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Impacts of Peer Collaboration, Teacher Feedback, and STEM Career Exposure on Girls' Attitudes Toward Science and Mathematics in Lagos State, Nigeria

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Abstract. The study examined impacts of Peer Collaboration, Teacher Feedback, and STEM Career Exposure on Girls' Attitudes Toward Science and Mathematics in Lagos State, Nigeria. The population for this study was made up of the all teachers and students in Education District V, Lagos State. The two instruments employed for data collection were a 4-point Likert scale questionnaire and teacher interview guide with a reliability value of 0.79 and 0.82 respectively. The data were analysed using Means and Standard deviation z-scores and P-values. The findings revealed that peer collaboration, teacher feedback, and STEM career exposure play pivotal roles in shaping girls' attitudes towards STEM subjects. The study recommended among other schools and policymakers should integrate structured peer learning programs, mentorship programs, and career exposure activities into the curriculum to ensure continuous engagement in STEM fields. Also, schools should provide regular teacher training programs to improve the effectiveness of feedback strategies and implement structured feedback mechanisms to provide timely and constructive support to foster girls' interest in STEM.

Keywords: Peer collaboration, teacher feedback, career exposure, learner engagement, attitude

1. Background to the Study

Peer collaboration in education is a pedagogical approach that emphasizes cooperative learning among learners. Peer collaboration refers to the structured or informal opportunities for learners to work together on science and mathematics tasks. This could include group projects, peer discussion, and problem-solving activities. Peer-collaboration, or collaborative learning, is an educational approach in which learners work together in groups to achieve common goals (Gillies, 2016). This approach improves critical thinking, communication skills, and overall understanding by encouraging students to engage with one another, exchange ideas, and construct knowledge collectively. Collaborative learning is particularly effective in stimulating active learning, increasing learners' involvement, and fostering a deeper grasp of material. In such a setting, learners converse with peers, present and defend ideas, exchange diverse perspectives, and are actively engaged (UNESCO, 2020).

UNESCO (2020) emphasized the role of peer collaboration in fostering inclusive and high-quality education. It highlights how collaborative learning strategies can improve students' engagement and outcomes, particularly in addressing global educational challenges.

In using collaborative learning as a teaching strategy, teacher's feedback is very vital. This is needed for clarification of facts, guidance, direction and motivation which would encourage the learners to stay on the task at hand and to succeed. Teacher feedback plays a crucial role in students' learning and development. Effective teacher feedback provides students with information about their performance, identifies areas for improvement, and reinforces positive behaviour (Hattie & Ganley, 2011). Teacher feedback is a critical component of formative assessment, encompassing the guidance, suggestions,

and evaluations provided by educators to enhance students 'understanding and performance in subjects like science and mathematics (Brookhart,2017). According to Jussim and Haber (2018), effective feedback plays a key role in learning, particularly when it helps students reflect on their errors and provides clear strategies for improvement. In the context of STEM, feedback is vital for promoting critical thinking, scientific inquiry, and metacognitive skills (Mackinney et al., 2021). Positive feedback from the teacher is critical in encouraging student engagement, especially among girls in STEM subjects. Research by Ganley et al. (2021) suggests that Positive and constructive feedback helps build students' confidence and motivates them to participate more actively in science learning. By recognizing students' effort, achievement, and progress, teachers have been shown to promote perseverance and resilience in scientific pursuit (Baranczyk & Best, 2020).

Conversely, negative or absent feedback can undermine students' self–efficacy and confidence in science, particularly for girls. A lack of supportive feedback can decrease students' belief in their ability to succeed, leading to lower engagement and interest in science'' (Eccles & Wang, 2021). Therefore, providing constructive and encouraging feedback is essential in nurturing a positive attitude towards science and mathematics. In the context of girls' attitudes towards science and mathematics, teacher feedback can play a significant role in shaping their perception of competence and value in these subjects. Positive feedback that highlights girls' contribution and encourages their scientific inquiry can help develop a sense of efficacy and increase their engagement in science related activities and career (Wang & Degol, 2017). The Key aspect of teacher feedback comprises timeliness, specificity, constructive and balanced, actionable, and student-centered (Baliram & Youde, 2018).

