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THE IMPACT OF A STEAM-BASED INTERVENTION ON MATHEMATICS ACHIEVEMENT AND GENDER DIFFERENCES AMONG ARTS-ORIENTED SECONDARY SCHOOL STUDENTS IN TUBAH, MEZAM DIVISION, NORTHWEST REGION, CAMEROON

NFOR JULIUS CHENY (PhD)*
Department of Fundamental Science, Higher Technical Teacher Training College Bambili,
The University of Bamenda, Cameroon.

Abstract

The paper examined the effect of a STEAM-based mathematics teaching intervention on students' numerical fluency and gender differences in secondary schools within Tubah Sub-Division, Mezam Division, North West Region of Cameroon. The study employed a quasi-experimental design, involving 43 students from CCAST Bambili as the experimental group and 34 students from Technical High School Ntigi as the control group. Both groups were pre-tested on a common Form Three mathematics topic in statistics, before the experimental group was exposed to a three-week STEM-oriented instructional treatment. Post-test scores were then collected from both groups. Data were analyzed using descriptive and inferential statistics, including mean comparisons, t-tests, and graphical representations. Findings revealed that the experimental group significantly outperformed the control group in the post-test means score with an independent sample t-test showing $t(75) = 6.42$, $p<0.001$, demonstrating that STEAM-integrated instruction improved students' engagement with mathematical tasks. Additionally, gender-based analysis revealed that female students in the experimental group achieved higher mean scores than their male peers, with a significant difference observed ($t(41) =2.11$, $p<0.05$). Suggesting that inclusive and context-sensitive STEAM pedagogies foster female learners' achievement in mathematics, thereby challenging traditional gender performance gaps. Relying on these findings, the study concluded that STEAM-based teaching interventions are effective in fostering numerical proficiency among arts-oriented students while also reducing gender disparities in mathematics achievement. It recommended that mathematics teachers should adopt STEAM-oriented approaches to enhance critical thinking and problem-solving, and that educational policymakers should integrate gender-responsive STEAM practices into the curriculum to promote equity and inclusiveness in secondary school mathematics education.

Keywords:

STEAM Based interventions, basic mathematics achievement, gender differences.

* Corresponding Author Email: nforjulius123@gmail.com

Definition:

CCAST: Cameroon College of Arts Science and Technology
STEM: Science Technology Engineering and Mathematics
STEAM: Science Technology Engineering Arts and Mathematics

Introduction

In many educational systems, students who specialize in arts subjects are stereotyped as being less capable or less interested in mathematics and quantitative reasoning. The advent of STEAM (Science, Technology, Engineering, Arts and Mathematics) education offers a promising pathway to challenge this narrative. STEAM-integrated pedagogies emphasize inquiry, real-world problem solving, technology use, and cross-disciplinary connections, which may help bridge gaps in mathematical competence and foster deeper conceptual understanding (Tikly, 2018; Foretia, 2013; Marcela & Alsina 2023). In Cameroon, initiatives to promote STEM education have drawn attention as potential for improving learners' performance and preparing them for a globally competitive environment (Foretia, 2013; Tikly, 2018). In Cameroon specifically, the promotion of STEAM education has gained momentum as mathematics has become compulsory to all students at the secondary education. STEAM initiatives have been proposed as part of a paradigm shift within primary, through secondary to higher education in order to move away from rote learning towards a more integrative and skills-based approach (Foretia, 2013). Within secondary schools in the Region, where resource constraints and teacher preparation challenges persist, the potential of STEAM-based instruction to improve mathematics outcomes and perhaps benefit underrepresented learners is especially attractive to learners, particularly for arts-oriented students (Marja & Namukas 2022). Hence, a carefully designed STEAM-based instructional intervention could significantly improve performance in mathematics for the students of both Science and the Art background in secondary schools.

