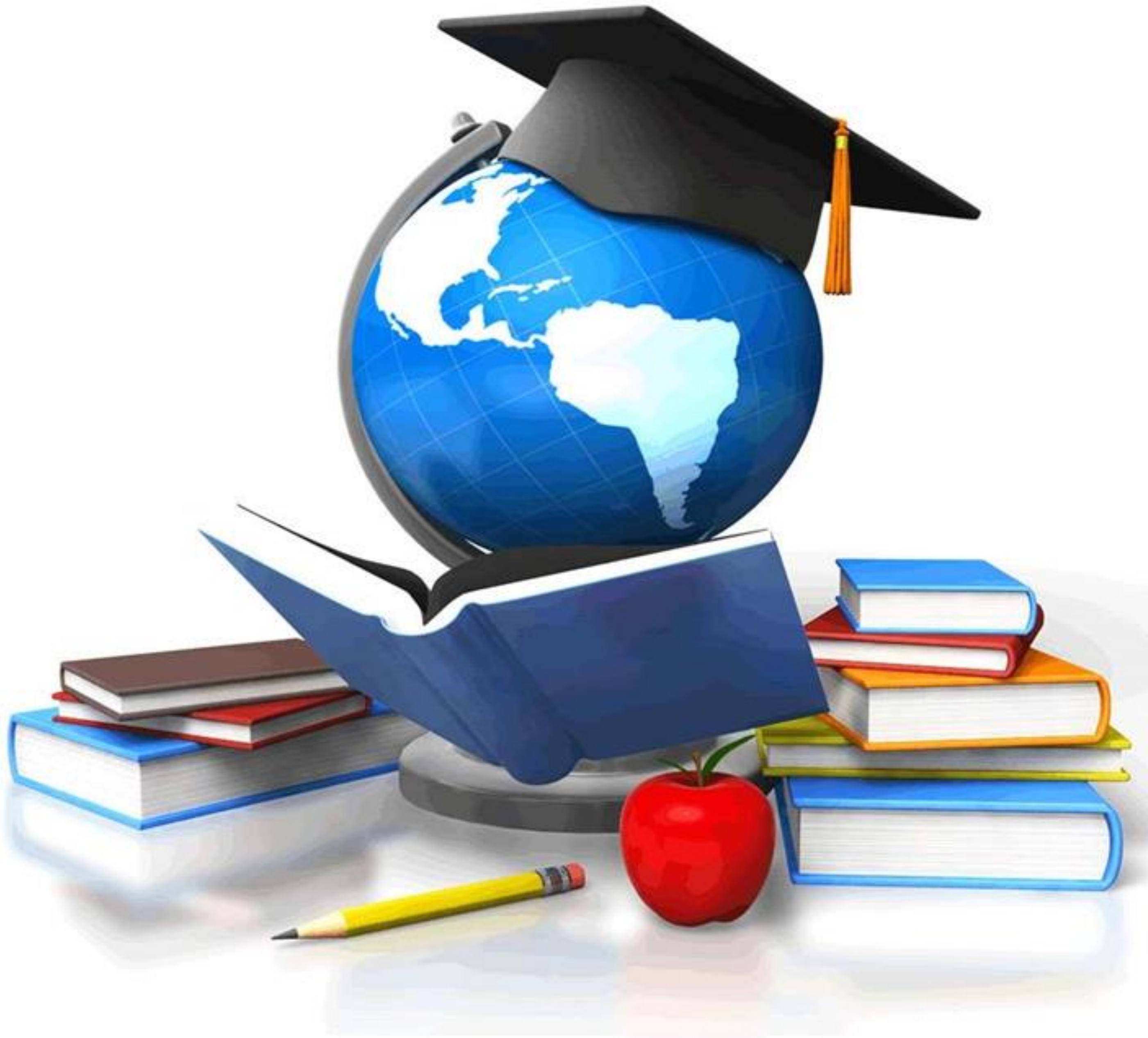
Journal of
Education and Practice
(JEP)

Examining the Impact of Knowledge of Mathematics on Academic Achievement in Physics, Among Students at Mawuli Senior High School, Ghana



