Impact of the Level of Scientific Literacy on Academic Achievement in IGCSE Physics in Arusha Region, Tanzania.

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Abstract

This study aimed to assess the impact of scientific literacy on academic achievement in IGCSE Physics among students in Arusha, Tanzania. It focused on the relationships between scientific vocabulary, knowledge, attitudes, and academic performance in Physics. The study used an ex post facto research design, where independent variables (scientific literacy) were not controlled but rather observed in existing student groups. A sample of 59 students was selected from a population of 69 using Yamane's formula, and primary data were collected via a questionnaire.

The results showed that scientific literacy significantly influenced academic performance in IGCSE Physics. Students with a higher level of scientific literacy, beyond basic understanding, performed better than those with only a nominal understanding. The study found a strong positive correlation between students' use of scientific vocabulary and their academic achievement. Those with a deeper grasp of scientific concepts and theories demonstrated better problem-solving skills, leading to higher academic success. Additionally, students with positive scientific attitudes—curiosity, open-mindedness, and ethical conduct—were more engaged and successful in Physics.

The study recommends integrating activities in the teaching process that enhance vocabulary and conceptual understanding. These activities should include hands-on tasks, inquiry-based learning, and collaboration to help students grasp abstract concepts and apply them in real-life situations. Regular assessments can help identify knowledge gaps and provide opportunities for timely intervention. Furthermore, academic institutions should foster a learning environment that nurtures scientific attitudes, encouraging curiosity and promoting lifelong learning and problem-solving skills among students.

Keywords: Scientific literacy, scientific attitudes, scientific vocabulary, academic achievement

1.0 Introduction

In the study of Physics, scientific literacy involves the ability of learners to use appropriate Physics-based concepts to apply in real-life situations, explain scientific phenomena using relevant scientific vocabulary, critical thinking, and use evidence to draw valid conclusions. Scientific literacy includes indicators like the use of scientific vocabulary, critical thinking, scientific context, scientific attitudes, ability to extract information from the physics-based text as well as understanding various terms used in the subject. In situations where scientific literacy is high, learners' academic achievement is observed to be also high. According to a study conducted by Temitope & Telima (2021) on the relationship between students' level of scientific literacy and academic performance in Physics concepts in River state, Nigeria concluded that students who are scientific literate perform better in various Physics concepts than those that are not scientifically literate. The study also found out that learners with high levels of scientific literacy were able to engage in constructive scientific arguments, conduct investigations using the scientific method, and explain many natural phenomena using scientific principles.

In Tanzania, the International General Certificate of Secondary Education(IGCSE) Physics syllabus developed by Cambridge Assessment International Education is offered by international secondary schools where the students can pursue either core or extended Physics in Year 10 and 11. The course involves experimental skills and investigations, use of knowledge and understanding of facts, laws, definitions, concepts, and theories, appropriate use of scientific vocabulary, terminology and conventions, correct use of scientific instruments and apparatus, scientific and technological applications with their social, economic and environmental implications, handling information and problem-solving. (Cambridge assessment International Education,2023)

Learners who display adequate scientific knowledge can engage in arguments that demand a deep conceptual understanding of facts. They can analyze the situations presented to them and interpret the phenomena correctly. Scientific knowledge enables learners to express themselves coherently and with clarity when explaining difficult aspects of Physics. A study conducted by Mukti et al, (2019) on a survey of high school students' scientific skills in different gender found that female students who participated in the study reported higher scores as a result of higher scientific knowledge compared to the male students. Learners with deep and broad scientific knowledge can use the appropriate scientific vocabulary to explain themselves, identify command words that carry meaning, and point out distractors. The learner can read and extract relevant information presented in scientific text and also write using the language of Physics. Proper understanding of these scientific vocabularies enables the students to communicate appropriately with other peers in the subject without misconceptions creeping in inadvertently.

The ability to write scientifically helps the learner to articulate their views with coherence, innovate a replicative procedure to perform various investigations in Physics experiments and present data in an academically acceptable format. A study conducted by Shana & Abulibdeh(2021) on the effect of practical work on students' academic attainment in scienceconcluded that students with higher scientific knowledge were able to design their experiments to conduct investigations and had a much greater understanding of various scientific phenomena that required scientific interpretation.

