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Gender Differences in Physics Achievement: Instructional Approach in Stem Learning Context to the Rescue

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Abstract. *Study focused on investigating the effectiveness of using an instructional approach in STEM leaning context to reducing or eradicating gender differences in physics achievements. A developed instructional module in STEM context for learning physics concepts was used for the study. Modules were validated by experts for face and content validity before usage in the study. Study was carried out in an afterschool environment. The developed instructional modules. Modules were subjected to use for learning the selected physics concepts in a single group design comprising of 48 male students and 41 female students in purposively selected secondary schools. Findings revealed that activities in STEM context had positive impacts on improving learners' knowledge and arousing their curiosity to learning perceived physics concepts as against the usual conventional method. Moreover, study found out that learning physics concepts in the context of of STEM learning, developed the secondary school girls' enthusiasm for the acquisition of skills in science, technology, engineering, and mathematics (STEM). Through the engaged hands-on STEM activities, the girls were able to explore, ask questions, show persistence and solved problem. The STEM instructional approach used in the study for learning physics concepts fuelled the students' curiosity especially the females through creative thinking and problem solving so that through the positive feelings associated with the STEM learning, the school girls were more able to find learning physics more pleasurable and increasingly interesting. Thus, these positive experiences improved both male and female students' achievement in physics learning. Study therefore recommended the use of STEM instructional approach in the learning of physics concepts to rescue from the common scenario of gender differences in physics achievement.*

Key words: *Male, Female, Achievement, STEM, Physics learning.*

Introduction

Traditional pedagogy has failed to provide opportunities for students' achievement(Collins, Totino, Hartry, Romero, Pedroso, & Nava, 2020)[1].Physics teachers' constant use of conventional teaching approach had over the time resulted to ineffectiveness in the teaching and learning of Physics concepts which had consequently resulted to poor achievements in Physics(Uwizeyimana, Yadav, Musengimana & Uwamahoro,2018)[23]. Besides, the poor teaching method used in physics had developed in students a preconceived negative idea that Physics is difficult as a subject at school and this had resulted to low students' achievement with an imparting negative effect on the technological development of the country(Jegede & Adebayo,2013)[11]. According to Regner, Steele, Ambady, Thinus-Blanc, and Huguet(2014)[15] observed that the majority of gender differences begin to emerge in adolescence with the girls being under-represented among highest achieving 15-year-olds and this gender differences in achievement continues into the university and even beyond.

The importance of achievement in physics cannot be over-emphasized because Physics education fosters critical thinking and problem-solving skills. Advancements in physics can lead to technological innovations and economic growth. Physics knowledge is essential in various industries such as healthcare, engineering, and technology. Physics education plays a crucial role in fostering critical thinking and problem-solving skills in individuals. By studying physics, students are able to develop logical reasoning, analytical skills, and the ability to think critically about complex issues. Physics challenges students to think creatively and come up with innovative solutions to complex problems. Knowledge of physics principles to address real-world problems and make groundbreaking discoveries. Overall, physics education provides a solid foundation for developing the skills necessary to excel in various fields, including science, engineering, technology, and entrepreneurship. .The study of physics leads to a unique and effective approach to problem solving which many employers value when looking for potential candidates. A degree in physics provides the foundation for many other sciences such as chemistry, oceanography, seismology, astronomy, and can also be applied to biological and medical sciences. At most, physics is crucial in helping to explore the world around, inside, and beyond our understanding (University of Pittsburgh,2024)[22].

Unfortunately, there is the problem of gender differences in physics achievements in schools particularly at the senior secondary school. Physics has one of the largest gender gaps in science, technology, engineering, mathematics and medicine (STEMM) Gender inequality according to Kong, Martin-Gutierrez and Karimi(2022)[12] manifests itself in the production of science and achievement outcomes .According to them, mounting evidence suggests that science and engineering fields suffer from gender biases particularly in physics , a discipline where women are still under-represented and gender disparities persist .According to Abuh (2021) many fields in physics are very male-dominated and has the few proportions of women that there is an amplification effect. Meaning, that if there are more men than women, it becomes very difficult to get women in because they are less attracted to that environment. In fact, women make up only 34% of the workforce in science, technology, engineering and math (STEM), and men vastly outnumber women majoring in most STEM fields. Thus this implies that science teachers should develop and integrate feminist pedagogical strategies in their courses to create inclusive student learning experiences and will ultimately shape the future of scientific innovation(Giddings & Price,2023)[7].