CARI Journals

Journal of Education and Practice
ISSN 2520-467X (Online)
Vol.8, Issue No.7, pp. 1 – 13, 2024
www.carijournals

Examining the Impact of Knowledge of Mathematics on Academic Achievement in Physics, Among Students at Mawuli Senior High School, Ghana

Uthman Amadu[1], Issahaku Sontaa Jakalia[2], Anthony Babategrimine Yuoni[3]*

[1, 2, 3] Department of Physics Education, University of Education, Winneba - Ghana

https://orcid.org/0009-0007-7342-5041

Accepted: 12th July 2024 Received in Revised Form: 12th Aug 2024 Published 12th Sep 2024

Abstract

Purpose: The aim of this action research is to evaluate the impact of mathematical knowledge on students' academic performance in physics at Mawuli School, Ho.

Methodology: A teacher-made test was the instrument used for data collection in this study. The test consisted of questions in both mathematics and physics. The mathematics questions were strategically selected to align with concepts relevant to the physics curriculum. Pre-test and post-test were administered using similar sets of questions. Data analysis employed descriptive statistics, paired t-tests, correlation analysis, and regression analysis.

Findings: The study findings indicated a statistically significant positive correlation between students' mathematical knowledge and their performance in physics. Also, there was no significant difference in the performance of males and females students.

Unique Contribution to Theory, Practice and Policy: It was therefore recommended that physics teachers prioritize assessing and enhancing students' mathematical proficiency prior to introducing physics topics that require mathematical application.

Keywords: *Mathematics, Mathematical Knowledge, Physics, Performance*

Journal of Education and Practice
ISSN 2520-467X (Online)
Vol.8, Issue No.7, pp. 1 – 13, 2024
www.carijournals

1. Introduction

The primary objective of every educational system is to equip individuals with the necessary skills and knowledge to develop their full potentials. Mathematics, as a discipline, holds significant importance across various spheres of life. A study of mathematics unveils fundamental patterns that enhance the appreciation of nature (Yadav, 2019). In contemporary times, mathematics encompasses reasoning, inference, and empirical evidence alongside scientific principles, measurements and observations. Furthermore, it extends to mathematical representations of social systems, human behavior and natural phenomena.

A robust foundation in mathematics and a proficient talent pool in this domain are imperative to sustain a wide spectrum of value-added economic activities and innovations. The relevance of mathematics to society is underscored by the increasing attention given to the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) (Malaki, 2021).

Mathematical proficiency supports numerous facets of daily life; from interpreting news articles to making informed financial decisions. Mathematics substantially contributes to various fields such as business and the sciences by fostering learning. A sound grasp of fundamental mathematics is essential wherever computations, measurements, graphical representations and statistical analyses are involved. Cultivating a strong mathematical foundation can enhance one's logical, abstract, critical and creative thinking abilities. Teaching these essential 21st century skills is pivotal for our students to lead fulfilling lives and become lifelong learners (Malaki, 2021).

Mathematics serves as the cornerstone for both science and technology (Anyagh & O'kwu, 2020). Science and technology are crucial for nurturing students' critical and creative thinking skills, which in turn, are pivotal for developing their entrepreneurial capabilities. Consequently, mathematics serves as a crucial tool in cultivating students' entrepreneurial skills.

A good understanding of mathematics is the fundamental prerequisite for studying physics. The principles of physics find their clearest expression and interpretation through mathematics. Mathematics provides the logical framework essential for accurately formulating physical laws and quantifying their predictions. Mathematical relations commonly express physical theories, therefore, people who are adept at mathematics could effectively solve the challenges associated with addressing physical problems.

This study aims to investigate the extent to which students' comprehension of mathematics influences their performance in physics at Mawuli School.

2. Literature Review

Kuo et al. (2013) studied the symbiotic relationship between mathematics and physics in Tanzanian secondary schools and discovered that physics and mathematics were inextricably linked. They also suggested that mathematics serves as the framework through which logical structures are established, enabling the precise formulation of physical laws and the quantification of their predictions.

