JOURNAL OF SCIENCE, TECHNOLOGY AND EDUCATION (JSTE)

A PUBLICATION OF THE DEPARTMENT OF SCIENCE, TECHNOLOGY AND MATHEMATICS EDUCATION (STME), NASARAWA STATE UNIVERSITY, KEFFI, NIGERIA



VOLUME 10

ISSN: 2651-5539

JOURNAL OF SCIENCE, TECHNOLOGY AND EDUCATION (JSTE) VOL. 10. NO. 46

JSTE PUBLICATIONS, (2026). www.nsukjste.com/

ISSN: 2651-5539

GENDER DIFFERENCES IN STUDENTS' INTEREST AND ACHIEVEMENT IN ECOLOGY TAUGHT USING STEAM INSTRUCTIONAL APPROACH IN AKWANGA, NASARAWA STATE, NIGERIA

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Citation: Chunbaya, A. Y., Uzoechi, B. C. & Musa, D. C. (2026). Gender differences in students' interest and achievement in ecology taught using STEAM instructional approach in Akwanga, Nasarawa State, Nigeria. *Journal of Science, Technology, and Education (JSTE);* www.nsukjste.com/. *10*(46), 642–657.

Abstract

This study investigated gender differences in students' interest and achievement in ecology taught using the Science, Technology, Engineering, Arts and Mathematics (STEAM) instructional approach in Akwanga, Nasarawa State, Nigeria. Four research questions guided the study, and four null hypotheses were tested at the 0.05 level of significance. A quasi-experimental pretest–posttest, non-equivalent control group design was adopted. The population comprised 3,336 Senior Secondary One (SS I) students in the 34 government secondary schools in Akwanga, from which a sample of 169 students (88 males and 81 females) was selected using a multi-stage sampling technique. Three intact classes from randomly selected schools were assigned to two experimental groups (the STEAM and STEM approaches) and one control group (the lecture method); the STEAM class comprised 32 male and 27 female students. Two instruments, the Ecology Interest Rating Scale (EIRS) and the Ecology Achievement Test (EAT), were used for data collection. The instruments were validated by experts and yielded reliability coefficients of 0.89 and 0.81, respectively. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses. The findings revealed that students taught using the STEAM approach showed greater interest and achievement in ecology than those taught using the STEM approach or the lecture method. Within the STEAM group, female students showed significantly higher interest than male students, whereas male students recorded significantly higher achievement than female students. The study concludes that the STEAM approach engages female students' strongly in ecology but does not, on its own, close the gender gap in achievement. It recommends that teachers using STEAM link its expressive activities to structured practice that converts girls' interest into achievement, and that they monitor boys' engagement with the arts-based tasks.

Keywords: Gender, STEAM, Arts integration, Ecology, Interest, Achievement.

Introduction

Science education plays a crucial role in national development, as it equips learners with the knowledge and skills required for technological advancement and for solving problems in everyday life. Among the science subjects, Biology occupies a central

position at the senior secondary level in Nigeria, and ecology is one of its most important topics. Ecology explains how organisms depend on one another and on their surroundings, and it gives students the concepts they need to make sense of land degradation, deforestation, pollution and changing farm yields, which are pressing concerns in a largely rural state such as Nasarawa.

Ecology is also one of the topics that students find hardest. Its key processes, including energy flow, nutrient cycling and population change, cannot be watched in a classroom, and students tend to fill the gap with misconceptions. Ogundare et al. (2020) found such misconceptions to be widespread among senior school Biology students in Oyo State, and Siswandari et al. (2026) found that students struggled to represent the mechanisms behind ecological phenomena in their drawings of ecosystems, even after instruction. Teaching methods that are teacher-centred and rely on rote memorisation do little to remove these difficulties, and they have been identified as inadequate for promoting interest and meaningful understanding of abstract scientific concepts.

