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Impact of Progressive Science Initiative and Progressive Mathematics Initiative Teaching Pedagogy on Achievement: A Quantitative Approach on STEM Students in Ogun State, Nigeria

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Abstract
The ongoing underperformance of students in Science, Technology, Engineering, and Mathematics (STEM) subjects within Nigerian secondary schools continues to be a significant educational issue, prompting the need for the investigation of novel teaching strategies. This research investigated the influence of the Progressive Science Initiative and Progressive Mathematics Initiative (PSI-PMI) pedagogical approach on the mathematical performance of STEM students in Ogun State, Nigeria, while also considering the moderating effects of gender and attitudes towards STEM disciplines. A quasi-experimental design utilising a pretest-posttest control group was employed, featuring a 2×2×2 factorial matrix that included treatment (PSI-PMI versus conventional), gender (male versus female), and attitude towards STEM (positive versus negative). Four null hypotheses were evaluated at the 0.05 level of significance. Participants included 102 Senior Secondary School Two (SSS 2) STEM students, selected purposefully from two public secondary schools located in the Ijebu Ode Local Government Area of Ogun State. Three instruments were utilised: the PSI-PMI Treatment Package (conceived by the researchers), the Mathematics Achievement Test (MAT; $r = .75$), and the Attitude Towards STEM Scale (ATSS; $r = .81$). The MAT and ATSS underwent validation via expert review and trial-testing, with internal consistency assessed through KR-20 and Cronbach's alpha, respectively. Data were subjected to analysis through the method of Analysis of Covariance (ANCOVA), utilising pretest MAT scores as a covariate. Findings indicated a statistically significant main effect of treatment on students' mathematics achievement, $F(1, 93) = 168.277$, $p < .05$, $\eta 2 = .644$, with PSI-PMI students ($\bar{X} = 21.80$) significantly surpassing their counterparts in the conventional group ($\bar{X} = 13.33$). Gender did not have a significant impact on mathematics achievement, $F(1, 93) = 2.385$, $p > .05$, and neither did attitude towards STEM, $F_{(1, 93)} = .039$, $p > .05$. In a similar vein, the interaction effects concerning gender and attitude, $F_{(1, 93)} = .098$, $p > .05$, as well as those involving treatment, gender, and attitude, $F_{(1, 93)} = 1.177$, $p > .05$, did not reach statistical significance. These findings illustrate that PSI-PMI pedagogy serves as a strong and inclusive instructional approach that improves STEM achievement regardless of students' gender or attitudes. It is advisable for mathematics and STEM educators to embrace PSI-PMI as a fundamental instructional method. Furthermore, it is essential for school administrators to support teacher training in its application, while government and educational policymakers should prioritise the establishment of the necessary technological infrastructure to ensure effective PSI-PMI implementation in secondary schools throughout Ogun State and Nigeria as a whole.

Keywords: Progressive Science Initiative, Progressive Mathematics Initiative, PSI-PMI, STEM achievement, gender, attitude, quasi-experimental, mathematics, Ogun State, Nigeria

1. Introduction

STEM education has become a crucial foundation for preparing learners with the skills necessary to thrive in a complex, technology-driven global economy. STEM fields foster critical thinking, scientific reasoning, creativity, and problem-solving abilities essential for personal productivity and country advancement (Honey et al., 2014; Hacioglu & Gulhan, 2021). In emerging nations, proficiency in STEM disciplines is crucial, since it influences the workforce's ability to foster technological innovation and economic transformation. Notwithstanding this acknowledgement, actual data continuously reveal ongoing and concerning underperformance among secondary school students in STEM disciplines, especially in mathematics and the sciences. In Nigeria, the West African Examinations Council (WAEC) has reported that less than 50% of candidates achieve credit-level passes in core science and mathematics subjects during the Senior Secondary Certificate Examination (SSCE), a trend that Ogun State has consistently mirrored in line with national averages (WAEC, 2023). This widespread underachievement signifies a significant educational crisis that requires

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thorough academic examination and evidence-based teaching strategies.