Scientific attitude is the most important outcome of science teaching and enables a student to think rationally. It is the combination of many qualities and virtues which is reflected through the behavior and action of the person. A study conducted by Vasimalairaja & Meenakshi(2019) on scientific attitudes among secondary school students found out that when students are good at scientific attitude, their academic achievement in all subjects is high. Further, the results of a study conducted by Faaz & Khan (2017) on the impact of attitude towards science on the academic achievement of students belonging to the upper primary stage suggested that for learners to achieve better in academics, it is a prerequisite for them to

inculcate a positive attitude towards science through educators who can make science as an interesting subject inside the classroom with the help of demonstrations and experimentation methods.
Scientific attitudes help students overcome challenges and persist in the face of difficult tasks. Resilience and a growth mindset, components of a scientific attitude, enable students to view failures as learning opportunities rather than setbacks. This perspective is particularly important in physics, where experimentation and iterative learning are fundamental (Samaras, 2011). Furthermore, students who exhibit scientific attitudes are more likely to collaborate effectively with peers, as they value diverse viewpoints and constructive criticism, enhancing the collective learning experience.
The importance of a scientific attitude extends beyond academic performance. It prepares students for future scientific based work and careers by instilling a mindset that values continuous learning and ethical practice. As the world increasingly relies on scientific and technological advancements, fostering a scientific attitude in students is crucial for developing the next generation of innovators and problem-solvers. In summary, scientific attitude significantly impacts IGCSE Physics performance by promoting deep engagement, resilience, ethical conduct, and collaborative learning.

1.1 Statement of the Problem

The study of Physics involves a deep conceptual understanding of the subject matter coupled with the correct understanding of methods and processes required for problem-solving. For learners to excel in the subject their attitude towards the subject must be positive which ensures that the learner is willing to challenge themselves to tackle various tasks in the subject in pursuit of deeper understanding. Their scientific knowledge must be deeper and broader to accommodate all the expectations of the subject's success criteria. Additionally, the learner must be able to express themselves with the correct scientific vocabulary relevant to the subject both in written and verbal means. Therefore, for learners to post excellent results in the International General Certificate of Secondary Education, the above indicators should be present in the whole teaching and learning process.

This research will explore some of the indicators of scientific literacy and the effect each of them will have on learners' academic performance in Physics. The research will seek to find out the extent to which each scientific literacy indicator under investigation directly contributes to academic performance in the International General Certificate of Secondary Education Physics. The study will focus specifically on scientific literacy indicators and their impact on learner academic achievement in Physics in international schools in the Arusha district in Tanzania.

1.2 Purpose of the Study

The study will investigate the impact of the level of scientific literacy on academic achievement in IGCSE Physics among students in the Arusha region, of Tanzania.

1.3 Research Objectives

a. To determine the relationship between the use of scientific vocabulary and academic achievement in IGCSE Physics
b. To establish the relationship between scientific knowledge and academic achievement in IGCSE Physics
c. To examine the influence of scientific attitudes on academic achievement in IGCSEPhysics.

1.4 Research Questions

a. What is the relationship between the use of scientific vocabulary and academic achievement in IGCSE Physics?
b. What is the relationship between scientific knowledge and academic achievement in IGCSE Physics?
c. How do scientific attitudes influence academic achievement in IGCSE Physics?

1.5 Significance of the Study

The results of this study will help learners adopt relevant learning strategies that will reinforce their efforts in acquiring more scientific knowledge that can help them apply various scientific concepts in real-life situations. They developed more skills to communicate with their peers using scientific language besides improving their quality of written communication using the appropriate scientific terms.

The results of this study will help physics teachers to incorporate feedback and reflection strategies that help them get a deeper insight into the level of scientific attitudes their learners have. This will help them tailor their teaching and learning processes to accommodate all learners with their learning challenges to help them acquire scientific attitudes that will help them learn more easily and correctly interpret various scientific terms. The teacher will become an efficient facilitator as learners will have acquired skills on how to pursue more challenging work in Physics. Curriculum developers will benefit from the results of this research as they will be able to provide a roadmap to help learners improve scientific literacy within the curriculum while at the same time reinforcing the use of teaching strategies that help the learners develop scientific attitudes.

Researchers in physics education and academic policymakers will be able to make evidence-based proposals on instructional methods in physics education besides using the results of this study to form the basis for further research.

2.0 Research methodology

This study used an ex-post facto research design, where the researcher observed existing characteristics of groups without direct control over independent variables. It aimed to compare students' level of scientific literacy (independent variable) with their academic performance in Physics (dependent variable). The target population consisted of IGCSE Physics students in Arusha, Tanzania, with 59 students selected from an international school with a diverse student body.

Proportionate stratified random sampling and purposive sampling was employed. Stratified sampling categorized students into lower, middle, and higher achievers based on their Physics records, while purposive sampling focussed on students who were most informative for the research. The sample size was 59 students from a population of 69, obtained using Yamane's formula, resulting in a sample size of 85.5%.