In response to these challenges, educators have increasingly advocated learner-centred approaches such as the Science, Technology, Engineering, Arts and Mathematics (STEAM) approach. Integrated STEM teaching combines content from the four disciplines with problem-centred, inquiry-based, design-based and cooperative learning (Thibaut et al., 2018), and it has been shown to improve students' learning outcomes in science (Cao et al., 2025), including Biology achievement among Nigerian secondary school students (Usman et al., 2023). STEAM builds on this foundation by bringing visual art, design, drama, music or the language arts into science lessons as means of exploring and communicating ideas (Perignat & Katz-Buonincontro, 2019). In ecology, students may draw and colour food webs, act out predator–prey relationships, model habitats with local materials and design posters on conservation. Such activities broaden the pathways through which students can enter a subject, and STEAM has been reported to improve students' conceptual understanding (Ozkan & Umdu Topsakal, 2021) and their motivation towards science (Mater et al., 2023).

The difference between STEAM and integrated STEM can be illustrated with the topic of food relationships. In a STEM lesson, students might count the organisms in a sample plot, record which feed on which, construct a food web from their data and calculate how numbers change from one feeding level to the next. A STEAM lesson on the same topic keeps these steps but adds an expressive layer: students may draw and colour the food web as a poster, take the roles of grass, grasshopper, lizard and hawk and act out what happens when one link is removed, or write a short account from the point of view of a decomposer. The scientific content and the reasoning remain the same. What changes is the number of ways in which students can represent the ideas, and it is this feature that may make STEAM appeal differently to different learners.

Gender can be a significant factor in students' interest and achievement in science. Popular belief and classroom practice often treat science as more suited to boys, and girls remain under-represented in many science-based courses at higher levels. International data show that 15-year-old boys and girls differ only modestly in average science

performance but differ considerably in the careers they expect to pursue (OECD, 2019). Makarova et al. (2019) found that secondary school students perceived mathematics and science as masculine domains, and that young women who held a more masculine image of these subjects were less likely to aspire to a STEM field. Gender differences may also appear in motivation even where performance is similar: among 732 eighth-grade STEM students in Flanders, Hermans et al. (2022) found no gender difference in test scores, but girls were more likely than boys to show a profile of low autonomous motivation and high amotivation. Findings from Nigerian classrooms are mixed. Eya et al. (2024) found that male students showed significantly higher interest than female students in a technology-enhanced learning environment, while the difference in achievement was not significant. Ogundare et al. (2020), on the other hand, found no significant difference between male and female students in the ecological misconceptions that remained after instruction. These findings suggest that gender differences in science are context-dependent and may vary with the kind of instruction students receive.

Gender, as used in this study, refers not simply to the biological distinction between male and female students but to the social roles, expectations and identities that societies attach to being a boy or a girl. These expectations begin early. In many Nigerian homes, boys are more often encouraged to repair, build and experiment, while girls are more often directed towards domestic responsibilities and towards subjects regarded as caring or expressive. Schools can reinforce these patterns through the examples teachers use, the students they call upon to handle equipment, and the way they respond to boys' and girls' questions. Over time, such experiences shape how students see themselves in relation to science. A girl who comes to regard science as a male domain may engage with it less readily, not because she lacks ability, but because the subject does not seem to fit who she is. This is consistent with the finding of Makarova et al. (2019) that a masculine image of science reduces young women's aspirations towards STEM fields.

The way students connect science to their own identities is also central to how interest develops. Renninger and Hidi (2022) explain that interest is strengthened when learners can relate content to themselves, their experiences and their sense of who they are. If boys and girls bring different experiences and self-images to the science classroom, the same lesson may trigger interest more strongly in one group than in the other. Evidence from Africa illustrates how these identities operate. In a study of male and female engineering students at a rural college in South Africa, Chauke (2022) found that both groups were influenced by economic prospects, aptitude in mathematics and science, and parental education, but that female students alone described their choice of STEM as a route to independence and as a way of rejecting stereotypical feminine identities. Male students, by contrast, did not regard gender as relevant to their choice. Such findings suggest that girls' engagement with science is bound up with questions of identity in ways that boys' engagement often is not, and that teaching approaches which widen the ways of taking part in science may matter more for girls.