A considerable amount of research has demonstrated that students' academic performance in STEM disciplines is profoundly influenced by two critical learner-level factors: attitude towards STEM and gender. Attitude, defined as a learner's evaluative stance towards STEM disciplines whether positive or negative has been extensively recognised as a predictor of academic motivation, classroom engagement, and overall success (Erol, et al., 2023). Students with negative attitudes towards mathematics and science often demonstrate diminished motivation, avoidance behaviour, and, as a result, poorer academic performance (Asigigan & Samur, 2021). Research across various educational settings has shown those students' attitudes towards STEM decline progressively during secondary school, especially among those in under-resourced environments where classroom experiences lack engagement, relevance, or intellectual stimulation (Hiğde & Aktamış, 2022; Annisa, et al, 2022). Regarding gender, the study evidence is inconclusive yet substantial. Some research indicate a sustained male advantage in mathematics and physical sciences, while others reveal a reduction or reversal of this disparity depending on the instructional method utilised (Kucuk & Sisman, 2020). In Nigeria's educational landscape, gender gaps in STEM participation and accomplishment endure, since socio-cultural expectations and a lack of role models frequently deter female students from continued involvement in STEM-focused academic trajectories. Comprehending the interplay between gender and attitude in relation to pedagogical methods is crucial for developing equitable and successful teaching strategies.

The prevalent reliance on traditional, teacher-centered pedagogical methods in Nigerian secondary schools is fundamental to the recorded underperformance in STEM disciplines. The conventional lecture method, marked by passive knowledge dissemination, minimal student engagement, lack of formative feedback, and restricted use of instructional technology, has faced significant criticism for its failure to foster deep conceptual comprehension and sustained academic involvement (Tucker, et al.,, 2024; Ramli, et al., 2020). In this educational framework, students largely behave as passive users of information instead of active knowledge creators, leading to superficial learning that fails to meet the conceptual requirements of modern STEM fields. The situation is exacerbated by systemic challenges within the Nigerian educational framework, including inadequate access to modern laboratories, limited availability of technological resources such as projectors, digital tools, and SMART classroom infrastructure, as well as ongoing deficiencies in teachers' readiness to impart interdisciplinary STEM content (Ramli et al., 2020). The systemic constraints, especially common in public secondary schools, cumulatively diminish the quality of STEM education and substantially contribute to students' ongoing poor academic performance. The inadequacy of traditional instructional methods to yield satisfactory STEM achievement results has prompted researchers and educational policymakers to investigate innovative pedagogical frameworks that can enhance the teaching and learning of STEM subjects in Nigerian secondary schools.

The Progressive Science Initiative and Progressive Mathematics Initiative (PSI-PMI) exemplifies a transformational educational paradigm with significant potential to improve STEM achievement. Rooted in the constructivist learning paradigm, PSI-PMI is a methodical instructional framework that incorporates interactive digital tools such as SMART TVs, digital videos, images, Plickers, and PowerPoint presentations, alongside systematic formative assessment practices aimed at delivering real-time diagnostic feedback during instruction (Moidunny, 2009). In the PSI-PMI methodology, instructional delivery is structured into concentrated parts of roughly 15 minutes, followed by student engagement with formative assessment assignments conducted using SMART response devices. Real-time student polling results, presented as pie charts or bar charts, allow educators to promptly identify knowledge gaps and make informed judgements on the reinforcement of instruction or progression to future material. This adaptive, learner-focused methodology fundamentally differs from the linear, uniform presentation of traditional teaching, providing learners with numerous possibilities for active involvement, collaborative exploration, and metacognitive reflection. Comparable studies on technology-integrated and constructivist pedagogical frameworks have recorded substantial enhancements in students' academic performance, problem-solving abilities, and learning motivation (Alatas & Yakin, 2021; Gong, et al., 2024; Wang et al., 2022). The incorporation of gamified assessment components, including competitive polling and immediate visualisation of aggregate responses, has been demonstrated to enhance creativity, maintain academic engagement, and increase students' ability to apply theoretical STEM knowledge to practical solutions (Asigigan & Samur, 2021; Ou Yang, et al., 2023).

