



Impact of mathematics competency on students' physics performance in senior secondary schools in Katsina, Nigeria

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Abstract

The study explored the impact of mathematics competency on students' physics performance in senior secondary schools in Katsina Zonal Quality Assurance, Katsina State, Nigeria. An ex-post-factor survey research design was used for the study. The population for this study covered all Senior Secondary III (SS III) Physics students in twelve public senior secondary schools in Katsina Zonal Quality Assurance of Katsina State, Nigeria, with a total number of 4,414. A simple random sampling technique was used to select five (5) schools with total sample of 256 (112 male and 144 female) physics students. Two instruments were used for the study, namely; Physics mock scores and Mathematics mock scores. Both the Physics and Mathematics mock scores of the students were collected from each school involved in selected samples. Two research questions were raised and two research hypotheses were tested at 0.05 level of significance. The research questions were addressed using descriptive statistics such as mean and standard deviation, and the Anova and Analysis of Covariance (ANCOVA) statistical analyses were employed to evaluate the hypotheses. Findings revealed that there was significant difference between students' performance in physics based on discrepancy in mathematical competency among senior secondary schools in Katsina Zonal Quality Assurance. This finding also showed that there was significant difference in physics academic performance of the male and female physics students with high mathematical competency. The finding further revealed that there was a significant impact of mathematical competency on students' physics performance among senior secondary schools in Katsina Zonal Quality Assurance. Based on this findings, it was recommended that physics students should be taught the fundamental mathematical concept related to physics concept as a prerequisite by physics tutors before proceeding to the teaching of physics concepts.

Keywords: Mathematics competency, physics achievement, ANCOVA

Introduction

In the realm of science education, Physics assumes a paramount position, serving as a fundamental subject that provides the essential foundation for understanding the natural world and its underlying principles (Hake, 1998) [7]. As students progress through their secondary education, Physics assumes even greater importance, as it plays a crucial role in shaping their academic and career paths, particularly for those pursuing science-related fields (NRC, 2012). However, mastering Physics is often closely intertwined with a firm grasp of mathematics, as both subjects share a symbiotic relationship, with mathematics serving as the language of Physics (Hsu, 2004) [8]. The majority of students believed that physics was a demanding subject in high school, and that it became even more difficult in college and graduate school (Ryan, 2013) [17]. Physics is a science that focuses on the physical characteristics of matter and how it interacts with energy. It is a systematic study of knowledge that is the result of careful observation, measurement, and experimentation with the goal of establishing fundamental laws and providing verifiable scientific justification for natural phenomena (Ibibo and Francis, 2017).

On the other hand, mathematics is often considered to provide the fundamental tools and concepts necessary to understand and solve complex physical problems. However, the level of mathematical ability possessed by students may vary significantly, and this could have a significant impact

on their performance in physics. Since mathematics and natural sciences are intimately related, it serves as a language of science to communicate scientific observation, experimentation, and conclusion (Omeodu, 2019) [15]. According to Awodun and Ojo (2013) [1], "Without Mathematics, there is no science, and without science, there is no modern technology, and without modern technology, there is no modern society; in other words, mathematics is the precursor and the Queen of science and technology, and the indispensable single element in modern societal development" (Awodun and Ojo, 2013) [1]. This statement highlights the significance of mathematics to the modern culture of science and technology. Yeo (2013) [22] argued that because both emphasize decision-making and problem-solving skills, physics and mathematics curricula have similar goals. Additionally, he said that symbolic expression helps students comprehend physics concepts more thoroughly and develops their procedural knowledge of how to relate different symbols when solving physics problems. He added that it is assumed that a student who excels in mathematics will also flourish in physics.

The relationship between mathematics and physics has been a subject of considerable interest in the field of education. The integration of mathematics and Physics education is evident in various facets of the subject, from formulating equations to analyzing data and solving complex problems (Deng *et al.*, 2016) [6]. Key concepts in Physics, such as force, motion, and energy, are intricately connected to

mathematical principles like calculus, algebra, and trigonometry (Lawson, 2001) ^[9]. Consequently, the competency of students in mathematics is believed to have a profound impact on their performance in Physics (Boo & Watson, 2001) ^[3].