Moreover, Ugwu (2011)[21] observed that gender has significant contribution on student's understanding of physics concepts and achievement. A meta-analysis of empirical studies in gender-related differences in achievement showed that gender is related to Physics achievement. Investigations, directed at eliminating gender difference in achievement in Physics would hold immense promise for an improvement of the status of Physics education in Nigeria. Gender was significantly related to senior secondary school Physics students' understanding of Physics concepts. The observed gender difference in understanding Physics concepts appears to explain gender gap in Physics education in Nigeria since the gender difference in attainment in physics is in favour of boys. Jugović (2017)[11] also observed that girls had a lower self-concept of ability and lower expectancies of achievement in physics compared to boys.On gender gap, physics as been observed to be a male dominated subject by traditional rolesand this have pushed many female studentsaway from doing physics because of their low achievement in it into doing other subjects like biology, and other sciences (Simeon & Yakob, 2022)[17]

If we want to see 50% of physicists being women sooner we need to implement new initiatives to do this – over and above any currently-running initiatives. In other words, evidence-based interventions are necessary to rescue this gender gap as Physics has one of the largest gender gaps in science, technology, engineering, mathematics and medicine (STEMM) . According to Giddings, Lesley-Ann & Price (2023) [7] innovators ought to see how STEM educators will continue to develop and integrate feminist pedagogical strategies in their courses to create inclusive student learning experiences. These pedagogies will ultimately shape the future of scientific innovation and bridge the gender gap.

Research Question

To guide the study, the following research was generated in the study**:**

1).Is there any significant difference between the posttest achievement of male and female students in physics learning after the effect of pretest is controlled

Research Hypotheses

To guide the study, the following research hypothesis was formulated**:**

1). There is no significant difference between the postest achievement of male and female students in learning physics in STEM context after the effect of pretest is controlled

Purpose of the Study

In the light of established gender differences in attainment or achievement in physics with male been observed as dominating the subject by traditional roles which have pushed many female students away from doing physics because of their low achievement, it become necessary to use an evidence-based interventions such as STEM instructional approach which integrates feminist pedagogical strategies in physics learning .Thus, the study intends to use STEM instructional approach in the learning of physics concepts to investigate the possibility of rescuing this gender gap in physics achievements.

INTERSECTIONALITY OF STEM LEARNING APPROACH FOR PHYSICS LEARNING

Science ,Technology ,Engineering and Mathematics(STEM) been shown to support the development of a generation of thinkers, collaborators, and problem solver in the contemporary world(Reinking & Martin,2018)[16]. According to Mpofu (2020)[13] STEM learning approach directs teachers to diffuse paradigmatic knowledge, skills, values and language differences and teach the integrated discipline as one cohesive entity. In doing so, teacher and student interactions should take the centre stage to enable them to collaboratively construct new knowledge, skills and beliefs at the intersection of more than one STEM subject area. Driving such interactions in the classrooms necessitates that teachers comprehend STEM content and acquire supportive pedagogical content knowledge specific to their subjects as well as working knowledge in another(Takeuchi , Sengupta, Shanahan, Adams, & Hachem, 2020)[19] . The integrated STEM education entails ‘an interconnected entity [of disciplines] with a strong collaborative connection to life

Mpofu (2020)[13] further asserts it is indisputable that Science, Technology, Engineering and Mathematics (STEM) are strong drivers of competitive national economies. Thus, throughout the world, nations are busy investing in STEM with the hope of grooming innovative minds to spearhead the development and sustainable growth of their economies. In education, strong STEM programmes are regarded as critical in developing students with twenty-first century competences (knowledge, skills and values). Twenty-first century com

STEM instructional approach can occur at the space where two or more STEM subjects such as Mathematics and Science intersect. Class interactions draw into this space the content and processes such as problem-solving and quantitative reasoning of both mathematics and science. Mathematics used in science or mathematically rigorous science education brings to the attentions of teachers an interdisciplinary understanding of STEM education that ‘does not create an independent meta-discipline while preserving the subject-specific knowledge, skills, and attitudes.

The integrated STEM education entails ‘an interconnected entity [of disciplines] with a strong collaborative connection to life. Teaching physics in the context of STEM learning makes the learning of physics concepts more authentic and understandable (Simeon, 2022).This according to him is because STEM learning focuses on real- world problems. According to him, the objectives of STEM learning are interwoven in the disciplines of science, technology engineering and mathematics so that physics students will begin to see physics being a science as not been isolated but in collaboration with the rigorous mathematics, while equally engaging in using technology and engineering designs to make attractive and economic products. Teaching physics concepts in the context of STEM learning eradicates or reduces teaching physics around the facts thereby changing the norm. Teaching Physics in STEM context according to him equips students with the potential for addressing real ecomic, social, human and environmental problems in the contemporary world.