Despite the increasing evidence favouring technology-integrated and constructivist pedagogical methods in STEM education globally, empirical documentation of the PSI-PMI technique specifically in Nigerian secondary schools is limited. The Ogun State Ministry of Education, Science and Technology, under the direction of Prof Arigbabu Abayomi (2025), has implemented intentional initiatives to promote PSI-PMI as an innovative pedagogical approach aimed at enhancing STEM learning outcomes in public secondary schools within the state. Nonetheless, the degree to which this method significantly affects pupils' mathematical success based on gender and attitudinal categories has not undergone thorough experimental scrutiny within this educational setting. Producing empirical evidence is essential for guiding evidence-based decisions about curriculum design, teacher capacity enhancement, and the distribution of educational resources to improve STEM outcomes in Ogun State and, by extension, throughout Nigeria. This study aims to address the gap by examining the influence of PSI-PMI teaching style on the mathematical performance of STEM students in Ogun State, specifically focusing on the moderating influences of gender and attitudes towards STEM.

1.1 Statement of the Problem

Despite ongoing policy focus and institutional investments in STEM education in Ogun State, secondary school students still demonstrate inadequate performance in mathematics and other STEM subjects during public examinations. This situation highlights a systemic failure of current instructional methods to foster the necessary level of conceptual understanding and academic engagement essential for proficiency in STEM fields. Traditional educational approaches, prevalent in the majority of public secondary schools, are marked by a one-sided transmission of knowledge, insufficient application of formative assessment, and minimal integration of technology-based learning tools conditions that are clearly inadequate for promoting profound STEM understanding and success. Although the Progressive Science Initiative and Progressive Mathematics Initiative (PSI-PMI) have been recognised and tested by the Ogun State Ministry of Education as a potentially transformative educational intervention, there is currently a lack of empirical evidence in the scholarly literature that documents its specific impact on the mathematics achievement of STEM students within the state. Moreover, the degree to which gender and students' attitudes towards STEM influence the connection between this innovative instructional method and mathematics achievement remains unexplored in this educational setting. In the absence of such evidence, decision-makers, curriculum developers, and educators are left without the empirical foundation necessary to support the adoption, expansion, or allocation of resources needed for the implementation of PSI-PMI. This study was motivated by the necessity to produce thorough experimental evidence regarding the influence of PSI-PMI teaching methods on the mathematics achievement of STEM students in Ogun State, while carefully analysing the moderating effects of gender and attitudes towards STEM.

1.2 Purpose of the Study

The primary purpose of this study was to examine the impact of the Progressive Science Initiative and Progressive Mathematics Initiative (PSI-PMI) teaching pedagogy on the mathematics achievement of Science, Technology, Engineering, and Mathematics (STEM) students in Ogun State, Nigeria. Specifically, the study sought to:

i. Examine the influence of gender on the mathematics achievement of STEM students in Ogun State;
ii. Determine the effect of attitude towards STEM on the mathematics achievement of STEM students in Ogun State;
iii. Investigate the interaction influence of gender and attitude on the mathematics achievement of STEM students in Ogun State; and
iv. Determine the interaction effect of treatment, gender, and attitude on the mathematics achievement of STEM students in Ogun State.

1.3 Research Hypotheses

The following null hypotheses were formulated and tested at the 0.05 level of significance:

$H_0$1: There is no significant effect of gender on the mathematics achievement of Science, Technology, Engineering, and Mathematics (STEM) students in Ogun State.

$H_0$2: There is no significant effect of attitude towards STEM on the mathematics achievement of Science, Technology, Engineering, and Mathematics (STEM) students in Ogun State.

$H_0$3: There is no significant interaction effect of gender and attitude on the mathematics achievement of Science, Technology, Engineering, and Mathematics (STEM) students in Ogun State.

$H_0$4: There is no significant interaction effect of treatment, gender, and attitude on the mathematics achievement of Science, Technology, Engineering, and Mathematics (STEM) students in Ogun State.