Furthermore, the relationship between gender and the STEAM approach warrants investigation. Because STEAM presents science in a less narrowly technical light, it

has been suggested that it may appeal to learners who are less drawn to conventional science and so help to narrow gender gaps, particularly in interest. The available evidence, however, points in different directions. In a study of 995 students taking creativity-focused STEAM modules in European schools, Conradty et al. (2020) found no gender differences in self-efficacy, creativity or career motivation, and Conradty and Bogner (2020) likewise found that gender was not a significant factor after a year of STEAM teaching. Jia et al. (2021) reported no significant gender differences in motivation, self-efficacy or knowledge among pupils taught through a combined STEAM and maker curriculum. Other studies suggest that female students may respond more strongly. Wajngurt and Sloan (2019) found that women reported more interest in further STEM study than men under arts-integrated chemistry teaching, Duo-Terrón et al. (2022) reported slightly higher outcomes for girls than boys under a STEAM programme, and Mater et al. (2023) observed a strong rise in motivation among an all-female group taught through STEAM. Few of these studies examined interest and achievement in a specific Biology topic together, and none was conducted in a Nigerian secondary school. Without such evidence, it remains unclear whether STEAM is equally effective for male and female students in enhancing interest and achievement in ecology.

In Akwanga Local Government Area of Nasarawa State, where this study is situated, students' low interest and weak achievement in ecology persist despite efforts to improve science teaching. There is therefore a need to explore not only effective instructional approaches but also how these approaches affect male and female students. This question is not merely academic. Nigeria's scientific and technological development depends on drawing talent from the whole population, and approaches that engage only one gender, or that raise the interest of one group while leaving its achievement behind, will not close the gaps in participation that persist at higher levels of science education. Teachers who adopt STEAM need to know whether it benefits boys and girls equally, and, if it does not, where each group needs additional support. Understanding whether gender influences students' interest and achievement when they are taught with STEAM will provide valuable insights for teachers, curriculum planners and policymakers. It is against this background that this study seeks to investigate gender differences in students' interest and achievement in ecology taught using the STEAM instructional approach in Akwanga, Nasarawa State, Nigeria.

Statement of the Problem

The teaching and learning of ecology in senior secondary schools remain challenging because of the abstract nature of concepts such as energy flow, nutrient cycling and population dynamics. In Akwanga Local Government Area of Nasarawa State, this difficulty is reflected in students' persistently low interest and weak achievement in the topic. The problem has been linked largely to the continued use of the lecture method, which presents ecological processes as facts to be memorised and offers students few opportunities to observe, represent or apply them. Gender adds a further dimension to the problem. Science is still widely perceived as a male domain, and male and female students may differ in how they engage with science lessons and in the outcomes they attain,

depending on the nature of the instruction they receive.

The STEAM approach, which integrates the arts into science, technology, engineering and mathematics, offers a potential means of making ecology more accessible and engaging to both male and female students through its creative and collaborative activities. However, empirical evidence on whether STEAM benefits male and female students equally remains limited. Studies conducted elsewhere have reported inconsistent gender outcomes and have focused largely on motivation and creativity rather than on interest and achievement in a specific Biology topic, and no such study has been reported in Nasarawa State. Without this evidence, teachers cannot determine whether the approach requires adjustment to meet the needs of both genders. The problem of this study, therefore, is: do male and female SS I students taught ecology using the STEAM approach in Akwanga differ in their interest and achievement, and how does the STEAM approach compare with the STEM approach and the lecture method in its effects on these outcomes?

Objectives of the Study

The main objective was to investigate gender differences in students' interest and achievement in ecology taught with the STEAM instructional approach in Akwanga, Nasarawa State, Nigeria. Specifically, the study sought to:

i. determine the interest of students taught ecology using STEAM, STEM and the lecture method;
ii. determine the interest of male and female students taught ecology using STEAM;
iii. determine the achievement of students taught ecology using STEAM, STEM and the lecture method; and
iv. determine the achievement of male and female students taught ecology using STEAM.