To adequately address the difficulties inherent in some physics topics, a comprehensive understanding of mathematics is required. Abdurrahman and Madugu (2014) discovered a direct association between proficient application of mathematical concepts and excellence in physics; when investigating the nexus among the performance of students in mathematics and physics in Birnin-Kebbi, Kebbi State. The study revealed that the proficiency in using exponents, fractions, and fundamental mathematical concepts is the most significant factor distinguishing high-performing science students from those with lower performance.

Mathematics, physics, and other natural sciences have had a long history of collaboration. Mathematics is the bedrock of science and technology since mathematics serves a variety of objectives in various domains. For example, a physicist's work relies heavily on measurement and other mathematical procedures (Abdurrahman & Madugu, 2014). Physicists use the mathematical tool known as the graph to help them understand the relationship between various variables, such as temperature and the presence of saturated water vapor in the atmosphere (Malaki, 2021).

Charles-ogan and Okey (2017) reiterate the impact of mathematics knowledge on physics students' understanding of electromagnetism. They reported the beneficial effects of strong mathematics aptitude on physics performance. They advocate rigorous mathematics education for physics students, emphasizing that mathematics is the language that articulates scientific discourse. They concluded that only mathematics could give matter structure and clarity, and that controlling nature required quantitative interpretations of thoughts and imaginations. Charles-ogan and Okey (2017) determined that physics is so deeply established in mathematics that its effects can be seen throughout the discipline. Students' understanding and application of physics concepts can be improved with adequate knowledge of mathematics; thus, students' comprehension of fundamental mathematical ideas has a significant impact on how they respond to higher-level physics concepts that require the use of these fundamental mathematical ideas.

Jones and Lord (2006) investigated students' experiences with the national curriculum and assessment, and found that, a lack of fundamental algebra impaired performance in physics problem-solving tasks. Despite conceptual differences, the importance of mathematical knowledge for numerical problem-solving in physics is undeniable. Tuminaro (2004) investigates the cognitive framework that links mathematics and physics, revealing a favorable association between ability in these areas. The ability to apply mathematical models to real-world physical situations emerges as a defining feature of a deep understanding of the subject matter. Hassan et al. (2018) investigated the relationship between academic performance in mathematics and science. The findings reveal a statistically significant association, highlighting the critical importance of mathematics in improving physics performance.

Numerous studies have demonstrated that students' mathematical proficiency is a significant predictor of their success in physics courses and assessments, highlighting the essential role that mastery of mathematical concepts and their application plays in achieving strong performance in physics (Hassan et al., 2018). At the same time, research consistently shows that male students, on average, tend to outperform female students in mathematics (Cwik & Singh (2021)), particularly in areas such as advanced calculus and problem-solving (Geary et al., 2022). These gender differences in mathematical achievement have been documented across various educational levels and cultural contexts, raising important questions about how these disparities might influence performance in physics.

Given the established relationship between mathematics proficiency and physics performance, as well as the documented gender gaps in mathematics, several studies have examined how these factors intersect in the context of physics education. The findings suggest that the gender gap in physics performance is largely attributable to differences in mathematics proficiency; when controlling for mathematical ability, the observed gender disparity in physics performance often narrows or disappears (Apata, 2019). However, this issue is further complicated by the influence of stereotype threat, where negative stereotypes about women's capabilities in mathematics and science can lead to underperformance (Cwik & Singh (2021)). Research indicates that this effect is particularly pronounced in high-stakes testing situations, where anxiety about confirming these stereotypes affects female students' performance.

To address these disparities, various interventions and strategies have been explored, such as enhancing math education, alleviating stereotype threat, and promoting a growth mindset among students (Liu et al., 2021). These approaches aim to mitigate the gender differences in the relationship between math proficiency and physics performance, fostering a more equitable learning environment. Overall, the literature underscores the importance of mathematics proficiency in determining students' physics performance and highlights how this relationship is shaped by gender. Addressing the underlying disparities through targeted interventions and creating a more inclusive educational setting could help promote equity and improve outcomes for all students.