The senior secondary school stage represents a pivotal point in a student's academic journey, where they are introduced to specialized subjects like Physics, laying the groundwork for potential careers in science, engineering, and related fields (Wynne & Pinho, 2017) ^[21]. At this stage, students are exposed to more advanced mathematical concepts, such as algebra, trigonometry, and calculus, which are essential for comprehending the complex principles of Physics (Cohen *et al.*, 2018) ^[5]. Despite the interconnectedness of these subjects, the educational system often treats them as separate entities, leading to a potential disconnect between the mathematics and Physics curricula (Martin *et al.*, 2019) ^[10].

The theoretical framework for this study was drawn upon several educational theories and models related to learning, cognition, and academic achievement. Some of the key theories that guided the study include:

Constructivism

Constructivism is a learning theory that emphasizes the active construction of knowledge by learners through their experiences and interactions with the environment. In the context of this study, constructivism suggests that students build their understanding of physics concepts based on their prior knowledge of mathematics and how they interpret and make sense of the information presented to them. Piaget's work on constructivism laid the foundation for this theory. In his book "To understand is to invent," he highlighted the importance of students' active involvement in the learning process and how they construct knowledge through their cognitive development.

Cognitive Load Theory

Cognitive Load Theory posits that learners have limited cognitive resources, and learning can be hindered when these resources are overloaded. The theory suggests that students with better mathematics competency may experience reduced cognitive load while studying physics, allowing them to focus more on understanding complex physics concepts. John Sweller's seminal work on cognitive load theory, specifically the article "Cognitive load during problem-solving: Effects on learning," provides insights into how cognitive load impacts learning and problem-solving abilities. It forms the basis for understanding the relationship between mathematics competency and physics performance in the context of cognitive load.

Zone of Proximal Development (ZPD)

The Zone of Proximal Development, proposed by Lev Vygotsky, refers to the range of tasks that a student can perform with the help of a more knowledgeable person. In the context of this study, the ZPD can be used to explore how students with varying levels of mathematics competency may benefit from targeted support to enhance their physics performance. Vygotsky's book "Mind in Society: The Development of Higher Psychological Processes" is a fundamental work that outlines his socio-cultural theory of cognitive development, including the concept of the Zone of Proximal Development. It provides a

theoretical framework for understanding how students' learning can be scaffolded and supported based on their existing capabilities.

Achievement Motivation Theory

Achievement Motivation Theory focuses on individuals' efforts and behaviors directed towards accomplishing tasks and achieving success in educational settings. In the context of this study, this theory can help explore how students' motivation to succeed in physics is influenced by their mathematics competency and how it affects their academic performance. David McClelland's book "Human Motivation" is a seminal work in the field of motivational psychology. The theory presented in this book provides insights into how individuals' motivation to achieve can vary based on their perceptions of their own abilities and the tasks at hand. By integrating these theoretical frameworks, the study gain a comprehensive understanding of how mathematics competency can impact students' physics performance in senior secondary schools. These theories provide a solid foundation for exploring the complex interactions between students' cognitive abilities, motivation, and the learning environment in the context of mathematics and physics education.