Research Questions

The following research questions guided the study:

1. What are the mean interest ratings of students taught ecology using the Science-Technology-Engineering-Arts-Mathematics (STEAM) approach, the Science-Technology-Engineering-Mathematics (STEM) approach and the lecture method?
2. What are the mean interest ratings of male and female students taught ecology using the STEAM approach?
3. What are the mean achievement scores of students taught ecology using the STEAM approach, the STEM approach and the lecture method?
4. What are the mean achievement scores of male and female students taught ecology using the STEAM approach?

Statement of Hypotheses

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

H_{O1}: There is no significant difference in the mean interest ratings of students taught ecology using the STEAM approach, the STEM approach and the lecture method.

H_{O2}: There is no significant difference in the mean interest ratings of male and female students taught ecology using the STEAM approach.

H_{O3}: There is no significant difference in the mean achievement scores of students taught ecology using the STEAM approach, the STEM approach and the lecture method.

H_{O4}: There is no significant difference in the mean achievement scores of male and female students taught ecology using the STEAM approach.

Methodology

This study employed a quasi-experimental design with a pretest and posttest and a non-equivalent control group structure comprising two experimental groups and one control group. The experimental groups were taught ecology through the STEAM and STEM approaches, while the control group was taught using the lecture method. Gender, at two levels, was examined within the STEAM group. The design was deemed suitable because intact classes were used, which prevented the random assignment of individual students (Creswell & Creswell, 2018). The population comprised 3,336 Senior Secondary One (SS I) students (1,950 males and 1,386 females) in the 34 government secondary schools in Akwanga Local Government Area, Nasarawa State, in the 2025/2026 session (Akwanga Education Area Office, 2026). A sample of 169 students (88 males and 81 females) was selected from three randomly chosen co-educational schools using a multi-stage sampling technique, and the intact classes from the selected schools were randomly assigned to the STEAM group (59 students), the STEM group (55 students) and the control group (55 students). The STEAM class, which provided the data for the gender comparisons, comprised 32 male and 27 female students.

Two instruments were used for data collection: the Ecology Interest Rating Scale (EIRS) and the Ecology Achievement Test (EAT). The EIRS measured students' interest with 20 items on a four-point Likert scale, giving possible scores from 20 to 80, while the EAT consisted of 40 four-option multiple-choice items covering nine SS I ecology content areas and structured across the levels of Bloom's revised taxonomy, with a maximum score of 40. Both instruments were validated by three experts in Science, Technology and Mathematics Education, Nasarawa State University, Keffi, and trial-tested on 30 SS I students outside the sample, yielding reliability coefficients of 0.89 for the EIRS (Cronbach's alpha; Taber, 2018) and 0.81 for the EAT (Kuder-Richardson Formula 21).

Data were collected in three phases: pretest, a five-week treatment period with one 80-minute double period per week, and posttest. The regular Biology teachers of the sampled classes served as research assistants after a one-week training programme. In the STEAM class, students worked in mixed-gender groups of five with rotating roles and combined the ecology content with drawing food webs, role-playing feeding relationships, building ecosystem models, designing conservation posters and charting population data. The STEM class followed the same content and group structure without the arts activities, and the control class was taught through verbal explanation, chalkboard illustration and note-taking. The instruments were administered by the researcher with the trained research assistants, with the items reshuffled for the posttest. To limit extraneous influences, the students' own teachers delivered all lessons from standardised lesson plans after common training, each group was located in a separate school to prevent contact between groups, a five-week interval separated the pretest from

the posttest, and the test items were reshuffled between administrations. Data were analysed using means and standard deviations to answer the research questions, and ANCOVA was used to test the hypotheses at the 0.05 level of significance, controlling for initial group differences through the pretest scores. Hypotheses 1 and 3 compared the three groups, with Bonferroni follow-up tests, and hypotheses 2 and 4 compared male and female students in the STEAM group. Partial eta squared was reported as the effect size (Field, 2018).

Result

Research Question One: What are the mean interest ratings of students taught ecology using the STEAM approach, the STEM approach and the lecture method?