A Likert scale questionnaire was used to assess students' scientific attitudes, with responses ranging from '1' (strongly disagree) to '5' (strongly agree). The researcher also used self-made tests to collect data on scientific vocabulary and knowledge. The mean and standard deviation of the Likert scale responses were calculated and compared with test scores to identify patterns.

Data from the 59 respondents was analysed using descriptive statistics, such as frequency, mean, and tables. Analysis of Variance (ANOVA) was used to determine presence of differences in achievement based on scientific literacy indicators. ANOVA is a statistical tool used to compare the mean scores across different groups

3.0 Findings and conclusion

3.1 Scientific knowledge

In this study, the impact of scientific knowledge on students' academic performance in IGCSE Physics was studied. According to Doe et al., (2022), learners' scientific knowledge affects their performance in physics since this knowledge is the basis upon which concepts and principles required to develop deeper understanding are built. Furthermore, a good scientific knowledge enables the learner to develop tenacity in problem solving. The ability to develop procedure and conduct experiments, collecting and interpreting data with relevant scientific method and physics laws is often pursued with effectiveness and clarity by students with a strong scientific knowledge background. This leads to better academic achievement in various forms of assessment in Physics.

3.1.1 Problem solving

This study engaged the respondents with a view to find out whether learners appreciate finding solution to problems and whether they are interested in finding various methods of finding solutions to the problems that are presented to them in IGCSE Physics.

Table 4.3: Finding solutions

	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)	Mean	SD
I find myself curious about the underlying principles of natural phenomena.	23.2	30.4	35.6	5.4	5.4	2.83	1.452
I enjoy seeking answers to questions related to the physical world.	25	48.2	21.4	0	5.4	3.19	1.554
I feel motivated to explore and understand complex concepts in physics.	28.6	37.4	30.4	1.8	1.8	3.19	1.554

From the findings**,**23.2% of learners strongly agreed that they are curious to find out solutions to various problems in the natural phenomena. In addition, 30.4 % agreed which was supported by an average of 2.83 and SD of 1.452. Additionally, 25.0% strongly agreed while 48.2% agreed to seeking answers to questions related to physical phenomena. This was supported by a mean of 3.19 and SD of 1.554.

From the results of analysis on those who strongly agreed and agreed ,28.6 % and 37.4 % of respondents respectively concurred to the query on whether they are motivated to engage in exploration that will help them get more insights on complex concepts., in addition to 37.4 % who agreed. The respondent's feedback was supported by a mean of 3.19 and a standard deviation of 1.554.

3.1.2 Conceptual understanding and Interdisciplinary connections

The study sought to find out the effect of conceptual understanding and connections with other disciplines on the learners' academic achievement in Physics. The results are presented in table 4.4.

Table 3.1 :Conceptual understanding

	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)	Mean	SD
I am inclined to question explanations that are not backed by evidence.	19.6	35.7	25	12.5	7.2	2.69	1.411
I enjoy discussing and debating scientific ideas with others.	32.1	33.9	25	3.6	5.4	3.18	1.553
I believe that critically evaluating scientific claims is essential for accurate understanding.	33.9	33.9	26.8	3.6	1.8	3.29	1.583

From the findings 19.6% strongly agreed that they are inclined to seek evidence for various explanations. Additionally,35.7% agreed that they often question explanations for solutions that are not backed by evidence. This was supported by a mean of 2.69 and a SD of 1. 411.On the other hand,25% of the respondents were neutral while 12.5% and 7.2% disagreed respectively.

On discussion of scientific ideas with others,32.1% strongly agreed while 33.9 % agreed to enjoying scientific rich ideas. This was supported by the mean of 3.18 and SD OF 1.553.

Respondents were asked give their views on whether it is essential to evaluate scientific claims. Among the respondents,33.9% strongly agreed while an equivalent percentage of respondents agreed to a deep review of the concepts that underpins any scientific claim. This was supported by a mean of 3.29 % and 1.583 respectively.

3.2 Scientific attitudes

The study was interested in finding out the effect that scientific attitude as an indicator of scientific literacy has on the academic performance of learners who pursue IGCSE Physics. The study results were displayed in table 4.5. Some of the scientific attitudes indicators including performing experiments ethically, engaging in inquiry to find solutions to challenges, inquisitiveness and approaching content with an open-mind have significant effect on learners' academic performance in physics. According to Smith et al.,(2023), these attributes help the learner excel in the subject due to their strong emphasis on developing creative thinking and problem-solving skills.

3.2.1. Ethical Conduct and Inquiry

The study sought to find out the effect of ethical conduct and inquiry, and open mindedness.