2. Methodology

This study utilised a pretest-posttest control group quasi-experimental design featuring a 2×2×2 factorial matrix. The independent and moderating variables included treatment (PSI-PMI vs. conventional instruction), gender (male vs. female), and attitude towards STEM (positive vs. negative). Students' mathematics achievement, assessed through the Mathematics Achievement Test (MAT), was designated as the dependent variable. This design was considered suitable due to the study's aim of evaluating the effectiveness of two instructional methods while statistically accounting for pre-existing group differences, thus allowing for valid causal inferences regarding the impacts of PSI-PMI pedagogy. The target population included all Senior Secondary School Two (SSS 2) STEM students in the Ogun Central Senatorial District of Ogun State, Nigeria. This educational zone was chosen due to its inclusion of schools identified by the Ogun State Ministry of Education, Science and Technology as participants in the state-wide PSI-PMI rollout initiative, thereby establishing it as the most suitable context for this investigation. Employing a purposive sampling technique, Ijebu Ode Local Government Area was chosen from the senatorial district due to the presence of two public secondary schools that satisfied the study's inclusion criteria: the experimental school needed to be fully outfitted with PSI-PMI instructional facilities (such as SMART TV, projector, and digital content delivery infrastructure), while the control school was expected to depend solely on traditional teaching facilities. One school was intentionally selected to serve as the experimental group, while the other was designated as the control group. From each school, an intact class of SSS 2 STEM students was selected, resulting in a total sample of 102 participants (51 per group). The decision to utilise intact classes was intentional, aimed at minimising disruption to regular school schedules and ensuring ecological validity within the experimental conditions. Three instruments were utilised for data collection. The PSI-PMI Treatment Package included structured lesson plans that incorporated digital videos, images, Plickers, SMART TV presentations, and PowerPoint slides, all aimed at promoting interactive, real-time formative assessment-driven instruction in line with the constructivist PSI-PMI framework. The Mathematics Achievement Test (MAT) was created utilising a table of specifications, resulting in an initial collection of 60 multiple-choice items with four options (A–D) derived from four mathematics topics chosen for instruction that had not been previously taught in the sampled schools. The items underwent a thorough assessment of their content, construct, and criterion-related validity by a panel of experts in mathematics education, measurement, and evaluation. Their feedback guided the revision, restructuring, and removal of any ambiguous or irrelevant items. The revised instrument underwent trial testing with 60 SSS 2 students in Remo North Local Government Area, which was outside the study sample. The internal consistency reliability was assessed using the Kuder-Richardson Formula 20 (KR-20), resulting in a coefficient of r = .75. From the initial pool of 60 items, 20 were selected for the final MAT. The Attitude Towards STEM Scale (ATSS), which was developed and validated by the team, assessed students' attitudes towards STEM subjects. It was given to the same trial-testing sample, with Cronbach's alpha indicating its internal consistency at r = .81, thereby confirming its reliability for the study. Students' ATSS scores were utilised to categorise them as exhibiting either a positive or negative disposition towards STEM. Prior to data collection, a formal letter of ethical clearance and research authorisation was obtained from the Ogun State Ministry of Education, Science and Technology in Abeokuta. Before the instruction began, the objectives and methods of the study were communicated to school principals, class teachers, and students. Informed consent was secured from all student participants, ensuring voluntary participation, confidentiality of data, and the absence of academic penalties for those who chose not to participate. Mathematics educators in the STEM departments of the chosen schools received training and were appointed as assistants, tasked with managing the administration of instruments and facilitating student involvement during the study. Both groups underwent the administration of the MAT and ATSS as pretests prior to the commencement of instruction. The experimental group underwent six weeks of instruction solely through the PSI-PMI teaching approach, employing SMART TVs, computers, digital videos, images, and Plickers projectors to enable technology-enhanced, formatively assessed learning. The control group was instructed on the same mathematical content using a traditional teacher-centered approach with a whiteboard, without the use of PSI-PMI tools or technology. Following the six-week instructional period, both groups took the MAT as a posttest to evaluate achievement outcomes. Data were analysed using Analysis of Covariance (ANCOVA), employing pretest MAT scores as a covariate to statistically control for any pre-existing differences in students' achievement levels. This approach ensures that the observed posttest differences can be attributed to the treatment and the moderating variables being investigated. All hypotheses underwent testing at the 0.05 level of significance.