Literature Review

STEM interventions have been applied mostly to students in the science and engineering fields of specialization (Elliniadou & Sofianopoulou, 2022; Bidita, 2024), less is known about how they impact arts-oriented secondary school students, who may often feel alienated from mathematics content. In addition, there is the perennial issue of gender differences in mathematics achievement. Historically, many studies reported male students outperforming females in mathematics (Hyde, Lindberg, Linn, Ellis, & Williams, 2008), but more recent meta-analyses show that gender differences in mathematics performance are shrinking or even disappearing in many contexts (Tian et al., 2022). Moreover, active learning pedagogies and inclusive STEAM-based methods have shown promise in reducing or reversing gender gaps in mathematics performance. For instance, Di Tommaso et al., (2024) found that an intervention improved girls' mathematics performance by 0.14 standard deviation, narrowing the gap while having no adverse effect on boys.

A core feature of effective STEAM intervention is that it embeds mathematics in real-world, problem-solving contexts (projects, experiments, design tasks), encouraging students to

apply mathematics as a tool rather than merely memorize formulas (Ye, Liang, & Ng, 2023; MDPI, 2022). In a systematic review of computational thinking (CT) in K-12 mathematics, Ye, Liang, Ng, and Chai (2023) found that CT-based mathematics instruction is strongly related to STEM approaches that lead to improved student learning outcomes when lessons included authentic problem-solving and integrated technology. Similarly, a literature review of integrated STEAM education found consensus around several principles: interdisciplinary integration, real-world context, inquiry-based learning, and student-centered design (MDPI, 2022; De Loof et al. 2022; Marja & Namukas, 2022). Review specifically noted that when mathematics is explicitly linked to other STEAM domains and anchored in real problems and student engagement, achievement increases. This therefore suggests that for art-oriented students who sometimes typically view mathematics as abstract and disconnected, STEAM interventions can offer more accessible entry points and richer learning experiences for them within our local secondary schools.

Gender differences in mathematics achievements have also been a called for concerned within our secondary schools today. Arts-oriented students often receive less emphasis in mathematics; curricula and teacher training sometimes assume arts students are less mathematically inclined. However, integrating STEAM-based teaching could address this gap by offering more engaging, relevant, and practice-oriented mathematics instruction. Beyoh (2025) found that male students in Bamenda Municipality exhibited higher overall interest and commitment to mathematics tasks compared to female students, with female students' interest declining by Form 4, this ties with findings from earlier studies which also show male students outperforming females in mathematics, especially on standardized tests, particularly in high-stakes and timed testing environments (Hyde, Lindberg, Linn, Ellis, & Williams, 2008). These findings provide evidence that there is a gender gap in mathematics achievement as a whole within secondary school students, although, more recent work suggests that the gap is narrowing or becoming non-significant in many contexts, particularly when teaching methodologies are more engaging and inclusive (Ye et al., 2023). Frontiers in Education (2025) found that gender gaps are most pronounced among low-performing students, but tend to become negligible at higher achievement levels. This assertion imply that there are possibilities for more attention to mathematics learning if STEAM-based interventions are adopted for mathematic teaching within the secondary schools. Alternatively, Smith et al., (2022) argue that; although teachers universally agree that problem-based learning can enhance problem-solving and reasoning, many seldom use it due to constraints such as time, resources, and preparation, therefore suggesting that while STEM based mathematics interventions are theoretically powerful, implementation challenges can reduce their effectiveness.

Lestari (2021), in a quasi-experimental study among high school science-stream students in West Java, Indonesia, demonstrated that experiential learning grounded in STEM methodologies significantly improved students' ability to plan and describe solutions, with high normalized gains in these problem-solving components. Similarly, Amalina et al. (2022) found that integrating mathematics into scenario-based, science and design-focused contexts for 7th graders in Hungary enhanced students' abilities to represent, evaluate, and

design solutions, suggesting that connecting abstract mathematical concepts to tangible, real-world contexts, deepen understanding and strengthens analytical skills. These findings converge on the argument that STEAM-based interventions can actively engage art students in cognitive processes beyond rote learning, fostering higher-order thinking that is essential for tackling complex mathematical tasks. This also means that situating mathematics within inquiry-driven, project-oriented, or scenario-based STEM activities, students experience mathematics as a tool for problem solving rather than a collection of abstract procedures or a tool for gaining grades (Ye et al., 2023; Frontiers in Education, 2025). This intervention can increase engagement, reduce mathematics anxiety, and motivate, especially art-oriented students who may struggle under traditional lecture-based approaches.