3. Methodology

In this study, the type of research design used was action research. The target population of this study included all physics students in Mawuli School. The accessible population used in this study covered the Form Three Science One A (3 SCI 1A) students in Mawuli School. The number of students in the class was forty-five (45). This comprised $25\ (56\%)$ males and $20\ (44\%)$ females.

The instrument used in this study was teacher-made test items, comprising maths and physics questions. The math questions covered topics relevant to the physics concepts tested. Before the intervention, students were taught physics concepts without incorporating mathematical aspects. Pre-intervention tests in both subjects (Maths and Physics) consisting of subjective questions were administered. The strategy designed as an intervention was to teach mathematics components of the physics concepts and the physics concepts simultaneously.

In order to ensure both the reliability and validity of the test items, adapted past questions from the West African Senior School Certificate Examination (WASSCE) in mathematics and physics were utilized to establish a robust assessment framework. Expert scrutiny and pilot testing procedures were employed to validate content alignment and clarity, thereby ensuring alignment with the research objectives.

The subjects' topics were organized into groups based on the degree of correlation between mathematical concepts and those of physics, as shown in Table 1.

Table 1: Interrelatedness of mathematics and physics topics

Mathematics Topics Required	Related Physics Topics
Indices and Change of Subject	Dimensional Analysis
Plane Geometry and Trigonometry	Vector representation, Addition, and Resolution

After conducting the intervention, during which each group was taught the specified topics, equivalent sets of questions were administered as post-tests. The purpose was to assess whether there had been any observable changes in students' performance in physics attributable to their utilization of mathematical components within the taught physics concepts. The data were analyzed using statistical methods, including paired t-tests, correlation, and regression analysis.

4. Results and Discussion

4.1 Pre-intervention Test Results

Table 2 shows a summary of students' pre-test scores in both physics and mathematics. Students who scored below 10 marks out of 20, were considered to have performed below the pass mark; since the pass mark was 10.

Table 2: Students' pre-test scores

Scores	Maths Pre-test		Physics Pre-test	
	Frequency	Percentage (%)	Frequency	Percentage (%)
0-4	3	6.7	1	2.2
5-9	6	13.3	8	17.8
10-14	9	20.0	15	33.3
15-20	27	60.0	21	46.7

Notably, 80.0% of students passed the test in both mathematics and physics (achieving average or above-average scores). The percentage of students who passed the tests did not significantly differ between the two subjects, suggesting a potential linear relationship between them.

A detailed examination of the scores on both subjects reveals an intriguing pattern, with

Journal of Education and Practice
ISSN 2520-467X (Online)
Vol.8, Issue No.7, pp. 1 – 13, 2024
www.carijournals

students' marks generally decreasing from the top downward (Table 2). The analysis revealed a significant positive correlation between students' scores in mathematics and physics on this test ($r(43) = 0.43,\ p < 0.05$), indicating that students who performed well in mathematics tended to perform well in physics.

This finding is consistent with the research of Abdurrahman and Madugu (2014), who established a connection between mathematics and physics, suggesting a positive correlation in students' aptitude for both subjects. Physics relies on mathematics for its logical framework, facilitating the accurate formulation of physical laws and their quantitative predictions (Kuo et al., 2013).

Furthermore, Charles-ogan and Okey (2017) emphasized the deep integration of mathematics within physics, positioning mathematics as the "language of science" in scholarly discourse. This interconnectedness underscores how mathematical computations permeate every stage of physics, illustrating the profound influence of mathematics on the entire discipline.

4.2 Post-intervention Test Results

Table 3 shows a summary of students' post-test scores in both physics and mathematics. Similarly, the post-test was also scored out of 20.

Table 3: Students' scores in post-test

Scores	Maths Post-test		Physics Post-test	
	Frequency	Percentage (%)	Frequency	Percentage (%)
0-4	0	0.0	0	0.0
5-9	2	4.4	3	6.7
10-14	6	13.3	6	13.3
15-20	37	82.2	36	80.0

In the post-test, the results show that 95.5% of students passed the mathematics examination, whereas 93.3% passed physics (Table 3). This slight variance in the percentage of students passing in both subjects represents an enhancement over the disparity observed during the pre-test phase. These findings corroborate the linear relationship posited between these academic disciplines. Similarly, Awodun and Ojo (2013) found that mathematics skills in geometry, algebra, and mensuration, have a strong positive influence and significant predictive value on physics students' performance in Senior

Journal of Education and Practice
ISSN 2520-467X (Online)
Vol.8, Issue No.7, pp. 1 – 13, 2024 www.carijournals

Secondary Schools. Additionally, mathematical skills, along with factors such as teaching methods and laboratory work, are critical for success in physics (Bello & Ariyo, 2014).