3. Results

Table 1 presents the distribution of participants across the treatment and control groups by gender and attitude towards STEM.

As shown in Table 1, female students outnumbered male students in both groups; PSI-PMI (52.9% female vs. 47.1% male) and conventional (62.7% female vs. 37.3% male) reflecting a higher female representation in the overall sample (57.8%). Regarding attitude, a higher proportion of PSI-PMI students exhibited a positive attitude towards STEM (64.7%) compared to students in the conventional group (54.9%), while fewer PSI-PMI students showed a negative attitude (35.3%) than those in the conventional group (45.1%). Across both groups combined, 59.8% of students demonstrated a positive attitude towards STEM. Table 2 presents the descriptive statistics of posttest MAT scores by treatment group, gender, and attitude.

Table 2 shows that students in the PSI-PMI group recorded substantially higher mean posttest MAT scores ($\bar{X}$ = 21.92) compared to those in the conventional group ($\bar{X}$ = 13.35) across all gender and attitude subcategories, indicating the superior effect of PSI-PMI instruction on mathematics achievement. Within the PSI-PMI group, female students ($\bar{X}$ = 22.52) slightly outperformed male students ($\bar{X}$ = 21.25), and students with positive attitudes ($\bar{X}$ = 22.06) performed marginally better than those with negative attitudes ($\bar{X}$ = 21.67), though these differences were minimal. The inferential analyses examining the four hypotheses are presented in Table 3.

As shown in Table 3, the ANCOVA revealed a statistically significant main effect of treatment (PSI-PMI vs. conventional instruction) on students' posttest MAT scores, $F(1, 93) = 168.277$, $p < .05$, $\eta 2 = .644$,

Table 1: Distribution of Participants in the Treatment Groups by Gender and Attitude Towards STEM

Treatment	Gender n(%)		Attitude Towards STEM n(%)		Total
	Male	Female	Negative	Positive	
PSI-PMI	24 (47.1)	27 (52.9)	18 (35.3)	33 (64.7)	51 (100)
Conventional	19 (37.3)	32 (62.7)	23 (45.1)	28 (54.9)	51 (100)
Total	43 (42.2)	59 (57.8)	41 (40.2)	61 (59.8)	102 (100)

Note. n = Number of participants; STEM = Science Technology Engineering Mathematics; PSI-PMI = Progressive Science Initiative and Progressive Mathematics Initiative; Figures in parentheses are percentages.

Table 2: Descriptive Statistics of Participants' MAT Posttest Scores by Gender and Attitude Towards STEM

Treatment	N	Gender $\bar{X}$ (SD)		Attitude Towards STEM $\bar{X}$ (SD)		Total $\bar{X}$ (SD)
		Male	Female	Negative	Positive	
PSI-PMI	51	21.25 (3.859)	22.52 (2.208)	21.67 (2.301)	22.06 (3.526)	21.92 (3.129)
Conventional	51	12.89 (3.178)	13.62 (2.709)	13.43 (2.608)	13.29 (3.137)	13.35 (2.883)
Total	102	17.56 (5.487)	17.69 (5.107)	17.05 (4.806)	18.03 (5.523)	17.64 (5.244)

Note. N = Number of participants; $\bar{X}$ = Mean; SD = Standard Deviation; PSI-PMI = Progressive Science Initiative and Progressive Mathematics Initiative.