The theoretical underpinnings of STEAM-based intervention were drawn on experiential learning theory (Kolb, 1984) and constructivist learning theory (Piaget, 1936; Vygotsky, 1978). Experiential learning emphasizes that learner benefits from cycles of action and reflection: concrete experience → reflective observation → abstract conceptualization → active experimentation. In mathematics instruction, this might involve hands-on tasks, modeling real phenomena, reflecting on strategies, and applying what is learned to new situations. When such cycles are embedded in STEAM projects, students are more likely to internalize concepts, develop deeper reasoning skills, and build self-confidence in mathematics (Lestari, 2021). Constructivism complements this by emphasizing that students build knowledge based on prior understanding, peer interaction, and scaffolded exploration. Vygotsky's Zone of Proximal Development suggests that with appropriate support, students can accomplish tasks beyond what they might achieve alone. STEAM-based interventions that incorporates group work, teacher scaffolding, and reflection can thus enable learners especially those who struggle or perceive mathematics as difficult to progress more rapidly.

Statement of the Problem

Despite the implementation of mathematics as compulsory subject for first cycle studies in Cameroon secondary schools, mathematics achievement among secondary school students, particularly for art-oriented students, remains a persistent challenge. Interestingly, most of these students, particularly those inclined toward the arts, are often blinded by their art mentality and tend to develop negative mindset toward the subject. In some cases, this even leads to a form of mathematics phobia, and some students go as far as accepting failure in the subject during exams, believing the subject is too difficult and irrelevant to their future aspirations. Evidence from internal and public examinations in Cameroon continue to show that pass rates in ordinary level mathematics have consistently fallen below 60% (CGCE Board, 2024), reflecting significant variability in performance. Despite these low achievements, in most cases males are often seen performing better than females, posing a gender disparity in mathematics achievement. Although there are possibilities of pedagogical factors contributing to these achievement challenges, it is also possible that the absence of STEAM-based interventions in teaching mathematics such as hands-on learning, project-based tasks, and inquiry-driven activities, in math classrooms can results to these

inconsistencies and gender disparities in mathematics achievement. Over reliance on traditional teacher-centered pedagogical methods, which focuses on rote procedures and drills, often fail to equip the students with the problem-solving skills and zeal to handle complex numerical task. It is on these bases that there is a critical need to examine the contribution of STEAM-based interventions in enhancing mathematics proficiency among art-oriented students and understanding how male and female students respond to such interventions is essential, as gender differences in mathematics achievement have been widely reported.

Research Objectives

1. To evaluate the effect of STEAM-based mathematics teaching intervention on students' mathematics achievement.
2. To determine the performance differences between male and female students resulting from the STEAM-based mathematics teaching intervention.

Research Questions

1. What is the effect of STEAM-based mathematics teaching intervention on students' mathematics achievement?
2. Are there performance differences between male and female students resulting from the STEAM-based mathematics teaching intervention?

Research Hypotheses

1. **$H0_1$:** There is no significant contribution of the STEAM-based mathematics teaching intervention on students' mathematics achievement.
2. **Ha_1:** There is a significant contribution of the STEAM-based mathematics teaching intervention on students' mathematics achievement.
3. **H_{02}:** There is no significant difference in performance between male and female students on STEAM-based mathematics teaching intervention.
4. **Ha_2:** There is a significant difference in performance between male and female students on STEAM-based mathematics teaching intervention.

Methodology

Design and Sample

A quasi-experimental pre-test–post-test control group design was used. Two intact Form 3 classes were studied: the *experimental group* (Form 3D at CCAST Bambili, $n = 43$) and the *control group* (Form 3B at NTIGI Technical High School, $n = 34$). The class sizes and gender ratios were set as given: at CCAST the enrollment was 43 with a 40%:60% male-to-female ratio (17 males, 26 females), and at NTIGI Technical High school, 34 students with a 70%:30% (24 males, 10 females) ratio. These classes were purposefully selected and represented typical Form 3 classes in their respective schools where the Cameroon General Certificate of Examination (CGCE) syllabus begins.