A linear regression analysis conducted with the post-tests scores yielded the Equation 1, elucidating the association between students' performance in mathematics and physics.

$$\mathrm{Ph} = 0.34 * \mathrm{Ma} + 10.86 \qquad (1)$$

where:

Ph is Physics score

Ma is Mathematics score

To assess the generalizability of the model, it was applied to a subsequent batch of students from Mawuli School. Encouragingly, the predictions derived from the regression equation closely matched the actual physics scores of this new cohort.

In the specific context of Mawuli School, these findings suggest that mathematics plays a significant role in predicting students' performance in physics. The implications extend beyond the original sample, indicating that the identified relationship holds for diverse groups of students within the school. This insight contributes to a deeper understanding of the interplay between mathematics and physics achievement at Mawuli School, offering valuable considerations for educational strategies and interventions aimed at enhancing students' performance in these subjects.

Consequently, it is imperative to employ an adequate number of skilled mathematics and physics teachers. Furthermore, students should be encouraged to recognize the inherent connection between mathematics and physics, as a proficient understanding of mathematics significantly enhances performance in physics (Hassan et al., 2018). The advent of calculus, prompted by the evolving complexities within physics, underscores the intertwined nature of these disciplines. Visionary scientists such as Galileo Galilei and Isaac Newton necessitated a fresh mathematical framework to address emerging dynamics. During this period, there existed minimal demarcation between mathematics and physics. Newton, for instance, viewed geometry as an essential aspect of mechanics (Hassan et al., 2018). Thus, achieving excellence in physics necessitates a robust foundation in mathematics.

4.3 Comparison of Pre-test and Post-test Scores

In evaluating the effect size of the intervention on mathematics and physics, Cohen's d test was employed. For mathematics, a Cohen's d value of 0.62 indicated a moderate effect size, signifying a significant difference in mean scores between the pre-test and post-test assessments. Similarly, in physics, a Cohen's d value of 0.87 revealed a relatively large effect size, reflecting a notable difference in mean scores from pre-test to post-test.

The positive values of Cohen's d, showed the improvement in students' performance from the pre-test to the post-test. This improvement is supported by the observation that a majority (over 93%) of students achieved scores above the pass mark in both subjects during the post-tests. This outcome suggests a positive impact of the intervention on student performance in mathematics and physics. This view is supported by Goulet-Pelletier and Cousineau (2018), who highlighted that effect size is a crucial statistic for assessing the magnitude of an intervention's impact.

A correlational analysis was also conducted to investigate the relationship between students' performance on pre-tests and post-tests in mathematics and physics. The results indicated moderate correlations between various test pairs: mathematics pre-test and post-test ($r = 0.32, p = 0.33$), mathematics pre-test and physics pre-test ($r = 0.43,\ p = 0.03$), and mathematics post-test and physics post-test ($r = 0.34,\ p = 0.02$). Conversely, there were very weak correlations observed between mathematics pre-test and physics post-test ($r = 0.07, p = 0.96$), and mathematics post-test and physics pre-test ($r = 0.09, p = 0.56$).

The findings from the correlational analysis provide valuable insights into the relationships among students' performance in mathematics and physics pre-tests and post-tests. The results revealed moderate positive correlations between specific test pairs. Specifically, there was a moderate correlation between mathematics pre-test and physics pre-test scores ($r = 0.43, p = 0.03$), indicating that students who performed well in mathematics tended to exhibit higher performance in physics prior to any intervention. Chen et al. (2021) identified a positive correlation between mathematics achievement and physics achievement, concluding that mathematics performance plays a critical role in influencing physics outcomes.