Table 3 Summary of 2×2×2 Analysis of Covariance of Post-test MAT Scores by Treatment, Gender, and Attitude Towards STEM

Source	Type III SS	df	Mean Square	F	Sig.	Partial η^2
Corrected Model	1913.004a	8	239.126	25.722	.000	.689
Intercept	4130.985	1	4130.985	444.359	.000	.827
Pretest (Covariate)	.814	1	.814	.088	.768	.001
Treatment	1564.387	1	1564.387	168.277	.000*	.644
Gender	22.169	1	22.169	2.385	.126	.025
Attitude Towards STEM	.359	1	.359	.039	.845	.000
Treatment × Gender	.612	1	.612	.066	.798	.001
Treatment × Attitude	1.120	1	1.120	.121	.729	.001
Gender × Attitude	.908	1	.908	.098	.755	.001
Treatment × Gender × Attitude	10.946	1	10.946	1.177	.281	.013
Error	864.574	93	9.296			
Total	34507.000	102				
Corrected Total	2777.578	101				

*R^2 = .689 (Adjusted R^2 = .662); *p < .05*

Note. SS = Sum of Squares; df = Degrees of Freedom; η2 = Partial Eta Squared.

Table 4: Estimated Marginal Means of Post-test MAT Scores According to Treatment Group

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
PSI-PMI	21.800a	.457	20.892	22.708
Conventional	13.334a	.451	12.439	14.229

Note. a. Covariates appearing in the model are evaluated at the following values: Pretest MAT = 7.21.

Table 5 Pairwise Comparisons of Adjusted Means for Post-test MAT Scores by Treatment Group

(I) Treatment	(J) Treatment	Mean Diff. (I-J)	Std. Error	Sig.	95% CI for Difference	
					Lower Bound	Upper Bound
PSI-PMI	Conventional	8.466*	.653	.000	7.170	9.762
Conventional	PSI-PMI	-8.466*	.653	.000	-9.762	-7.170

Note. *The mean difference is significant at the .05 level. Adjustment for multiple comparisons: Least Significant Difference.

indicating that the instructional approach substantially explained 64.4% of the variance in achievement outcomes. To further illustrate the source of this significant treatment effect, Estimated Marginal Means (EMM) are presented in Table 4.

Table 4 reveals that students in the PSI-PMI group recorded an adjusted mean MAT posttest score of 21.800 compared to 13.334 for students in the conventional group, confirming a practically significant differential impact of PSI-PMI instruction on STEM students' mathematics achievement. Table 5 presents the pairwise comparison further elucidating this significant difference.

As shown in Table 5, the mean difference between the PSI-PMI and conventional groups was 8.466 (95% CI: 7.170–9.762), which was statistically significant ($p < .05$), confirming the superior effectiveness of PSI-PMI teaching pedagogy in enhancing mathematics achievement among STEM students.

3.1 Test of Hypotheses

Hypothesis One ($H_0 1$): There is no significant effect of gender on the mathematics achievement of STEM students in Ogun State.

The ANCOVA results presented in Table 3 revealed no statistically significant main effect of gender on students' posttest MAT scores, $F(1, 93) = 2.385$, $p > .05$, $\eta 2 = .025$. Accordingly, H_{01} was not rejected. This finding indicates that gender did not significantly influence the mathematics achievement of STEM students in Ogun State, and that both male and female students derived comparable benefits from the instructional approaches employed in the study.

Hypothesis Two ($H_0 2$): There is no significant effect of attitude towards STEM on the mathematics achievement of STEM students in Ogun State.

Results in Table 3 showed no statistically significant main effect of attitude towards STEM on posttest MAT scores, $F_{(1, 93)} = .039$, $p > .05$, $\eta 2 = .000$. H_{02} was therefore not rejected. This finding suggests those students' attitudinal dispositions towards STEM whether positive or negative did not significantly determine their mathematics achievement outcomes within the context of this study.

Hypothesis Three ($H_0 3$): There is no significant interaction effect of gender and attitude on the mathematics achievement of STEM students in Ogun State.

The ANCOVA results in Table 3 indicated no statistically significant interaction effect between gender and attitude towards STEM on posttest MAT scores, $F_{(1, 93)} = .098$, $p > .05$, $\eta 2 = .001$. H_{03} was not rejected, indicating that the combined influence of gender and attitude did not significantly affect students' mathematics achievement.

Hypothesis Four ($H_0 4$): There is no significant interaction effect of treatment, gender, and attitude on the mathematics achievement of STEM students in Ogun State.