Gendered Socialization Theory

Overwhelmingly, girls and boys are socialized differently in the United States. This is generally based on preconceived ideas of gender roles. Gender roles are sets of "behaviors, attitudes, and personality characteristics expected and encouraged of a person based on his or her sex." What has been found is that, "boys are raised to conform to the male gender role, and girls are raised to conform to the female gender role" (SparkNotes, 2006) [18].While experts still do not agree if the socialization and stereo-types of gender is based in genetic differences, the socialization practices are apparent from an early age. The ideas of gender roles and socialization relate directly to the concept of the STEM field gender gap because researchers have continually found evidence of gender stereotypes related to STEM professions. Two researchers, Dasgupta and Stout (2014) [4], found that women are leaving the STEM pipeline before entering the official STEM profession. This STEM pipeline phenomenon loses women who could become the next generation of scientists, engineers, and creators of technology. Researchers have found that one of the reasons women are leaving the STEM pipeline and professional field is because women are bombarded with socialized ideas and negative stereotypes, specifically about women's subpar math abilities (Gunderson et al., 2011) [8]. It has been found that these mentalities and stereotypes are communicated to girls at a young age through their parents and teachers, sometimes un-consciously. Regardless of the conscious or unconscious nature of the mentalities, these gendered stereotypes shape girls' math attitudes and ultimately diminish their interest in STEM fields. It can be argued that stereotypes and stereotype threats are two reasons why women are underrepresented in STEM fields. Socialization also occurs in family contexts. Parents and/or guardians who raise children have an influence on their motivation when it comes to achievement in settings such as those structured around STEM related topics (Partridge, Brustard & Stellino, 2008) [14]. Specifically, Eccles (2014)[5] describes and analyses "families' influences on gender differences in STEM disciplines. In her research she describes how parents' beliefs and perceptions influence children's outcomes and activity choices. Parents influence children through their advice, the materials(i.e. toys) available, and exposure to a variety of experiences. In her research she found that "parents do make gender-stereotypic causal attributions and these differences help to explain…children's abilities and interests". Overall, Eccles's research (2014) [5], along with other research, displays the theory of gender socialization which marginalizes women in STEM fields. The marginalization diminishes women's voice and legitimacy in the workforce and classroom (Regner, Steele, Ambady, Thinus-Blanc, & Huguet, 2014)[15].

RESEARCH METHODOLOGY

Research Design

The study was carried out in an after school environment .The study could not randomize nor use a control group but rather an existing intact group of the physics class as the single group. Borg and Gall (1989)[2] justified the use of such single group design in school environments where the school do not make possible provisions nor do they allow the researcher for any control groups in the school. Also justifying the use of a single group design is Thompson(1986)[20] who affirmed that the single – group research design is highly flexible and that it highlights individual differences in a response to the effect of such study' s intervention.

Sample and Sampling Technique

The two schools used for this study were purportedly selected in the federal capital territory, Nigeria. This was based on schools that will allow an afterschool school programme in their school. After which ethical considerations of writing to the relevant school authorities for permission to use school and students for research purpose was done. Study involved 48 male and 41 female participants giving a total of 89 participating students on the overall in the two selected schools. A total of 10 students were used after the use of the instructional module to obtain feedback by interview for study thematic analysis of the impact of instructional module on learning selected physics concept. Study purportedly used an intact class of senior secondary school 2(SS2)made up of 48 males and 41 females in a purportedly selected senior secondary school in Kwali Area council , Abuja, Nigeria. This is a school that allowed their students to have such an after school environment for studying physics**.**

Procedure

The developed STEM learning instructional module was to enhance learning difficult physics concepts is such as driven by NGSS standards to complements the trans-disciplinary philosophy. According to Glancy and Moore. (2013) [6], STEM is the combination of each component of science, technology, mathematics and engineering and the translations connecting them. The framework of STEM translation model depicts that interdisciplinary STEM instructions and learning activities are optimal when students are made to focus on making translations between the ideas of each of these STEM components of science, technology, mathematics and engineering. Therefore, participants were allowed to generate some solutions to world problem through the well outlined Physics instructional approach in STEM context.

Instrumentation

Moreover, for the building a rural community sturdy bridge challenge, the main goal is identifying some problems with the Nigeria Railroad Corporation which has newly acquired a set of fleets of trains for transportation of goods and services across the country. Unfortunately, in one section of the railroad plan, there exist a narrow river which runs through a deep valley so that construction of an additional railroad for the trains to cross the valley in a community is a problem. Participants generating some solutions to the problem by designing a truss bridge as shown in Figure 3 was the imminent challenge goal study for the participants. Therefore, the truss bridge design challenge goal was to use the design thinking process to solve the problem of some villagers in a remote area.