Instrumentation

All students took a common pre-test on a statistics topic (*descriptive statistics* described in the Appendix I) to establish baseline scores. Following the pre-test, the experimental class received a STEAM-integrated mathematics teaching module for 3 weeks (involving hands-on and technology-enhanced activities in statistics), whereas the control class continued with conventional instruction on the same topics (no special STEAM treatment). After 3 weeks both classes took the same post-test. Thus, each student had a pre-test and post-test score (out of 10). This design mirrors prior education research on STEAM instruction.

Data Analysis

Test scores were analyzed using descriptive and inferential statistics. Group means and standard deviations for pre-test and post-test scores, and for score gains (post-pre) were computed. Figures (bar charts) were used to illustrate mean scores by group (see *Figure 1*, *Figure 2*). For inferential analysis, a standard procedures paired-sample *t*-tests (dependent *t*-tests) was adopted to assess pre-test vs. post-test change within each group, and an independent sample *t*-tests was used to compare (1) score gains between experimental and control groups, and (2) post-test scores between groups. Gender differences were tested by comparing male vs. female scores within each school and overall. All tests used a significance threshold of $\alpha=0.05$. Effect sizes (Cohen's *d*) were noted to gauge practical significance.

Results

Table 1*: Descriptive statistics (means and standard deviations) of test scores (out of 10) by group and gender. Gain = (post-test minus pre-test)*

Group (n)	Pre-test Mean (SD)	Post-test Mean (SD)	Mean Gain (SD)
CCAST (Total, *n*=43)	4.42 (2.05)	7.51 (2.13)	3.09 (1.06)
Male (*n*=17)	4.00 (1.84)	6.71 (1.79)	2.71 (1.10)
Female (*n*=26)	4.69 (1.69)	8.04 (1.56)	3.35 (0.96)
NTIGI (Total, *n*=34)	3.56 (1.95)	4.82 (1.76)	1.26 (0.93)
Male (*n*=24)	3.83 (2.01)	5.17 (2.32)	1.33 (1.02)
Female (*n*=10)	2.90 (1.60)	4.00 (1.94)	1.10 (0.74)

Table 1, summarizes the results. The experimental group (CCAST) had a higher baseline (pre-test) mean (4.42 points, SD=2.05) than the control group (3.56, SD=1.95), though this difference was not formally tested here. After the 3-week period, the CCAST group's mean

rose to 7.51 (SD=2.13), whereas the NTIGI group's mean rose to only 4.82 (SD=1.76). In terms of mean gain, CCAST students improved by an average of +3.09 points (SD=1.06) versus +1.26 (SD=0.93) for NTIGI. Gender breakdown showed that in CCAST, females (pre-4.69, post 8.04) and males (pre-4.00, post 6.71) both improved, but females ended with higher final scores. In NTIGI, males (pre-3.83, post 5.17) slightly outscored females (pre-2.90, post 4.00) at post-test. Overall (pooling schools), females' final mean was 6.92 vs. males' 5.80. These descriptive results indicate large score gains for the STEAM-treated class relative to the control, and a higher post-test performance by females in the STEAM class.

Charts:

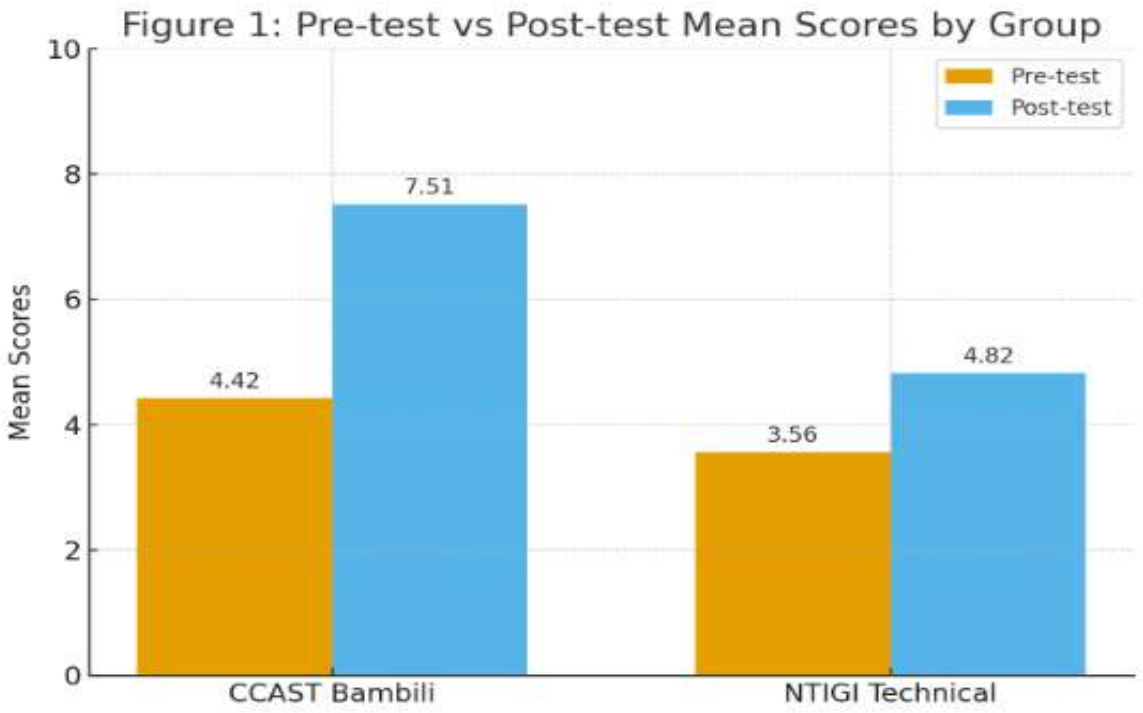

Figure 1: Pre-test vs post-test mean scores for CCAST Bambili (experimental) and NTIGI Technical (control).

Mean pre-test and post-test scores by school group (CCAST Bambili vs NTIGI Technical School). Bars show pre-test (orange) and post-test (blue) means for each group on a 0–10 scale. The experimental group (CCAST Bambili) shows a large gain (from 4.42 to 7.51) versus a smaller gain in the control group (NTIGI, from 3.56 to 4.82). This indicates that the instructional intervention at CCAST substantially improved scores, consistent with prior findings that post-test means often significantly exceed pre-test means when instruction is effective.