As shown in Table 3, the three-way interaction effect of treatment, gender, and attitude towards STEM on posttest MAT scores was not statistically significant, $F_{(1, 93)} = 1.177$, $p > .05$, $\eta 2 = .013$. H_{04} was therefore not rejected. This finding confirms that the beneficial impact of PSI-PMI pedagogy on mathematics achievement was uniform across all student subcategories, regardless of their gender or attitudinal profile.

4. Discussion of Findings

The results of this study present persuasive experimental evidence indicating that the PSI-PMI teaching methodology markedly improves the mathematics performance of STEM students in Ogun State. The treatment group achieved a notably higher adjusted mean score of 21.800 compared to the conventional group, which recorded 13.334, resulting in a substantial effect size of $\eta 2$ = .644. This finding aligns with an expanding corpus of research that highlights the enhanced effectiveness of technology-integrated, constructivist instructional strategies compared to traditional teaching methods in the realm of STEM education. Alatas and Yakin (2021) similarly observed that the incorporation of STEM-integrated learning methodologies yielded notable enhancements in students' problem-solving capabilities and academic performance when compared to conventional instructional methods. In a related vein, Gong, Cai, and Cheng (2024) provided meta-analytic evidence indicating that innovative instructional frameworks, such as the flipped classroom model, significantly enhanced STEM students' academic performance. This finding aligns with the PSI-PMI approach's focus on preparatory instruction, real-time assessment, and responsive teaching. The interactive and formatively driven nature of PSI-PMI, utilising digital tools and gamified assessment mechanisms to maintain student engagement and deliver immediate corrective feedback, closely aligns with the theoretical foundations of constructivism. This perspective asserts that learners build meaningful knowledge through active participation rather than passive reception (Moidunny, 2009; Alam & Mohanty, 2024). Moreover, Wang et al. (2022) demonstrated through a meta-analysis that digital game-based STEM education markedly improved students' academic performance, thereby offering additional external validation for the current finding. Within the Nigerian context, the focus of the Ogun State Ministry of Education on PSI-PMI as a novel pedagogical approach (Arigbabu, 2025) is strongly substantiated by the empirical findings of this study, underscoring the policy significance and adaptability of the intervention within the Nigerian secondary education framework.

The observation that gender did not have a statistically significant effect on students' mathematics achievement ($F_{(1, 93)}$ = 2.385, $p > .05$) indicates that the PSI-PMI pedagogical approach is fair in its influence, providing equal advantages to both male and female learners. While female students exhibited slightly elevated mean scores compared to their male peers in both treatment groups, these discrepancies failed to reach statistical significance, suggesting that the instructional method effectively mitigated any performance disparities based on gender. This finding is consistent with the research conducted by Kucuk and Sisman (2020), which illustrated that gender disparities in STEM engagement and performance became non-significant upon the implementation of effective, technology-enhanced instructional strategies. It further supports the findings of Asigigan and Samur (2021), who discovered that gamified STEM instructional environments yielded similar achievement outcomes for both male and female students. This indicates that innovative and engaging pedagogical strategies can alleviate the socio-cultural and motivational challenges that have traditionally hindered female learners in Nigerian STEM classrooms. The gender-neutrality of the PSI-PMI effect carries significant policy implications, indicating that this approach can function as a means to promote gender equity in STEM education without the need for gender-specific instructional interventions.

The lack of a substantial main effect of attitude towards STEM on mathematics achievement ($F_{(1, 93)}$ = .039, $p > .05$) constitutes a significant finding that calls into question the prevailing belief that attitudinal dispositions serve as robust predictors of academic performance in STEM disciplines. While students exhibiting favourable attitudes attained slightly superior scores within the PSI-PMI group, this benefit did not attain statistical significance, suggesting that the effectiveness of PSI-PMI instruction was not dependent on students' prior attitudinal dispositions towards STEM. This finding tentatively indicates that the engaging and interactive nature of PSI-PMI pedagogy may have the potential to inspire and motivate learners who are initially disinclined, thus separating instructional effectiveness from previous attitudinal dispositions. This aligns with the findings of Erol et al. (2023), who discovered that educational robotics activities enhanced students' academic engagement regardless of their initial attitudes towards STEM. Similarly, Hiğde and Aktamış (2022) illustrated that thoughtfully crafted STEM activities could effectively reshape students' perspectives on science subjects throughout an instructional period. These findings highlight the significant capacity of novel instructional methods to alter the emotional aspects of STEM education, even in the face of previously negative attitudes.