STEM (Science, Technology, Engineering, and Mathematics) education is recognized as an interdisciplinary approach that integrates academic concepts with real-world application, fostering critical thinking, creativity, and innovation among students. Recently, there has been an emphasis not only on developing students' cognitive skills, such as problem solving and critical thinking, but also on fostering critical thinking, but also on fostering behavioral competencies like perseverance, collaboration, and adaptability (National Science and Technology Council [NSTC], 2018).

STEM career exposure refers to activities and experiences that give students insight into potential careers in science, technology, engineering, and mathematics. This includes career talks, mentorship programs, science fairs, field trips, and interaction with female STEM role models. Shin et al. (2019), "Exposure to STEM careers and role models is crucial in shaping students' interest and persistence in STEM fields. Such exposure involves providing students with opportunities to explore and learn about careers in STEM. STEM careers are critical in broadening students' understanding of the diverse careers available within STEM fields, and they inspire them to pursue these pathways. (Eechles and Wang, (2021). According to Wang and Degol, (2017), Exposure to STEM careers is essential for students to visualize themselves in these roles, which in turn increase the motivation to pursue STEM education. STEM career highlights the relevance of STEM skills in a real-world context (Feber et al., 2021). For example, mentorship programs, STEM career fairs, and shadowing STEM professionals that connect students with female role models in STEM can play a pivotal role in helping girls see themselves in STEM careers. As Master et al. (2021) emphasize, "Female role models can increase girls' sense of belonging in STEM, which is crucial for their identification with and pursuit of STEM careers.

1.1 Statement of the Problem

The under-representation of women in STEM fields remains a global issue. According to UNESCO (2020), women account for only a little of the workforce in science, technology, engineering and mathematics (STEM) worldwide. A clear indication of a persistent gender gap, particularly in secondary, where girls are significantly less involved in STEM activities compared to boys." "In Nigeria, as in many other developing countries, girls are less likely to pursue STEM subjects and careers due to various socio–cultural and institutional barriers (Aina, 2022).

Research has highlighted several factors contributing to this disparity, including gender stereotype, male-dominated environment, math anxiety, negative attitude, and a lack of confidence, which can discourage girls from pursuing STEM pathways (Master et al., 2021). Despite the growing recognition of the importance of fostering positive attitudes toward STEM among girls, there is limited research exploring the specific factors that influence girls' attitudes within the Nigerian context (Adeyemi & Afolabi, 2021). Existing studies often overlook the critical roles that peer collaboration, teacher feedback, and STEM career exposure play in shaping girls' perceptions of science and mathematics in secondary education (Dewitt et al, 2019).

Lastly, STEM career exposure plays a very important role in broadening girls' aspirations and motivation, and challenging traditional gender roles. According to Archer et al. (2019), Exposing girls to STEM careers and female role models can significantly enhance their interest and confidence in pursuing STEM pathways. STEM career programs, internships, and mentorship opportunities can help dismantle misconceptions about STEM fields, demonstrating that these careers are accessible and rewarding. However, in Nigeria, the availability and effectiveness of such programs remain limited, often contributing to a narrow perception of what is possible for girls in STEM (Aing, 2022). Hence, this study is on the impact of Peer collaboration, Teacher feedback, and STEM career exposure on girls' attitudes toward science and mathematics in Lagos state, Nigeria.

1.2 Purpose of Study

The main purpose of the study is to investigate the effect of peer collaboration, teachers' feedback, and STEM career exposure on girls' attitudes towards science in secondary education in Educational District V of Lagos state.

The specific objectives of the study are to:

- Evaluate the influence of peer collaboration on girls' interest and confidence in engaging with science–related subjects and Mathematics in secondary school education.
- Analyze the role of teacher feedback in fostering girls' engagement and cultivating a positive attitude towards STEM subjects.
- Evaluate students' exposure to STEM career opportunities and knowledge by exploring their awareness, availability of STEM resources, involvement in STEM initiatives, and the influence of schools and teachers in career guidance.
- Investigate how exposure to STEM careers shapes girls' aspirations and perceptions of Science and Mathematics as a rewarding and attractive career option.