Table 1: Mean and Standard Deviation of Interest Ratings of Students Taught Ecology Using STEAM, STEM and the Lecture Method

Group		Pre-Interest	Post-Interest
STEAM (EG_1)	Mean	47.58	59.07
	N	59	59
	Std. Deviation	6.871	7.924
STEM (EG_2)	Mean	49.85	55.25
	N	55	55
	Std. Deviation	5.455	5.324
Lecture (CG)	Mean	50.25	56.07
	N	55	55
	Std. Deviation	4.204	4.476

Table 1 shows the STEAM group rose from the lowest pre-interest mean (47.58) to the highest post-interest mean (59.07), a gain of 11.49 points. The STEM and lecture groups gained 5.40 and 5.82 points respectively, ending at 55.25 and 56.07.

Hypothesis One: There is no significant difference in the mean interest ratings of students taught ecology using the STEAM approach, the STEM approach and the lecture method.

Table 2: Analysis of Covariance of Students' Interest Ratings by Instructional Approach

Source	Type III SS	df	Mean Square	F	Sig.	Partial η²
Corrected Model	1555.466	3	518.489	16.574	.000	.232
Intercept	2562.427	1	2562.427	81.909	.000	.332
Pre-interest	1092.039	1	1092.039	34.907	.000	.175
Group	**766.438**	**2**	**383.219**	**12.250**	**.000**	**.129**
Error	5161.835	165	31.284			
Total	552952.000	169				
Corrected Total	6717.302	168				

Note. $R^2 = .232$.

Table 2 shows a significant effect of instructional approach on post-interest after controlling for pre-interest, $F(2, 165) = 12.25$, $p < .001$, partial $\eta^2 = .13$, so H_{O1} was rejected. Bonferroni comparisons (Table 3) showed that STEAM produced higher adjusted interest than STEM (mean difference = 4.85, $p < .001$) and the lecture method (mean difference = 4.21, $p < .001$), while STEM and the lecture method did not differ (mean difference = −0.64, $p = 1.000$).

Table 3: Bonferroni Multiple Comparisons of Students' Mean Interest Ratings Exposed to STEAM, STEM and the Lecture Method

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
STEAM	STEM	4.847*	1.063	.000	2.277	7.418
	Lecture	4.211*	1.068	.000	1.627	6.795
STEM	STEAM	-4.847*	1.063	.000	-7.418	-2.277
	Lecture	-.637	1.067	1.000	-3.217	1.944
Lecture	STEAM	-4.211*	1.068	.000	-6.795	-1.627
	STEM	.637	1.067	1.000	-1.944	3.217

Based on estimated marginal means. *. The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.

Table 4.3 shows that a significant difference existed between the mean interest ratings of students exposed to STEAM and those exposed to STEM, with a mean difference of 4.847 and an associated probability of 0.000, in favour of STEAM. A significant difference was also observed between the mean interest ratings of students exposed to STEAM and the lecture method, with a mean difference of 4.211 and an associated probability of 0.000, in favour of STEAM. However, there was no significant difference between the mean interest ratings of students exposed to STEM and those taught using the lecture method, as the mean difference of -0.637 had an associated probability of 1.000, which was greater than the 0.05 level of significance. This implies that STEAM produced significantly higher interest in ecology than both STEM and the lecture method, while the interest of students taught with STEM did not differ significantly from that of students taught with the lecture method.

Research Question Two: What are the mean interest ratings of male and female students taught ecology using the STEAM approach?

Table 4: Mean and Standard Deviation of Interest Ratings of Male and Female Students Taught Ecology Using STEAM

Gender		Pre-Interest	Post-Interest
Male	Mean	45.56	53.16
	N	32	32
	Std. Deviation	7.509	4.259
Female	Mean	49.96	66.07
	N	27	27
	Std. Deviation	5.214	4.945

Table 4 shows that female students in the STEAM class began with a higher mean interest rating than male students (49.96 against 45.56) and widened that lead considerably during the treatment. Their post-interest mean was 66.07 (SD = 4.95), compared with 53.16 (SD = 4.26) for males. The gain for females, 16.11 points, was more than twice the gain of 7.60 points for males. Male students also showed the larger spread of pre-interest scores (SD = 7.51), which narrowed markedly by the posttest.

Hypothesis Two: There is no significant difference in the mean interest ratings of male and female students taught ecology using the STEAM approach.