The non-significant interaction effects observed between gender and attitude ($F(1, 93)$ = .098, $p > .05$) as well as among treatment, gender, and attitude ($F_{(1, 93)}$ = 1.177, $p > .05$) further substantiate the assertion that PSI-PMI pedagogy yields consistently superior mathematics achievement outcomes across various student subgroups, regardless of their demographic characteristics or attitudinal orientations. This finding is consistent with the argument put forth by Tucker et al. (2024) that meticulously crafted STEM instructional strategies, when executed with precision, can produce equitable learning outcomes across diverse learner characteristics. The uniformity of the PSI-PMI effect across all subcategories analysed in this study underscores the strength and comprehensiveness of this educational methodology as a reform strategy aimed at improving STEM achievement in secondary schools within Ogun State. It aligns with the findings of Ou Yang, et al (2023), who reported that instructional frameworks that integrate technology and respond to assessments yielded equitable enhancements in learning achievement, irrespective of the students' initial demographic or motivational characteristics.

5. Conclusion

This study presents compelling experimental evidence that the Progressive Science Initiative and Progressive Mathematics Initiative (PSI-PMI) teaching methodology markedly improves the mathematics performance of STEM students in Ogun State, Nigeria, surpassing traditional instructional methods by a considerable and practically significant extent. Although gender and attitudes towards STEM did not prove to be significant factors influencing achievement, the consistently superior performance of students exposed to PSI-PMI across all demographic and attitudinal subgroups underscores the inclusive, equitable, and transformative nature of this innovative pedagogical method. The ramifications of these findings transcend the classroom, holding considerable significance for educational policy, teacher training, and curriculum change aimed at enhancing STEM achievement in Nigerian secondary schools. It is essential to recognise that the study was restricted to a singular local government area within the Ogun Central Senatorial District, potentially constraining the generalisability of its findings to other geographic, socio-economic, and subject-area contexts. Consequently, future research should aim to replicate and expand this investigation across a wider array of educational settings, encompassing various STEM disciplines and educational levels, to fortify the evidence base for PSI-PMI as a sustainable and scalable instructional reform strategy.

6. Recommendations

Based on the findings of this study, the following recommendations are offered:

1. Mathematics and STEM educators in secondary schools within Ogun State ought to embrace PSI-PMI as a fundamental instructional approach. This should be bolstered by professional development initiatives, workshops, and training seminars orchestrated by school administrators and the Ministry of Education, aimed at enhancing teachers' competencies for its proficient implementation in the classroom.
2. The Ogun State Government, alongside the Ministry of Education, Science and Technology, ought to emphasise the necessity of establishing sufficient technological infrastructure in public secondary schools. This includes the provision of SMART TVs, projectors, computers, and digital content resources. Furthermore, it is essential to formally integrate PSI-PMI into the STEM curriculum policy frameworks, adopting a gender-inclusive and equity-driven instructional methodology.
3. Curriculum planners and higher education institutions ought to incorporate PSI-PMI pedagogical principles into pre-service teacher education programmes. This integration will ensure that future STEM educators are equipped to implement technology-integrated, formatively responsive instructional strategies across secondary schools, even in environments marked by negative attitudes towards mathematics, given the approach's proven effectiveness irrespective of students' previous attitudinal dispositions.
4. Future researchers ought to undertake longitudinal and multi-site experimental studies to explore the enduring impacts of PSI-PMI pedagogy on STEM achievement, shifts in attitude, and the cultivation of 21st-century skills across various subjects, educational tiers, and geographical regions in Nigeria. This approach would significantly enhance the evidence base required for comprehensive national educational reform.

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