1.3 Research Questions

The following research questions were formulated from the objective to guide this study:

- How does peer collaboration influence girls' interest and confidence in engaging with science-related subjects in secondary school?
- What is the impact of teachers' feedback on girls' engagement and contribution to the development of positive attitudes towards science and mathematics?
- What is the extent of students' exposure to STEM career opportunities and knowledge?
- In what ways does STEM careers exposure affect girls' aspirations and perceptions of science and mathematics as a rewarding and attractive career option?

2. Expectancy – Value Theory

Developed by Eccles and his colleagues, Expectancy–value theory provides a comprehensive explanation of the motivation behind students' choices and performance in academic settings, particularly focusing on how students' beliefs about their abilities (expectancies) and the perceived value of task influence their attitudes and behaviour (Wigfield & Eccles, 2000).In the context of the study, expectancy–value theory is used to shape girls' engagement and attitudes towards STEM subjects, which are traditionally perceived as a male–dominated field. According to this theory, students are more likely to engage and persist in a task that they believe they can succeed in and perceive as important or useful.

Students are more likely to engage in subjects they perceive as useful for their future goals. Providing girls with opportunities to learn about STEM careers through guest speakers, internships, or mentorship can increase their understanding of these subjects are applied in a real–world context." "This, in turn, enhances their perception of utility value and encourages greater engagement. Shine et al. (2021) opined that, "Students who see the relevance of STEM to their career aspiration are more motivated to invest effort and persistence in these subjects. Exposure to female role models in STEM careers is particularly significant in increasing both the utility and attainment value of STEM subjects. Girls are more likely to identify with and aspire to emulate individuals who share their gender and background, making the pursuit of a STEM career seem more attainable. Seeing stereotypes enables girls to envision themselves in similar roles (Wang & Degol, 2017)

When girls are exposed to successful professionals in STEM who have overcome obstacles, they may view the challenges of pursuing these fields are more manageable and worth the effort. By diminishing the perceived cost and enhancing the utility and attainment value of STEM subjects, career exposure plays a crucial role in shaping a positive attitude toward science and mathematics. Feedback that connects classroom learning to real–world applications can increase students' sense of utility

value, a crucial component of EVT. Teachers who make explicit connections between STEM content and career paths, particularly those that defy traditional gender expectations, can significantly enhance girls' interest and engagement in these subjects.

3. Research Methodology

This study adopts a mixed-method survey approach combining quantitative and qualitative methods to investigate the effect of peer collaboration, teacher feedback, and STEM career exposure on girls' attitude towards science and mathematics in education District V of Lagos State." The population of this study comprises all female students and STEM teachers in the 159 public secondary schools within Education District V, Lagos State.

Education District V was randomly selected out of the six education districts in Lagos State. 20 schools (10 junior and 10 senior schools) were randomly selected from the total of 159 Secondary schools in Education District V. Purposive sampling was used to select 30 Female students offering science and mathematics in each selected secondary school. Making a total of 600 students who participated in the study. 10 STEM Teachers were randomly selected for the interview.

3.1 Instrument for Data Collection

Both quantitative and qualitative instruments were used in this study. The quantitative instrument was a structured Likert-scale questionnaire. The qualitative instrument involves an in-depth semi-structured interview with selected STEM teachers conducted face-to-face. To ensure the validity of the instrument, the instruments were reviewed by two experts, one of whom is an expert in STEM and the other is an expert in test and measurement. The reliability of the instruments was established by conducting a trial test on a sample of 30 students and 5 teachers from Education District 1. Cronbach's Alpha values of 0.79 and 0.82 were obtained, indicating strong alignment among the items."

3.2 Procedure for Data Collection

The instrument was administered to the respondents by the researchers and with the help of 3 research assistants. The questionnaire was collected on the spot to ensure a high response rate. In-depth interviews with teachers were conducted in a quiet space at the school. Each interview lasted for 10-15 minutes and was recorded (with consent) for transcription and analysis.