Numerous research have been done on the impact of students' mathematical knowledge, aptitude, or abilities on their success in physics. A study by Awodun and Ojo (2013) ^[1] looked into how mathematics abilities, including computation, geometry, algebra, reading graphs and tables, measurement, and probability and statistics, predicted the performance of physics students in senior secondary schools in the Ado Local Government Area of Ekiti State, Nigeria. According to the study, all mathematical abilities—including computation, geometry, algebra, reading graphs and tables, measurement, and probability and statistics—have a significant positive impact on and are highly predictive of students' physics performance in senior secondary schools. A similar study by Ayodele, Awofala, and Adekoya (2014) ^[2] investigated the effect of students' mathematics background knowledge on their performance in physics as senior secondary school students, and they observed a significant positive relationship between the two. The study also discovered that there was no statistically significant association between students' post-test accomplishment scores in physics and their gender or math knowledge. In addition, a study by Charles-Organ and Okey (2017) ^[4] explored the impact of math competency on students' electromagnetism performance and discovered a favorable correlation between mathematics competency and students' success in physics. Furthermore, a study by Muhammad and Ahmad (2014) ^[12] investigated the relationship between students' mathematics and physics performance in senior secondary schools and concluded that there was no discernible connection between students' mathematics and physics performance. Moreover, Omeodu's (2019) ^[15] investigated the "Role of Mathematical Competency in Enhancing Students' Academic Performance in Physics in Port Harcourt Local Government Area Rivers. According to the study, the majority of respondents (46.77%) have low mathematics skills, followed by 22.58% who have strong mathematical skills and 30.65% who have medium mathematical skills. The study also discovered a strong positive correlation between mathematical competency and performance in physics, with students with

high mathematical competency outperforming those with medium and low mathematical competency in physics tests. Lastly, a study by Samson (2011) ^[18] examined how mathematics competency affected junior high school students' performance in science in Benin metropolis, Edo State. The study's findings demonstrated a strong relationship between math prowess and scientific achievement. The results also demonstrated a direct correlation between junior secondary school scientific achievement and all six mathematics skills, including calculation, algebra, geometry, measurement, interpretation of graphs and tables, and daily statistics.

Statement of the Problem

The current state of students' final examination performance in senior secondary schools is far from commendable. According to the chief examiner's reports from the West Africa Examination Council (WAEC) from 2008 to 2020, students' poor performance in physics is due to their weakness in problems involving calculations, drawing conclusions from graphs, being able to measure accuracy precisely, having a thorough understanding of the wide range of topics covered by the syllabus, correctly interpreting physics questions that result in the wrong answers, and language barriers. The language of physics is math. Every student of physics is therefore expected to be proficient in mathematics and to be able to use their mathematical knowledge to solve common difficulties in physics. In light of these claims, the study examined how mathematics competency affected senior secondary school students' physics performance in Katsina Zonal Quality Assurance, Katsina State, Nigeria.

Research Objectives

The primary objectives of this study are as follows:

1. To assess the mathematics competency of senior secondary school students.
2. To evaluate the performance of senior secondary school students in physics.
3. To examine the impact between mathematics competency and physics performance among senior secondary school students.

Table 1: Summary of analysis of physics achievement scores due to the level of mathematics competency of physics students.

Group	No of students	Physics achievement mean score	Standard deviation	Mean difference		
				HMC	MMC	LMC
HMC	91	57.64	20.57	0	2.59	10.30
MMC	61	55.05	17.74	-2.59	0	7.71
LMC	104	47.34	22.23	-10.30	-7.71	0
TOTAL	256					

Field Study, 2022

The difference in the mean physics achievement score between students with HMC, MMC, and LMC is displayed in Table 1. According to the study, there was a 10.30 difference in the mean scores of students with HMC and LMC compared to a 2.59 difference between those with HMC and MMC. This shows that students with HMC did significantly better than those with MMC and are superior to those with LMC. Moreover, there was a 7.71 point difference in the mean physics achievement scores of students with MMC and LMC. In other words, MMC

Research Question

1. Is there any difference in the physics achievement mean score of students with High, Medium, and Low Mathematical Competency?
2. Is there any difference in physics achievement between male and female student due to their level of mathematics?

Research Hypothesis

1. There is no significant impact of Mathematics competency on students' physics performance among senior secondary schools in Katsina Zonal Educational Quality Assurance.
2. There is no significant interaction effect of mathematics competency and gender on students' achievement in physics.