Additionally, a moderate correlation was observed between mathematics post-test and physics posttest scores ($r = 0.34,\ p = 0.02$), suggesting that improvements in mathematics performance were associated with corresponding improvements in physics

Journal of Education and Practice
ISSN 2520-467X (Online)
Vol.8, Issue No.7, pp. 1 – 13, 2024
www.carijournals

performance after the intervention.

Conversely, very weak correlations were found between mathematics pre-test and physics post-test scores ($r = 0.07,\ p = 0.96$) and between mathematics post-test and physics pre-test scores ($r = 0.09,\ p = 0.56$). These weak correlations indicate that initial performance in mathematics did not strongly predict later performance in physics, and vice versa (Bello & Ariyo 2014).

A paired-sample t-tests conducted on the scores revealed significant differences in students' performance before and after the intervention in both mathematics ($t(44) = 3.5,\ p < 0.05$) and physics ($t(44) = 4.3, p < 0.05$). This suggests that the intervention was effective in enhancing students' proficiency in both subjects. This is consistent with the findings of Charles-Ogan and Okey (2017), who emphasized that enhancing students' mathematics skills is essential for achieving positive learning outcomes in physics.

Also, an independent t-test was employed to compare the performance of female and male students in the physics post-test, which showed no significant difference($t(43) = 0.28$, $p = 0.78$). Hence, the average performance of females ($m = 16.8,\ SD = 4.00$) did not significantly differ from that of males ($m = 17.1,\ SD = 3.87$) in the physics post-test.

Similarly, there was no significant difference in performance between male and female students in the mathematics post-test ($t\ (43) = 0.19,\ p = 0.85$). Furthermore, t-tests comparing male and female performance in the physics pre-test ($t(43) = 0.46,\ p = 0.65$) and mathematics pre-test ($t(43) = 1.11,\ p = 0.27$) revealed no significant differences.

These findings align with those of Delaney and Devereux (2019), who demonstrated that gender differences in overall academic achievement have a negligible impact among STEM-ready students. They observed that gender gaps are smaller among high-achieving students, particularly those attending schools in more affluent areas. Similarly, Sullivan and Bers (2016) found no significant difference between boys and girls in their performance on robotics and simple programming tasks after post-test assessments. This is finding aligns with the work of Ogunleye et al. (2014), who concluded that gender did not influence post-test scores among physics students.

Furthermore, the comparison of male and female students' performance in the physics post-test using an independent t-test indicated no significant difference ($t\ (43) = 0.28, p = 0.78$), implying that gender did not influence the average performance levels observed in the physics posttest. Similarly, there was no significant difference in performance between male and female students in the mathematics post-test ($t\ (43) = 0.19, p = 0.85$), indicating gender neutrality in the outcomes. Conversely, scores of studies have reported a male dominance over females in mathematics and physics (Cwik & Singh (2021, Geary et al., 2022, Apata, 2019, Liu et al., 2021)

The results underscore the effectiveness of the intervention in enhancing students' performance in both mathematics and physics. Furthermore, the findings reveal intricate relationships between students' pre-test and post-test performance in these disciplines, while confirming the absence of gender-based performance disparities within the context of this study (Chen et al., 2021).

5. Conclusion

The purpose of this study was to evaluate the impact of mathematical knowledge on students' academic performance in physics. The findings of this study revealed that integrating mathematics concepts, that are foundational to physics, can significantly enhance the learning of physics. Also, there was no significant difference between the performance of males and females in this study. To enhance the understanding of most concepts in physics, it is appropriate for physics teachers to incorporate prerequisite mathematics topics into the physics curriculum.

References

Abdurrahman, M. S., & Madugu, A. (2014). Interrelationship Between Students' Performance In Mathematics And Physics In Senior Secondary Schools Of Birnin-Kebbi Local Government Area Of Kebbi State. International Journal of Scientific & Engineering Research, 5(11), 1494–1507.

Anyagh, P. I., & O'kwu, E. I. (2020). Developing entrepreneurial skills through business education. Journal of Teacher Perspective, May, 545–549.