3.3 Method of Data Analysis

The data obtained was analyzed using both descriptive and inferential statistics. Means and Standard deviation z-scores and P-values were used to analyze the data at a 0.05. Thematic coding was used for the qualitative analysis of interview responses.

4. Results

Research Question One: How does peer influence affect girls' interest and confidence, in engaging with STEM subjects in secondary school?

Table 1: Influence of peer collaboration on STEM Engagement Among Female Students

Item	Mean	Standard Deviation	Standard Error	Z-value	P-value
Working with my classmate increases my interest in STEM subjects.	3.93	0.30	0.0126	113.75	0.00
Collaborating with my peers helps me feel more confident in talking about science and mathematics problems.	3.86	0.38	0.0156	86.89	0.00
I perform better in STEM subjects when I collaborate with my classmates.	3.84	0.41	0.0168	79.65	0.00
Group work in science and mathematics makes the subject more enjoyable for me.	3.97	0.23	0.0094	157.08	0.00
I prefer collaborating with peers rather than working alone on science and mathematics assignments.	3.88	0.44	0.0182	75.74	0.00

Table 1 revealed the mean responses of the respondents, the p-values, and the z-values, respectively. The mean responses of all the variables on the influence of peer collaboration on STEM Engagement among female students were greater than 3.0 ($X \geq 3.0$), which is the criterion mean for a 5-point Likert scale data. Also, Z-values were extremely large, ranging from 75 to 157, P=0.00, which is significant at 0.05. This implies peer collaboration enhances STEM Engagement among female Students

Research Question Two: What is the impact of teachers' feedback on girls' engagement and Contribution to the development of a positive attitude towards science and mathematics?

Table 2: Impact of teachers' feedback on female students' engagement and attitude towards STEM

Question	Agree + Strongly Agree (n)	Proportion (p)	Z-Value	P-Value	Significance
Teacher feedback encourages me to participate more	570	0.9828	23.20	< 0.00001	Significant ($p < 0.05$)
Feedback motivates me to study science and mathematics	520	0.8966	19.07	< 0.00001	Significant ($p < 0.05$)
My confidence improves after receiving feedback	570	0.9828	23.20	< 0.00001	Significant ($p < 0.05$)
Feedback helps me understand difficult concepts	500	0.8621	17.39	< 0.00001	Significant ($p < 0.05$)
More likely to contribute to the discussion when given positive feedback	510	0.8793	18.24	< 0.00001	Significant ($p < 0.05$)

Table 2 presents the respondents' mean responses on the impact of teachers' feedback on girls' engagement and contribution to the development of a positive attitude towards science and mathematics. The mean responses of the respondents were greater than or equal to 3 3 ($x \geq 3.0$)

Z-values were extremely large, ranging from 75 to 157, P=0.00 which is significant at 0.05. Z-values are extremely large, ranging from 17.39 to 23.20, $P < 0.00001$ which is significant at 0.05 level of probability. Therefore, teacher's feedback contributes to learners' engagement and the development of a positive attitude towards science and mathematics among female students.

Research Question 3: What is the extent of students' exposure to STEM career opportunity and knowledge?

Table 3: Student STEM career exposure and knowledge.

SN	Question	Agree % (A + SA)	Z-value	P-value	Conclusion (α = 0.05)
1	My school offers adequate information about STEM (science, technology, engineering, mathematics) careers.	72.4%	10.80	< 0.0001	Significant
2	I am often given the chance to take part in hands-on STEM workshops or activities	56.9%	3.32	0.0004	Significant
3	My teachers or mentors regularly encourage me to explore career opportunities in STEM	98.3%	23.25	< 0.0001	Significant
4	I have a good understanding of the different career paths available in STEM fields	39.7%	-4.98	1.0000	Not Significant
	I have access to resources (e.g. books, websites, and videos) and STEM professionals who help me learn about STEM careers.				
3	I have access to resources (e.g., books, websites, and videos) and STEM professionals who help me learn about STEM careers.	70.7%	9.97	< 0.0001	Significant

Table 3 shows that the respondents agree unanimously on 4 out of the 5 items (items 1,2, 3, and 5) identified on the extent to which students are exposed to STEM careers and opportunities. Item 4 shows significantly fewer than 50% agree, indicating a potential gap in understanding STEM career paths. Z-values of the 4 items are large enough, ranging from 3.32 to 10.80 p-values less than 0.05. However, a z-value of -4.9 and a p-value of 1 >0.5 was observed for item 4, indicating a potential gap in understanding of the career path.