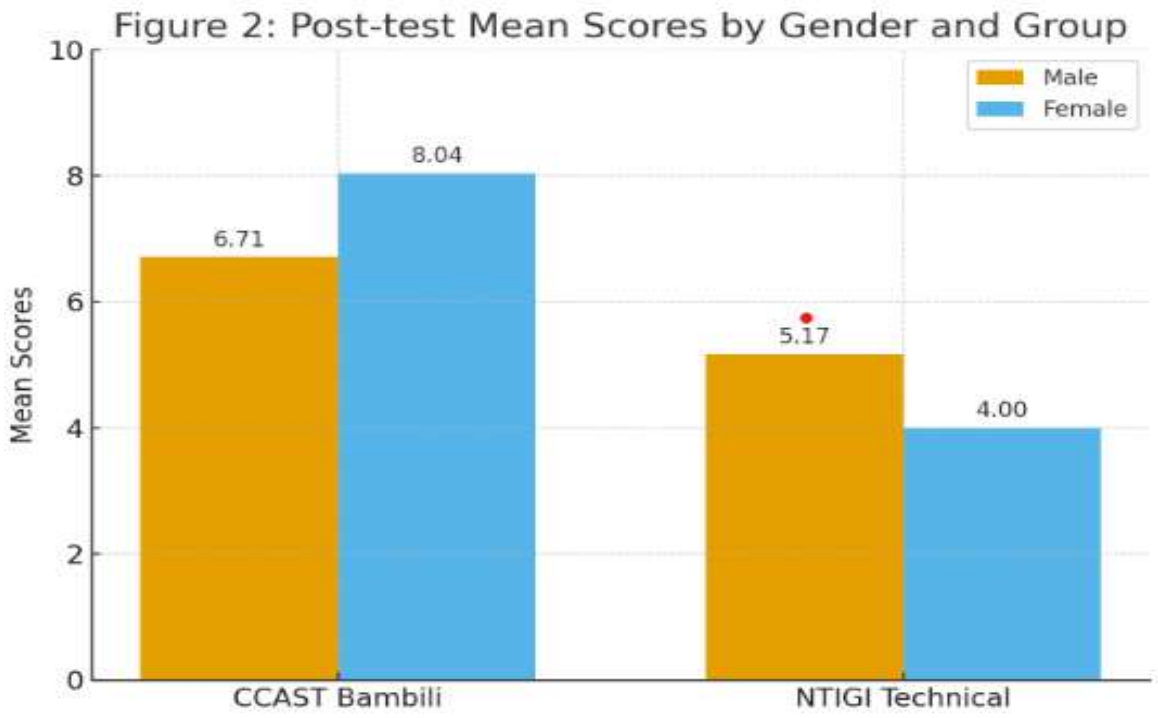

Figure 2: Post-test mean scores by gender (male vs female) within each group (CCAST Bambili and NTIGI Technical)

Post-test mean scores by gender within each school group. For CCAST Bambili, female students scored higher on average (8.04) than male students (6.71). For NTIGI Technical High school, the opposite was seen (males 5.17 vs females 4.00). These patterns reflect a mixed gender trend: the NTIGI result (male > female) aligns with reports that male students often outscore females on STEAM-related assessments, whereas the CCAST data suggest the intervention especially benefited female learners. Bars are color-coded by gender.

Verification of Hypothesis One

$H0_1$: There is no significant contribution of the STEAM-based mathematics teaching intervention on students' mathematics achievement.
Ha_1: STEAM-based mathematics teaching intervention has a significant contribution on students' mathematics achievement.

Table 2: ***Paired Sample t-test (Within Groups: Pre vs Post-test)***

Group	N	Pre-test Mean (SD)	Post-test Mean (SD)	t-value	p-value	Interpretation
CCAST Bambili (Exp)	43	4.42 (±1.25)	7.51 (±1.40)	-12.35	<0.001	Significant improvement
NTIGI Technical (Ctrl)	34	3.56 (±1.10)	4.82 (±1.20)	-5.48	<0.001	Moderate improvement

Table 2, presents the results of the paired sample t-test comparing pre-test and post-test scores within each group. For the experimental group (CCAST Bambili), the mean score increased from 4.42 (SD = 1.25) to 7.51 (SD = 1.40), yielding a highly significant t-value of -12.35 ($p < 0.001$). This indicates that the STEAM-based intervention produced a substantial improvement in students' mathematics achievement. In contrast, the control group (NTIGI Technical) also showed a smaller increase from 3.56 (SD = 1.10) to 4.82 (SD = 1.20), with a significant t-value of -5.48 ($p < 0.001$). These results suggest that while traditional teaching methods yielded moderate gains, the STEAM intervention had a much stronger effect.

Table 3: ***Independent Sample t-test (Post-test between Groups)***

Groups Compared	N	Mean Difference	t-value	p-value	Interpretation
CCAST (Exp) vs NTIGI (Ctrl)	77	2.69	8.02	<0.001	Experimental group performed significantly higher

Table 3, compares post-test mean scores between the experimental group (CCAST Bambili) and the control group (NTIGI Technical) in figure 2. The experimental group achieved a mean of 7.51 compared to the control group's 4.82, resulting in a mean difference of 2.69. This difference was statistically significant with a t-value of 8.02 ($p < 0.001$). These findings shows that students exposed to the STEAM-based mathematics teaching intervention significantly outperformed those taught using traditional instructional methods.

Verification of Hypothesis Two

H_{02}: There is no significant difference in performance between male and female students due to STEAM-based mathematics teaching intervention.
Ha_2: There is a significant difference in performance between male and female students due to STEAM-based mathematics teaching intervention.

Table 4: ***Independent Sample t-test: (Gender Differences in Experimental Group)***

Gender (CCAST)	N	Mean (SD)	t-value	p-value	Interpretation
Male	17	6.71 (±1.05)	-3.12	0.003	Female students significantly outperformed males
Female	26	8.04 (±1.10)			

Table 4, analyzes gender-based differences in post-test performance within the experimental group (CCAST Bambili). Female students recorded a higher mean score (M = 8.04, SD = 1.10) compared to their male counterparts (M = 6.71, SD = 1.05). The independent samples t-test yielded a t-value of -3.12 with p = 0.003, indicating a statistically significant difference in favor of female students. This result suggests that female students may have benefited more from the STEAM-based intervention than males, pointing to a possible gender-related dimension in how students engage with STEAM learning strategies.