Methodology

An ex-post-factor survey research design was used for the study. The population for this study covered all Senior Secondary III (SS III) Physics students in twelve public senior secondary schools in Katsina Zonal Quality Assurance of Katsina State, Nigeria, with a total number of 4,414. A simple random sampling technique was used to select five (5) schools with total sample of 256 (112 male and 144 female) physics students. Two instruments were used for the study, namely; Physics mock scores and Mathematics mock scores. Both the Physics and Mathematics mock scores of the students were collected from each school involved in selected samples. Two research questions were raised and two research hypotheses were tested at 0.05 level of significance. The research questions were addressed using descriptive statistics such as mean and standard deviation, and the Anova and Analysis of Covariance (ANCOVA) statistical analyses were employed to evaluate the hypotheses.

Results of the Study

Research Question one

Is there any difference in the PHYSICS achievement mean score of students with High, Medium, and Low Mathematical Competency among senior secondary schools in Katsina Zonal Educational Quality Assurance?

students outperformed LMC students in terms of performance. Based on the results of this study, it is clear that students' performance in physics is mostly determined by their mathematical competency.

Research Question two

Is there any difference in physics achievement between males and females due to their level of mathematics competency among senior secondary schools students in Katsina Zonal Educational Quality Assurance?

Table 2: Summary of analysis of physics achievement scores due to the level of mathematics competency and gender of physics students.

		Level of mathematical competency		
		HMC	MMC	LOW
Male	Mean	42.3778	43.7931	38.5263
	Standard deviation	17.40597	15.40264	19.10814
	N	45	29	38
Female	Mean	72.5652	65.2500	52.4394
	Standard deviation	9.46256	12.98883	22.43495
	N	46	32	66
Mean difference		-30.1874	-21.4569	-13.9131
Total (N)		91	61	104

Field source: 2022

Table 2 displays the variation in students' mean scores on the physics achievement test by gender and math competency. Higher achievement mean scores in physics were recorded by female students in the high level of mathematics achievement (M=72.5652, SD=9.46256) than by their male counterparts (M=42.3778, SD=17.40597), higher achievement mean scores in physics were also recorded by female students in the medium level of mathematics achievement (M=65.2500, SD=12.98883) than by their male counterparts (M=43.7931, SD=15.40264), and higher achievement mean. According to this tables, female students outperformed male students in terms of their achievement in physics among students with high, medium, and low mathematics competency, with mean differences of 30.1874, 21.4569, and 13.9131 in favor of female students, respectively. The study indicates that female students outperformed their male counterparts at all levels of mathematics competency as well as in their performance in physics. This suggests that regardless of gender, the students

Table 4: Summary of analysis of covariance of physics achievement scores by level of mathematics competency and gender.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	37921.378 ^a	5	7584.276	25.127	.000
Intercept	656216.674	1	656216.674	2174.102	.000
Gender	28431.690	1	28431.690	94.197	.000
Level of mathematics competency	7205.843	2	3602.921	11.937	.000
gender * Level of mathematics competency	3101.758	2	1550.879	5.138	.007
Error	75458.372	250	301.833		
Total	828250.000	256			
Corrected Total	113379.750	255			

a. R Squared = 0.334 (Adjusted R Squared = 0.321)

Source: Field Study, 2022.

Table 4 shows that the gender has a considerable impact on academic achievement in physics, with an F (1, 250) = 94.197, p =.000. This suggests that the amount of mathematics competency between male and female physics students causes a considerable variation in their academic success. Thus, the second hypothesis is rejected.

Discussion of results

According to the study's findings (table 1), students with HMC did much better than those with MMC and much better than those with LMC. It is also shown that students with MMC outperformed those with LMC in terms of performance. The finding may be taken as evidence that students' performance in physics is mostly determined by their mathematical abilities. The results support the claims

With more mathematical attitude or understanding outperformed everyone else.

Hypothesis

H01: There is no significant influence of Mathematics competency on students' physics performance among senior secondary schools in Katsina Zonal Educational Quality Assurance.