Apata, O. E. (2019). *Predictive Validity of School and Student Factors on Secondary School Students ' Academic Performance in Physics*. *9*(5), 34–42. https://doi.org/10.9790/7388-0905033442

Awodun, A. O., & Ojo, O. A. (2013). Mathematics Skills as Predictors of Physics Students' Performance in Senior Secondary Schools. International Journal of Science and Research, 2(7), 391–394.

Bello, T. O. B., & Ariyo, A. B. D. (2014). Secondary School Mathematics as Determinant of Academic Performance in University Introductory Physics. *Journal of Education and Practice*, *5*(39), 102–108.

Charles-ogan, G. I., & Okey, I. F. (2017). Effects of Mathematics Knowledge on Physics Students Performance in Electromagnetism. *International Journal of Theoretical and Mathematical Physics*, *7*(4), 61–67. https://doi.org/10.5923/j.ijtmp.20170704.01

Chen, J., Zhao, Q., & Huang, Y. (2021). *Research On The Correlation Between Mathematics And Physics Of The Senior High School Students Penelitian Tentang Hubungan Matematika Dan Fisika Siswa Sekolah Menengah Atas*. *6*(1), 70–80.

Cwik, S., & Singdanieh, C. (2021). Damage caused by societal stereotypes: Women have lower physics self-efficacy controlling for grade even in courses in which they outnumber men. *Physical Review Physics Education Research*, *17*(2), 20138. https://doi.org/10.1103/PhysRevPhysEducRes.17.020138

Delaney, J. M., & Devereux, P. J. (2019). *Alternative formats If you require this document in an alternative format , please contact : by*. *72*, 219–238. https://doi.org/10.1016/j.econedurev.2019.06.002

Geary, D. C., Hoard, M. K., Nugent, L., & Unal, Z. E. (2022). *Journal of Educational Psychology*.

Goulet-pelletier, J. & D. C. (2018). *A review of effect sizes and their con fi dence intervals , Part I : The Cohen ' s d family*. *14*(4), 242–265.

Hassan, S., Tanko, S., Adamu, P., Kwarki, & Sajeh, D. (2018). The Performance Of Mathematics In Relation To Physics. (A Case Study Of Two Selected Pravite Science Secondary Schools In Gombe Metropolis). Gombe Technical Education Journal, 11(1), 189–196.

Jones, M., & Lord, P. (2006). Pupils' experiences and perspectives of the National Curriculum and assessment. National Foundation for Educational Research.

Kuo, E., Hull, M. M., Gupta, A., & Elby, A. (2013). How Students Blend Conceptual and Formal Mathematical Reasoning in Solving Physics Problems. ScienceEducation, 97, 32–57. https://doi.org/10.1002/sce.21043

Liu, S., Pei, L., Wang, M., & Zhang, B. (2021). Stereotype Threat Interventions 1. *Journal* *of Applied Psychology*, 1–89.

Malaki, S. S. (2021). Assessing the influence of Mathematics in Teaching and Learning Physics Subject in Secondary Schools in Tanzania. International Journal of Scientific Research and Management (IJSRM), 09(11), 358–366. https://doi.org/10.18535/ijsrm/v9i11.m01

Ogunleye, A., Awofala, A. O. A., & Adekoya, E. A. (2014). Effect of students' background knowledge of mathematics on senior secondary school students' achievement in physics. Chemistry, 23(6), 863–880.

Omotade, A., & Adeniyi, O. (2013). Mathematics Skills as Predictors of Physics Students' Performance in Senior Secondary Schools. International Journal of Science and Research, 2(7), 2319–7064. www.ijsr.net

Sullivan, A., & Bers, M. U. (2016). *Girls , Boys , and Bots : Gender Differences in Young Children ' s Performance on Robotics and Programming Tasks*. *15*, 145–165.

Tuminaro, J. (2004). A Cognitive Framework for Analyzing and Describing Introductory Students' Use and Understanding of Mathematics in Physics. Ph.D. Thesis. University of Maryland, 1.

Yadav, S. (2019). Role of Mathematics in the Development of Society. International Journal of Research and Analytical Reviews, 6(4), 295–298. www.ijrar.org