The following Table 1 outlined the step by step of specific objectives in the truss bridge STEM-Design challenge:

Table 1. Description of Specific Objectives in the Truss Bridge STEM challenge For Physics Learning

S/NO	STEM standard	Description of Objectives
1	**Science** in Building a community sturdy Truss Bridge challenge.	1.To know the concept of Newton "s third law of motion , equilibrium , static and dynamic, vibrations , tension and compression forces
2	**Technology** in Building a community sturdy Truss Bridge challenge.	2.To know how to design a model Truss Bridge for peoples' needs by generating ideas ,showing creative thinking and exploring solutions from different perspectives.
3		3.To know the geometry and vectors for determining the state of equilibrium for truss bridges . Plotting mathematical graph of strength prediction of the designed Truss Bridge.
4	**Mathematics** in Building a community sturdy Truss Bridge challenge.	4.To know the fundamental principles of engineering in bridge design, application of force concepts in bridge designs, coupling imagination, creativity with analytical skills to meet the users ' need reflective and independent thinking , seeking new dimensions of knowledge and learning from failure within the engineering context
	Engineering in Building a community sturdy Truss Bridge challenge	

RESULT

Result of One-Way ANCOVA for Significant Difference Between Male and Female Students 'Achievements in Physics Learning at Posttest.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4.235[a]	2	2.12	.27	.76	.006
Intercept	2812.940	1	2812.94	362.21	.00	.808
Pre_test	1.947	1	1.95	.25	.62	.003
Gender	3.577	1	3.58	.46	.50	.005
Error	667.878	86	7.77			
Total	280511111.000	89				
Corrrected Total	672.112	88				

a.R Squared= .006(Adjusted R Squared = -.017)

From the one-way between –groups analysis of covariance (ANCOVA) carried out, the pretest was the participants' achievement score in physics learning before the intervention was used as the covariate .After adjusting the pre-test on students 'achievement in physics there was no significant difference male and female on post –test achievement scores in physics after the use of STEM instructional module .since $p>0.05$ (two-tailed), η_p(partial eta squared)=.005.This therefore implies that there was no significant difference between the post-test achievement of male and female students in physics learning after the effect of pretest is controlled. This also means that the study intervention which is learning physics concept in the context of STEM had positive effects on both male and female student's achievement in physics alike with significant increase from the pre-test to post achievement in physics learning.

DISCUSSION AND CONCLUSION

Study findings revealed that the use of the developed learner-centered, activity based and facilitators 'assisted modules on physics learning in STEM context had the capacity to improve students' knowledge and achievement in learning physics concepts of force especially that of closing gender gap such that the female students' achievement in physics was not different from that of their male counterparts as there was no significant difference between them. The female students like their male counterparts also had significant increase in their achievements in physics. The STEM instructional approach used in the study for learning physics concepts fuelled the students' curiosity especially the females through creative thinking and problem solving so that through the positive feelings associated with the STEM learning , the school girls were more able to find learning physics more pleasurable and increasingly interesting. Thus, these positive experiences improved both male and female students' achievement in physics learning.

Therefore, study observed that innovative pedagogical delivery of physics concepts should be done with such instructional modules developed around several non-negotiable design elements to offer supportive STEM learning environment as well as give exposure to real-world learning opportunities. Study concluded that the STEM instructional approach should used for learning physics concepts because it fueled the students' curiosity especially the females through creative thinking and problem solving so that through the positive feelings associated with the STEM learning, the school girls were more able to find learning physics more pleasurably and increasingly interested in learning physics. Thus, these positive experiences in STEM learning improved both male and female students' achievement in physics learning.

This is with the intention of improving students' achievement, knowledge acquisitions and interest in physics learning. This is in line with the assertions of Gutulo and Tekello (2015)[9] that to accelerate development in physics education, instructional delivery must be learner-centered, teacher-assisted, action oriented and project- based. Findings is concomitant with the observations of Reinking, et al(2018) [16] that not only do girls need to have positive experiences, but girls also need to be given the freedom to explore, ask questions, be curious, and be creative which are the ingredients of learning

Physics concepts in STEM context . The physics instruction in STEM context developed the secondary school girls' enthusiasm for skills in science, technology, engineering, and mathematics (STEM). Through the hands-on activities, the girls explored, asked questions, persisted, and solved problem. The STEM instructional approach for learning physics fuelled students' curiosity through creative thinking and problem solving so that through the positive feelings associated with the STEM learning , the school girls were more able to find learning physics more pleasurable and continue to be engaged and interested in it. These positive experiences improved both male and female students' achievement in physics learning. *Study therefore recommended the use of STEM instructional approach in the learning of physics concepts to rescue from the common scenario of gender differences in physics achievement.*

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