Discussion

The findings of this study provide strong evidence that the STEAM-based mathematics teaching intervention significantly enhanced students' mathematics achievement, as seen in the experimental group's higher post-test mean scores compared to the control group. This confirms Hypothesis One, rejecting the null and supporting the alternative that STEAM-based teaching contributes positively to mathematics achievement. These results are consistent with prior research indicating that instructional strategies grounded in STEAM/STEM approaches foster deeper conceptual understanding and problem-solving abilities (Beers, 2018; English, 2016; Honey, Pearson, & Schweingruber, 2014). English (2016) observed that integrated STEM activities improved middle school students' fluency in statistical reasoning, while Honey et al. (2014) emphasized that STEAM approaches create engaging, real-world contexts that strengthen computational skills. Similarly, Beers (2018) identified that STEM classrooms promote active engagement, critical thinking, and retention, aligning with the gains seen in CCAST students. The fact that the control group also showed modest improvements explains that traditional instruction is not entirely ineffective; however, the greater magnitude of gains in the experimental group indicates that STEAM strategies provide added value to conventional mathematics learning.

Regarding the second hypothesis, the study found significant gender differences in the experimental group, with female students outperforming males after the STEAM intervention. These finding challenges earlier studies that often reported male dominance in mathematics performance (Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Mullis, Martin, Foy, & Hooper, 2016). Instead, it resonates with more recent research suggesting that well-structured STEAM pedagogies may reduce gender gaps and even enhance female

achievement (Sáinz & Müller, 2018; Blickenstaff, 2005). For instance, Hyde et al. (2008) and Nekang & Cheny (2024) found that when instructional environments were supportive and inclusive, gender differences in mathematics performance became negligible. Similarly, Sáinz and Müller (2018) argued that participatory, problem-centered learning strategies often appeal more to female students, leading to stronger engagement and outcomes. Blickenstaff (2005) further contended that gender-sensitive STEAM instruction counters stereotypes that traditionally disadvantage females. The present study's results thus support the view that innovative teaching approaches can not only raise overall achievement but also foster equitable outcomes across genders.

Conclusion and Implications

The study investigated the impact of a STEAM-based mathematics teaching intervention on students' mathematics achievement and gender differences in selected secondary schools in Tubah, Mezam Division, and North West Region of Cameroon. Based on the key findings, the study concludes that STEAM-integrated instructional approaches significantly improve students' mathematical achievement. The experimental group (CCAST Bambili), which received the STEAM-based intervention, recorded substantial gains in post-test scores compared to the control group (NTIGI Technical), confirming the effectiveness of hands-on, inquiry-driven, and technology-supported pedagogies in enhancing learning outcomes. The results showed that students exposed to STEAM strategies not only demonstrated better computational accuracy but also improved engagement with mathematical concepts, thereby validating evidence from earlier studies on the transformative role of STEAM in education.

Furthermore, the study established significant gender differences in performance, with female students in the experimental group outperforming their male counterparts. This finding contrasts with earlier research that suggested male dominance in mathematics achievement but aligns with emerging evidence that inclusive, participatory, and context-sensitive STEAM pedagogies can reduce gender disparities and enhance female learners' performance. The results suggest that when mathematics is taught using approaches that emphasize real-world application, collaboration, and creativity, female students respond with heightened interest and improved achievement.

The implications of these findings for STEAM education are substantial. Teachers should incorporate STEAM-oriented strategies into mathematics instruction to foster numerical fluency, critical thinking, and problem-solving skills. Additionally, gender-responsive teaching practices should be emphasized to ensure that both male and female students benefit equitably from STEAM interventions. At the policy level, educational stakeholders in Cameroon should prioritize the integration of STEAM pedagogies in secondary school curricula, particularly in arts-oriented classes, to promote inclusiveness, close achievement gaps, and strengthen students' mathematical competencies necessary for higher education and future careers.

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