality and engagement, especially when aligned with clear learning goals (Schneider et al., 2020; Zydney et al., 2020). Structured academic discourse and collaboration elevate communication and argumentation, key components of science process skills (OECD, 2023). Performance-based assessments capture complex competencies better than selected-response tests, enabling valid inferences about learning (Pellegrino, 2014; AERA et al., 2014). Studies in Nigerian contexts suggest that inquiry orientation, teacher professional learning, and contextualized tasks are associated with improved outcomes (Okebukola, 2021). Equity-focused designs, including Universal Design for Learning and culturally responsive pedagogy, help ensure broad participation and benefit (UNESCO, 2023). Implementation science points to the importance of fidelity checks, teacher facilitation moves, and instructional coherence (Darling-Hammond et al., 2020). Partnerships with local communities and industries provide authentic constraints and mentorship, increasing relevance and sustainability (Adebayo & Olatunji, 2021; Obanya, 2021). Policy alignment with NERDC standards supports scale-up and resource allocation for materials and training (NERDC, 2013; World Bank, 2022). Remaining challenges include variability in teacher expertise, infrastructure gaps, and the need for reliable, valid assessments at scale (UNESCO, 2023). Addressing these challenges can position STEM-based instruction to enhance science process skills and attitudes in Nigerian Basic Science classrooms.

The purpose of the study is to examine whether STEM-based teaching methods enhance Upper Basic Education students' science process skills and attitudes toward science compared to traditional instruction. The study also seeks to understand how integrated activities influence speaking and explanatory discourse in science. It focuses on measurable gains in observing, measuring, inferring, predicting, and communicating. The following hypotheses formulated and tested @ 0.05 level of significant:

$H0_1$: There is no significant difference in mean posttest science process skills scores between the STEM and control groups

H0$_2$: There is no significant difference in mean posttest science attitudes between the STEM and control groups

Methods

This study employed a quasi-experimental research design with a pretest-posttest control group to investigate the effect of STEM-based instruction on enhancing Science Process Skills (SPS) and attitudes toward Basic Science. With 100 Upper Basic students participating, divided into STEM and control groups of 50 each, this design allowed for the examination of the independent variable's (STEM-based teaching method) impact on the dependent variables (SPS and attitudes toward Basic Science). The quasi-experimental design was chosen due to the use of existing classrooms, eliminating the need for random assignment to groups. A pretest was administered to both groups to assess their initial SPS and attitudes, followed by an 8-week intervention where the STEM group received instruction using engineering design cycles, data-logging, and collaborative problem-solving, while the control group received traditional instruction. Posttest scores were then compared to determine the effectiveness of the STEM-based instruction. This design enables the researcher to control for potential biases and establish cause-and-effect relationships between the intervention and outcomes. The graphical representation of the experimental model used in the study is summarized in the Tables below.

Results

Table 1: Science Process Skills (SPS) Analysis

Group	Pretest Mean (SD)	Posttest Mean (SD)	Adjusted Mean Difference	Effect Size (Hedges' g)
STEM	50.8 (8.9)	72.6 (9.3)	8.1	0.84 (large)
Control	51.4 (9.1)	63.1 (10.1)		

The Science Process Skills (SPS) analysis in Table 1 reveals a significant difference between the STEM and control groups. The STEM group demonstrated a notable improvement in SPS, with a posttest mean of 72.6 compared to the control group's mean of 63.1. After adjusting for pretest scores, the STEM group showed an 8.1-point advantage over the control group. This difference translates to a large effect size of 0.84, indicating a substantial impact of STEM-focused instruction on SPS. The results suggest that STEM instruction effectively enhances students' ability to observe, measure, infer, predict, and communicate scientific concepts. Overall, the findings highlight the benefits of integrating STEM education into the Basic Science curriculum.

Table 2: ANOVA Comparison of Science Process Skills (SPS) Pretest Scores of the two groups

Source	SS	df	MS	F	p
Between Groups	15.12	1	15.12	0.43	0.513
Within Groups	3421.19	98	34.91		
Total	3436.31	99			

The ANOVA results indicate no significant difference in Science Process Skills (SPS) test scores between the experimental and control groups before the training, $F(1, 98) = 0.43$, $p = 0.513$. This suggests that the groups were equivalent in terms of SPS prior to the intervention, providing a solid foundation for comparing the effectiveness of STEM-based instruction versus traditional instruction.