Research Question Four: How does STEM career exposure affect girls' aspirations and perception of science and Mathematics as a rewarding and attractive career?

Table 4: Effect of STEM career exposure on girls' career aspirations and Perceptions

S/N	ITEM	Agree % (SA+A)	Z-value	P-value	Conclusion (α = 0.05)
1	Exposure to STEM careers has increased my interest in studying science and mathematics.	94.8%	21.59	< 0.0001	Significant
2	Learning about STEM careers motivates me to pursue a career in science or mathematics.	96.6%	22.42	< 0.0001	Significant
3	Knowing about successful women in STEM has positively influenced my career aspirations.	99.1%	23.67	< 0.0001	Significant
4	Attending STEM workshops or events has increased my awareness of career opportunities in science and mathematics.	98.3%	23.23	< 0.0001	Significant
5	STEM career exposure has made me realize science and mathematics as more rewarding career paths.	98.3%	24.21	< 0.0001	Significant

The respondents agreed overwhelmingly with all 5 items identified with very high proportions and extremely small p-values. This indicates a strong positive impact of STEM exposure on interest, motivation, and career perception in science and math. Z-values range from 14.12 to 23.67, p< 0.0001 is significant at 0.05. Hence, STEM career exposure affects girls' aspirations and perception of science and mathematics as a rewarding and attractive career option

Qualitative Analysis (Teachers' Interview)

Introduction

This section presents a qualitative analysis of teacher interviews, focusing on how peer collaboration, teacher feedback, and STEM career exposure influence girls' interest in science and mathematics in Education District V, Lagos State. The thematic analysis revealed five key themes: peer collaboration, teacher feedback, STEM career exposure, school initiatives, and parental support in promoting STEM participation among female students.The teachers' insights were drawn to provide a rich understanding of the factors influencing girls' participation and confidence in STEM.

Thematic Analysis of Teacher Interviews.

This section presents insights from interviews conducted with sampled STEM teachers, exploring their perspectives on factors influencing girls' engagement in STEM." "Key themes identified include peer collaboration, teacher feedback, STEM career exposure, school initiatives, and parental/community involvement. The analysis highlights strategies employed by teachers to foster interest and participation in STEM subjects, supported by direct quotes from the interviews.

Peer Collaboration as a Teacher Interview: The teachers' emphasis on peer collaboration highlights the significance of social interaction in learning. The several interviews that girls often feel more comfortable and supported when learning alongside their peers." "They emphasized that group learning helps girls overcome fear and build confidence in STEM subjects. Some of the strategies used by teachers include small group discussions, student pairing (peer teaching), project–based learning, and collaborative competitions."
One teacher explained,
"Mixing students of different skill levels allows high achievers to encourage those struggling, improving overall confidence and participation".
Teacher Feedback as a Motivational Tool
The teachers' insights into the role of feedback reveal a strong commitment to fostering growth mindsets. Their strategies focus on encouragement and constructive criticism, rather than punitive measures. Many girls have preconceived fears about mathematics and science, and without supportive teacher feedback, they may lose interest or confidence. As one of the teachers stated:
"I don't use harsh words when giving feedback because negative reinforcement discourages female students from STEM subjects."
Teachers stressed the importance of personalized feedback and continuous assessment to address individual student needs.
Another teacher added: "Students who initially performed poorly in mathematics improved after continuous feedback and encouragement."
Personalized feedback, formative assessments, performance tracking, and encouraging language usage are some strategies outlined by the teachers.

STEM Career Exposure as a Career Catalyst

Teachers reported that many female students lack awareness of STEM careers and opportunities, making career exposure essential in shaping their aspirations. "Introducing students to real-world STEM application through mentorship, industry visits, guest speaker sessions, and STEM clubs increases their interest in science and mathematics."
A teacher highlighted that: "Many female students changed their attitudes towards STEM after visiting industries where women worked as engineers and scientists".