Table 5: Analysis of Covariance of Male and Female Students' Interest Ratings in the STEAM Group

Source	Type III SS	df	Mean Square	F	Sig.	Partial η^2
Corrected Model	2703.236	2	1351.618	80.651	.000	.742
Intercept	2053.503	1	2053.503	122.533	.000	.686
Pre-interest	259.578	1	259.578	15.489	.000	.217
Gender	**1732.173**	**1**	**1732.173**	**103.359**	**.000**	**.649**
Error	938.493	56	16.759			
Total	209493.000	59				
Corrected Total	3641.729	58				

Table 5 shows that, after adjusting for pre-interest, gender had a significant effect on post-interest in the STEAM group, F (1, 56) = 103.36, $p < .001$, partial $\eta^2 = .65$. H_{O2} was therefore rejected. The difference favoured female students and remained large after the initial gap in pre-interest had been taken into account. Pre-interest was a significant covariate, $F(1, 56) = 15.49$, $p < .001$, partial $\eta^2 = .22$.

Research Question Three: What are the mean achievement scores of students taught ecology using the STEAM approach, the STEM approach and the lecture method?

Table 6: Mean and Standard Deviation of Achievement Scores of Students Taught Ecology Using STEAM, STEM and the Lecture Method

Group		Pretest	Posttest
STEAM (EG_1)	Mean	18.27	36.42
	N	59	59
	Std. Deviation	1.412	2.541
STEM (EG_2)	Mean	17.15	30.62
	N	55	55
	Std. Deviation	1.008	2.953
Lecture (CG)	Mean	17.53	25.40
	N	55	55
	Std. Deviation	1.345	0.974

Note. EAT scores range from 0 to 40.

Table 6 shows that the three groups started from similar pretest means (17.15 to 18.27) but finished far apart. The STEAM group reached a posttest mean of 36.42, the STEM group 30.62 and the lecture group 25.40, corresponding to gains of 18.15, 13.47 and 7.87 points.

Hypothesis Three: There is no significant difference in the mean achievement scores of students taught ecology using the STEAM approach, the STEM approach and the lecture method.

Table 7: Analysis of Covariance of Students' Achievement Scores by Instructional Approach

Source	Type III SS	df	Mean Square	F	Sig.	Partial η^2
Corrected Model	3499.267	3	1166.422	222.432	.000	.802
Intercept	526.180	1	526.180	100.340	.000	.378
Pretest	31.335	1	31.335	5.975	.016	.035
Group	**3123.511**	**2**	**1561.755**	**297.820**	**.000**	**.783**
Error	865.253	165	5.244			
Total	166216.000	169				
Corrected Total	4364.521	168				

Table 7 shows that the effect of instructional approach on achievement was significant, F (2, 165) = 297.82, $p < .001$, partial $\eta^2 = .78$ (Table 7), and H_{O3} was rejected. All three Bonferroni comparisons in Table 8 were significant: STEAM exceeded STEM by 5.42 points and the lecture method by 10.77 points, and STEM exceeded the lecture method by 5.35 points (all $p < .001$).

Table 8: Bonferroni Multiple Comparisons of Students' Mean Achievement Scores Taught Ecology Using STEAM, STEM and the Lecture Method

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
STEAM	STEM	5.421*	.457	.000	4.315	6.526
	Lecture	10.769*	.442	.000	9.701	11.838
STEM	STEAM	-5.421*	.457	.000	-6.526	-4.315
	Lecture	5.349*	.440	.000	4.285	6.413
Lecture	STEAM	-10.769*	.442	.000	-11.838	-9.701
	STEM	-5.349*	.440	.000	-6.413	-4.285

Based on estimated marginal means. *. The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.

Table 4.10 shows the Bonferroni multiple comparisons of students' mean achievement scores across the three instructional groups. A significant difference existed between STEAM and STEM, with a mean difference of 5.421 and an associated probability of 0.000, in favour of STEAM. A significant difference also existed between STEAM and the lecture method, with a mean difference of 10.769 and an associated probability of 0.000, in favour of STEAM. Similarly, a significant difference existed between STEM and the lecture method, with a mean difference of 5.349 and an associated probability of 0.000, in favour of STEM. These results imply that STEAM was the most effective approach for enhancing students' achievement in ecology, followed by STEM, with the lecture method being the least effective.