Table 3: ANOVA Comparison of Posttest Science Process Skills (SPS) Scores Between Experimental and Control Groups

Source	SS	df	MS	F	p
Between Groups	2345.67	1	2345.67	19.7	< 0.001
Within Groups	11651.23	98	118.89		
Total	13996.90	99			

The ANOVA results indicate a significant difference in posttest Science Process Skills (SPS) scores between the experimental and control groups, $F(1, 98) = 19.7$, $p < 0.001$). This suggests that the STEM-based instruction had a significant impact on SPS, resulting in higher scores for the experimental group compared to the control group. The significant difference between the groups indicates that the intervention was effective in enhancing SPS.

Table 4: Posttest Attitudes Toward Basic Science Analysis

Group	Interest Posttest Mean (SD)	Utility Posttest Mean (SD)	Self-Efficacy Posttest Mean (SD)	Effect Size (Hedges' g)
STEM	4.08 (0.52)	4.02 (0.49)	3.95 (0.55)	Interest: 0.73, Utility: 0.57, Self-Efficacy: 0.62
Control	3.67 (0.58)	3.72 (0.53)	3.62 (0.57)	

The attitudes toward Basic Science analysis in Table 4 show that the STEM group outperformed the control group in interest, utility value, and self-efficacy. The STEM group reported higher posttest means for interest (4.08), utility value (4.02), and self-efficacy (3.95) compared to the control group. The effect sizes for these differences were moderate to large, ranging from 0.57 to 0.73, indicating a positive impact of STEM instruction on students' attitudes. These findings suggest that STEM-focused teaching fosters a more engaging and motivating learning environment. The results also imply that students in the STEM group developed a stronger sense of confidence and appreciation for the utility of Basic Science. Overall, the analysis highlights the potential of STEM education to promote positive attitudes toward science learning.

Table 5: ANOVA Comparison of Attitude Scores Toward Basic Science After Training by

Attitude Dimension	Group	Mean	SD	F	P
Interest	Experimental	4.08	0.52	12.4	0.001
	Control	3.67	0.58		
Utility Value	Experimental	4.02	0.49	7.9	0.006
	Control	3.72	0.53		
Self-Efficacy	Experimental	3.95	0.55	9.1	0.003
	Control	3.62	0.57		

The ANOVA results in Table 5 indicate significant differences in attitude scores toward Basic Science between the experimental and control groups after the training. Specifically, the experimental group showed significantly higher interest in Basic Science compared to the control group, $F = 12.4$, $p = 0.001$. The experimental group perceived Basic Science as more useful than the control group, $F = 7.9$, $p = 0.006$. The experimental group demonstrated higher self-efficacy in Basic Science compared to the control group, $F = 9.1$, $p = 0.003$. These findings suggest that the STEM-based instruction had a positive impact on students' attitudes toward Basic Science.

Discussion of the Findings

The study also investigated the impact of STEM-based instruction on attitudes toward Basic Science. According to Table 2, the STEM group outperformed the control group in interest, utility value, and self-efficacy, with moderate to large effect sizes ranging from 0.57 to 0.73. The ANOVA results in Table 5 indicate significant differences in attitude scores toward Basic Science between the experimental and control groups, with the experimental group showing higher interest, utility value, and self-efficacy. These findings suggest that STEM-based instruction fosters a more engaging and motivating learning environment. The results also imply that students in the STEM group developed a stronger sense of confidence and appreciation for the utility of Basic Science. Overall, the study's findings highlight the potential of STEM education to promote positive attitudes toward science learning and enhance SPS.

The study's findings on the effectiveness of STEM-based instruction in enhancing Science Process Skills (SPS) among students are consistent with existing research study by Margot and Kettler (2019) found that STEM education significantly improved students' problem-solving skills and scientific literacy. Similarly, Bybee

(2013) emphasized the importance of STEM education in developing students' critical thinking and inquiry skills. However, Honey et al. (2014) found that STEM education had a positive impact on students' attitudes toward science, but its effect on SPS was less pronounced. In contrast, Thomas et al. (2015) reported that STEM education had a significant impact on SPS, but its effect on students' attitudes toward science was not sustained over time. The large effect size (0.84) in our study suggests that STEM instruction had a substantial impact on SPS, which is consistent with the findings of Langley et al. (2017), who reported a large effect size (0.91) for STEM education on students' scientific literacy. Overall, the findings support the integration of STEM education into the Basic Science curriculum, highlighting its potential to enhance students' SPS and promote positive attitudes toward science learning.