School Initiative and Gender Inclusion

Teachers emphasized the importance of school-wide initiatives in creating equitable and inclusive learning environments. "They highlighted the importance of STEM competitions and Olympiad, scholarships and mentorship programs, encouraging gender – neutral class participation and teacher training on gender sensitivity on high–achieving girls in STEM subjects." One of the teachers mentioned: "We organize science competitions where girls can showcase their abilities, which has greatly improved their confidence".

Parental and Community Support in STEM Engagement

Teachers recognized the significant influence of parental and community support on girls' engagement in STEM. Teachers emphasized that parental support is essential for sustaining girls' interest in STEM subjects. Some parents hold traditional beliefs that discourage girls from pursuing STEM careers, making community sensitization efforts necessary. Some of the strategies agreed to be adopted by schools include STEM-focused PTA meetings, encouraging parents to support STEM learning at home, and community-based STEM programs and workshops.

5. Discussion of Findings

The findings from this study indicated that peer collaboration, teacher feedback, and STEM career exposure play a significant role in enhancing girls' attitudes toward science and mathematics in secondary school. The quantitative analysis of students' and teachers' questionnaires demonstrated that students, irrespective of their level, generally benefit from peer collaboration as it strengthens their confidence, engagement, and problem–solving skills. This finding is in line with that of (Adeoye, & Igbinedion, (2018); Animola (2019); Olaniyan, &Yusuf, (2019); Adejimi, et al. (2021); Aniaku et al. (2021) who in their respective studies affirmed the effectiveness of peer tutoring / collaborative learning in enhancing students' academic achievement

Students identified personalized learning and constructive teachers' feedback as significant motivators in STEM, boosting confidence and inducing learner interest. The findings support that of Aniaku, etal (2021) and Animola (2019), who in their respective studies affirmed the efficacy of peer tutoring in students' achievement and motivation to learning. Similarly, exposure to STEM careers, through initiatives like industry visits and mentorship, significantly shaped students' aspirations. Teachers also noted that STEM clubs, scholarships, and career guidance enhanced interest. However, they highlighted financial limitations and inadequate industry partnerships as challenges. This corroborates the findings of Adeoye and Igbinedion (2018) & Adejimi et al. (2021), who affirmed that collaborative strategies can enhance learners' motivation and achievement.

The qualitative analysis of teacher interviews supported the quantitative data, revealing that peer collaboration builds students' confidence, targeted feedback improved learning outcomes, and exposure to STEM careers cultivates lasting interest. Teachers emphasized the need for gender-inclusive teaching strategies, STEM competitions, parental involvement, and community-based STEM initiatives to sustain girls' interest in science and mathematics. This is in line with the findings of Pajares (2020) & Salam, et al. (2020), who opined that increasing self-efficacy and motivation in learners is necessary for optimal performance and a positive attitude to learning.

6. Conclusion and Recommendations

In conclusion, the findings suggest that peer collaboration, teacher feedback, and STEM career exposure play pivotal roles in shaping girls' attitudes towards STEM subjects. However, there is a decline in positive perception as students' progress in school, particularly in teacher feedback and career exposure. This prioritized the need for continuous interventions to maintain engagement and interest in STEM throughout secondary education.

Based on the findings of the study, the following recommendations were made:

- Schools and policymakers should integrate structured peer learning programs, mentorship programs, and career exposure

activities into the curriculum to ensure continuous engagement in STEM fields.

- Schools should provide regular teacher training programs to improve the effectiveness of feedback strategies. They should also implement structured feedback mechanisms to provide timely and constructive support to foster girls' interest in STEM.
- Schools should engage parents and communities through awareness programs and STEM–focused PTA meetings to foster a supportive learning environment.
- Practical, hands–on STEM activities and personalized career guidance should be provided to prevent declining interest among senior students.
- The government and school administrators should ensure access to modern STEM learning tools, laboratories, and extracurricular programs to enhance engagement.
- Education policymakers should implement targeted initiatives such as scholarships, leadership programs, and mentorship to bridge the gender gap in STEM participation.

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