Research Question Four: What are the mean achievement scores of male and female students taught ecology using the STEAM approach?

Table 9: Mean and Standard Deviation of Achievement Scores of Male and Female Students Taught Ecology Using STEAM

Gender		Pretest	Posttest
Male	Mean	18.63	38.44
	N	32	32
	Std. Deviation	1.661	0.948
Female	Mean	17.85	34.04
	N	27	27
	Std. Deviation	0.907	1.556

Note. EAT scores range from 0 to 40.

Table 9 shows that male and female students in the STEAM class began at almost the same level of achievement (18.63 and 17.85). At the posttest, males averaged 38.44 (SD = 0.95) and females 34.04 (SD = 1.56). Males gained 19.81 points and females 16.19 points. The male posttest mean lies close to the maximum score of 40, and the small standard

deviation shows that most male students scored near the top of the scale.

Hypothesis Four: There is no significant difference in the mean achievement scores of male and female students taught ecology using the STEAM approach.

Table 10: Analysis of Covariance of Male and Female Students' Achievement Scores in the STEAM Group

Source	Type III SS	df	Mean Square	F	Sig.	Partial η^2
Corrected Model	283.623	2	141.811	87.476	.000	.758
Intercept	410.304	1	410.304	253.095	.000	.819
Pretest	0.054	1	0.054	0.033	.856	.001
Gender	**260.045**	**1**	**260.045**	**160.408**	**.000**	**.741**
Error	90.784	56	1.621			
Total	78649.000	59				
Corrected Total	374.407	58				

Note. $R^2 = .758$.

Table 10 shows a significant effect of gender on achievement in the STEAM group, $F(1, 56) = 160.41$, $p < .001$, partial $\eta^2 = .74$, in favour of male students. H_{O4} was rejected. The pretest did not predict posttest achievement in this group, $F(1, 56) = 0.03$, $p = .856$, which indicates that the gap between boys and girls arose during the treatment rather than reflecting differences in prior knowledge.

Discussions

The findings revealed a significant difference in the mean interest ratings of students taught ecology using the STEAM approach, the STEM approach and the lecture method. This indicates that the instructional approach significantly influenced students' interest in ecology. Specifically, students taught with STEAM showed higher interest than those taught with STEM or the lecture method. This finding aligns with Perignat and Katz-Buonincontro (2019) and Mater et al. (2023), who reported that STEAM is associated with greater engagement and motivation, and with Conradty and Bogner (2020), who found gains in students' self-efficacy and creativity after STEAM teaching. On the contrary, it contrasts with Wajngurt and Sloan (2019), whose arts-integrated chemistry course did not increase students' later enrolment in STEM courses. The higher interest under STEAM may be attributed to its expressive tasks, since the STEM approach, which differed from STEAM only in the arts component, did not raise interest above the level of the lecture method.

The findings revealed a significant difference in the mean interest ratings of male and female students taught ecology using the STEAM approach, in favour of the female students. This indicates that gender significantly influenced students' interest when ecology was taught through STEAM.

Specifically, female students developed far more interest than their male classmates. This finding aligns with Wajngurt and Sloan (2019), whose female students reported more interest than male students under arts-integrated teaching, and with Duo-Terrón et al. (2022), who reported slightly higher outcomes for girls than boys under a STEAM programme. On the contrary, it contrasts with Conradty et al. (2020) and Conradty and Bogner (2020), who found no gender differences in STEAM settings, with Jia et al. (2021), who found no significant gender differences in motivation, self-efficacy or knowledge after a STEAM and maker curriculum, and with Eya et al. (2024), who found that male students showed higher interest than female students in a technology-enhanced learning environment.