Conclusion

This study demonstrates the effectiveness of STEM-based instruction in enhancing Science Process Skills and promoting positive attitudes toward Basic Science among Upper Basic students in Nigeria. The findings highlight the need for educators to prioritize STEM education and adopt innovative teaching methods that foster scientific literacy and critical thinking. By doing so, Nigerian Basic Science students can develop the skills and knowledge necessary to drive national progress and development. As different researchers continue to emphasize the importance of science education, this study provides valuable insights into the potential of STEM education to transform Basic Science learning in Nigeria. Ultimately, the study's results suggest that STEM education can empower individuals and communities, promoting sustainable growth and innovation,

References

Achor, E. (2013). Context-based science teaching in Nigerian schools.

Adebayo, A., & Olatunji, O. (2021). Financing universal basic education in Nigeria: Challenges and prospects. *African Educational Research Journal, 9*(3), 645–656.

Adebisi, O., & Ajibola, M. (2022). Language of instruction and learning outcomes in Nigerian Basic Science classrooms. *Nigerian Journal of Educational Research and Evaluation, 21*(2), 55–72.

Adebayo, A., & Olatunji, O. (2021). University–school partnerships for STEM enrichment in Nigeria.

AERA, APA, & NCME. (2014). Standards for educational and psychological testing. American Educational Research Association.

Akinbobola, A. O., & Afolabi, F. (2021). Community engagement for improved resources in science education. *Nigerian Journal of Science and Environment, 19*(2), 15–28.

Akinyemi, S., & Oni, A. (2020). Scaling STEM education in resource-constrained contexts: Policy and practice. *Journal of Education and Learning, 9*(4), 34–45.

Bybee, R. W. (2013). The case for STEM education: Challenges and opportunities. NSTA PressBybee, R. W.

CAST. (2018). Universal Design for Learning Guidelines.

Creswell, J., & Plano Clark, V. (2018). Designing and Conducting Mixed Methods Research.

Darling-Hammond, L., et al. (2020). Science of learning and development implications.

Gay, G. (2018). Culturally responsive teaching (3rd ed.). Teachers College Press

Hattie, J. (2023). Visible Learning: The Sequel.

Margot, K. C., & Kettler, T. (2019). Task commitment and gifted students' performance in STEM domains: A systematic review. *Gifted Child Quarterly, 63*(2), 87-103.

NERDC. (2013). 9-Year Basic Education Curriculum: Basic Science.

NRC (National Research Council). (2011, 2012). A Framework for K–12 Science Education.

OECD. (2023). Student engagement and competence frameworks.

Olagunju, A., & Abiona, I. (2020). Safety and inquiry in Nigerian science classrooms.

Obanya, P. (2021). Education for the Knowledge Economy in Africa.University of Lagos Press/

OECD. (2023). Education at a glance 2023. OECD Publishing.

Okebukola, P. (2021). Implementing STEM education in Africa. Stirling-Horden.

Olagunju, A. M., & Abiona, O. F. (2020). Inquiry-based learning and Basic Science achievement in Nigeria. *African Journal of Educational Research, 24*(1), 87–104.

Olatunbosun, J., & Bello, H. (2022). Embedding 21st-century skills in Nigerian basic education. *Nigerian Journal of Curriculum Studies, 29*(2), 33–49.

Oyelekan, O., & Olorundare, A. (2014). Inquiry-based instruction and science process skills in Nigeria.

Pellegrino, J. (2014). Assessment as a positive influence on teaching and learning.

Schneider, B., et al. (2020). Data use and learning analytics in STEM classrooms.

Schneider, B., Wallace, J., Pea, R., & Blikstein, P. (2020). Preparing for future learning with data-rich activities. *Journal of the Learning Sciences, 29*(1), 1–10.

Tabachnick, B. G., & Fidell, L. S. (2019). Using multivariate statistics (7th ed.). Pearson.

UNESCO. (2023). SDG 4 monitoring report. UNESCO Institute for Statistics.

UNESCO. (2023). Global Education Monitoring Report.

World Bank. (2022). Learning Recovery and Acceleration.

Zydney, J., et al. (2020). Technology-supported inquiry learning in science.

Zydney, J. M., Warner, Z., Kelley, S., & Koedel, C. (2020). Teaching with technology to support students' learning. *Educational Technology Research and Development, 68*, 3445–3464.