Table 3: Analysis of Variance (ANOVA) on the impact of Mathematics competency on students' physics performance among senior secondary schools in Katsina Zonal Educational Quality Assurance.

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	5520.028	2	2760.014	6.474	.002
Within Groups	107859.722	253	426.323		
Total	113379.750	255			

Based on their degree of mathematical competency, the students' physics performance varied significantly (p = 0.002), according to the data shown in Table 3. Fc = 6.474, p > 0.05. Therefore, the students who performed better in math also greatly outperformed them in physics. This implies that students' poor performance in physics is due to their lack of mathematical competency. The outcome makes it quite evident that students can only succeed in physics if they have a solid background in mathematics. This indicates that among senior secondary schools in Katsina Zonal Educational Quality Assurance, Mathematical competency had a significant impact on students' physics performance. The null hypothesis was thus rejected.

H02: There is no significant interaction effect of mathematics competency and gender on students' achievement in physics among senior secondary schools in Katsina Zonal Educational Quality Assurance.

made by Awodun and Ojo (2013) ^[1] that all mathematics skills, including computation, geometry, algebra, reading graphs and tables, measurement, probability, and statistics, have a strong positive impact on and are highly predictive of students' physics performance in senior secondary schools. The results are in line with Omeodu (2019) ^[15], who discovered a strong positive correlation between mathematical competency and physics performance as well as the fact that students with high mathematical competency outperformed those with medium and low mathematical competency.

According to Table 2, there was a significant correlation between students' physics achievement and their mathematical competency. Therefore, the students who fared better in math also greatly outperformed them in

physics. This suggests that students' poor performance in physics is a result of their inadequate mathematical understanding. The outcome makes it quite evident that students can only succeed in physics if they have a solid background in mathematics. The study's findings do not corroborate Muhammad and Ahmad's (2014) ^[12] result that there was no meaningful relationship between students' performance in mathematics and physics. It is consistent with Samson's (2011) ^[18] findings that math competency and science achievement are significantly correlated. Samson (2011) ^[18] also found that junior secondary school science competency is directly impacted by each of the six mathematics skills, including computation, algebra, geometry, measurement, and interpretation of graphs and tables.

Conclusion

According to the study's findings, the majority of physics students at senior secondary schools in the Katsina metropolitan lack mathematical competency, with the majority falling into the low mathematical competency (LMC) group. Other elements that may contribute to this low level of mathematical competency include the socioeconomic situation of the students, their educational backgrounds, the nature of the school, the effectiveness of the teachers, the teaching style, the absence of proper classroom facilities, and many more. As a result, students who performed well on the mathematics achievement test also did well on the physics achievement test, and those who achieved well on both tests did so exceptionally well. This study demonstrates that mathematical competency not only demonstrates a predictability in physics accomplishment but also aids in understanding why some students outperform others. In light of these findings, students who lack mathematical competency or who are unable to apply their knowledge should not be expected to perform better on physics exams that include mathematical operations. There are students who, although having greater mathematical aptitude, struggle to perform better in physics. Additionally, there are students who struggle with math yet excel in physics. In general, it can be said that the students who did well in physics are also good math students.

Recommendations

The following recommendations were made in light of the study:

- Before moving on to the major idea of physics, physics teachers should first introduce the fundamental mathematical notion to their students.
- Physics teachers should be aware of the fundamentals behind the mathematical concepts in physics and use them to carry out calculations pertaining to those concepts.
- To achieve effective teaching and learning of physics, policy makers and curriculum developers should incorporate some mathematical concepts into the curriculum. These concepts include the law of indices, the law of logarithm, surds, geometrics, the construction of graphs, and others.
- Due to their failure in the subject, students should not perceive physics as a challenging topic; rather, all they need to do is strengthen their mathematical abilities. Due to this, the students' interest in the subject of physics will increase, which will result in a highly favorable attitude toward physics.

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