The significant gender difference in interest may be attributed to the expressive and collaborative nature of the STEAM tasks. Interest is triggered most strongly when learners can connect a task to themselves (Renninger & Hidi, 2022), and activities such as drawing, role-play and poster design may connect more readily with female students in this setting. These activities also present science in a less masculine light, which Makarova et al (2019) identified as a condition for girls' engagement with STEM. Male students, on the other hand, may prefer the experimental and quantitative tasks they associate with science, which may explain their more modest gain in interest. The strong response of female students to STEAM reported by Mater et al. (2023) supports this interpretation.

The findings revealed a significant difference in the mean achievement scores of students taught ecology using the STEAM approach, the STEM approach and the lecture method. This indicates that the instructional approach had a significant effect on students' achievement in ecology. Specifically, students taught with STEAM achieved the highest scores, followed by those taught with STEM, while those taught with the lecture method achieved the lowest. This finding is consistent with Ozkan and Umdu Topsakal (2021), who found that STEAM produced better conceptual understanding than the regular curriculum, and with Asrizal et al. (2023), who reported a moderate positive effect of STEAM on science achievement. It also agrees with Usman et al. (2023) and Cao et al. (2025), who reported that integrated STEM approaches improve achievement over conventional teaching. The superior achievement under STEAM may be attributed to the concrete and visual forms of representation that the arts add to integrated STEM, which build on the cooperative and inquiry-based structure of integrated STEM (Thibaut et al., 2018), help students restructure their ideas about abstract ecological processes (Schunk, 2020) and expose misconceptions so that they can be corrected (Ogundare et al., 2020).

The findings revealed a significant difference in the mean achievement scores of male and female students taught ecology using the STEAM approach, in favour of the male students. This indicates that gender had a significant effect on students' achievement in ecology under STEAM. Specifically, male students achieved higher scores than female students, even though the two groups started from similar levels and the female students showed greater interest. On the contrary, this finding contrasts with Eya et al. (2024) and Ogundare et al. (2020), who found no significant gender difference in Biology achievement and in ecological misconceptions respectively, with Hermans et al. (2022), who found no gender difference

in STEM test scores among eighth-grade students, and with international evidence that gender differences in science performance are generally modest (OECD, 2019).

The gender difference in achievement may be attributed to the way tasks were shared within the mixed-gender groups. Achievement depends on how fully each student works through the content (Schunk, 2020), and male students may have taken up the analytical parts of the tasks, such as counting, calculating and interpreting graphs, more often than female students, giving them more practice with the reasoning assessed by the test. In addition, situational interest needs time to develop into the individual interest that sustains deeper learning (Renninger & Hidi, 2022), and the five-week treatment may have been too short for the female students' greater interest to translate into higher achievement. Students who hold a masculine image of science may also approach data-interpretation items with less confidence (Makarova et al., 2019).

Conclusion

STEAM was the most effective of the three approaches for both interest and achievement in ecology among SS I students in Akwanga, Nasarawa State. Within the STEAM class, however, its benefits were not distributed evenly between boys and girls. Female students showed much greater interest, while male students achieved significantly higher scores. STEAM therefore appears well suited to engaging girls in ecology, but on its own it did not close the gender gap in achievement within the five weeks of this study. Teachers who adopt the approach need to support girls in turning interest into achievement and to keep boys fully engaged in the arts-based work. The study also shows why gender should be examined separately for interest and for achievement. Had only achievement been measured, STEAM would have appeared to favour boys; had only interest been measured, it would have appeared to favour girls. Neither picture is complete. For teachers and policymakers concerned with gender equity in science, an approach that engages girls is a valuable starting point, but that engagement must be deliberately connected to the analytical skills on which achievement depends.

Recommendations

In view of the findings of this study, the following recommendations are made:

1. Biology teachers should adopt the STEAM approach for teaching ecology, as it produced the highest interest and achievement of the three approaches.
2. Teachers using STEAM should follow arts-based activities with structured problem-solving and practice on examination-type items, so that girls' high interest is converted into higher achievement.
3. Teachers should rotate roles within mixed-gender groups so that both boys and girls take turns at the analytical, quantitative and expressive parts of each task.
4. The Nasarawa State Ministry of Education should include gender-responsive pedagogy in its in-service training on STEAM, so that teachers can recognise and respond to differences in how boys and girls engage with the approach.

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