Table 3.2: Ethical conduct

	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)	Mean	SD
I think it's important to follow ethical guidelines when conducting scientific experiments.	42.9	33.9	16	3.6	3.6	3.55	1.654
I believe scientists should be transparent about their methods and findings.	46.4	26.8	16	5.4	5.4	3.52	1.647
I consider the potential societal impact of scientific advancements.	23.1	42.9	25	3.6	5.4	3.02	1.506

The results of the study showed that 42.9 % of the respondents strongly agreed that they respect ethical expectations required when conducting various scientific experiments. A further 33.9 % of the respondents concurred with following ethical guidelines and that they find them crucial when conducting research. The results were supported by an average of 3.55 and a standard deviation of 1.654. Further analysis of the results showed that 16% of the responded as neutral to appreciating of ethical guidelines while 3.6 % strongly disagreed with appreciating the importance of ethical behavior in scientific research.

On transparency on methods and findings of scientific research ,46.4 % strongly agreed while 26.8 % agreed that they believe scientists should be transparent about their methods and findings. This was supported by the mean of 3.52 and standard deviation of 1.647.

From the research results those who responded as neutral were 16% while the respondents who disagreed and strongly disagreed respectively were 5.4%.

The researched posed a question to respondents to express their opinion on the potential effect of scientific advancements on the societies that they live in. After the analysis of responses,23.1% and 42.9% strongly agreed and agreed respectively. Additionally,25% selected neutral, 3.6% disagreed while 5.4% disagreed strongly that they appreciate the social impacts of scientific advancements. These findings were supported by a mean of 3.02 and standard deviation of 1.506.

3.2.2 Open-mindedness and curiosity

The respondents were requested to complete a questionnaire with the aim of identifying their level inquisitiveness coupled with openness to many relevant ideas of solving problems. The results were presented in table 4.6.

Table 3.3: Open mindedness and curiosity

	Strongly agree (%)	Agree (%)	Neutral (%)	Disagree (%)	Strongly disagree (%)	Mean	SD
I am willing to explore different perspectives even if they challenge my existing beliefs.	28.6	37.6	19.6	7.1	7.1	3.06	1.520
I'm open to revising my ideas based on new evidence or information.	32.1	42.9	17.8	1.8	5.4	3.32	1.592
I appreciate the uncertainty that comes with scientific exploration.	16.1	32.1	41	5.4	5.4	2.62	1.389

From the findings 28.6 % strongly agreed that they are willing to explore different perspectives even if they challenge their existing beliefs. Additionally,35.7% agreed that scientific exploration is not limited by their personal beliefs. This was supported by a mean of 3.06 and a SD of 1. 520.On the other hand,25% of the respondents were neutral while 7.1% disagreed while a similar percentage disagreed strongly with question.

On the openness to revising previous ideas based on new evidence,32.1% strongly agreed while 42.9 % agreed to flexibility in accommodating new ideas and revising their previous understanding. This was supported by the mean of 3.32 and SD OF 1.592. Conversely ,1.8 % disagreed while 5.4% disagreed strongly on being flexible to accommodate new ideas from new research findings that will challenge their earlier standing.

Respondents were asked to respond on the uncertainty that comes with scientific research. Among the respondents,16.1 % strongly agreed while 32.1% of respondents agreed that scientific exploration can result to unexpected outcomes. This was supported by a mean of 2.62 and SD of 1.389 respectively.

3.3 Scientific vocabulary

Scientific vocabulary significantly enhances performance in physics by enabling precise comprehension and communication of complex concepts. A strong vocabulary allows students to accurately follow instructions, understand textbooks, and articulate their knowledge during assessments and discussions. Mastery of scientific terms aids in the interpretation of problems and the application of appropriate formulas and theories. Furthermore, a well-developed scientific vocabulary supports cognitive processes such as analysis and synthesis, essential for problem-solving in physics. Research indicates that students with a strong grasp of scientific vocabulary tend to perform better in physics due to improved comprehension and communication skills (Green et al., 2021; Lee & Nguyen, 2022).The results of the findings were presented in table 4.7.

Table 3.3: Scientific vocabulary among learners

	Correct responses (%)	Incorrect responses (%)	Total (%)
Vocabulary matching	87.2	12.8	100
Application of vocabulary	68.1	31.9	100
Sentence completion	76.6	23.4	100
Term identification	89.4	10.6	100
Scientific knowledge	66.0	34.0	100

Respondents were tested on the use of scientific vocabulary in different contexts of Physics. This involved matching of vocabulary with the correct description, use of scientific vocabulary correctly in written physics text, completing sentences with the appropriate scientific language, identifying the correct term that describes a given phenomenon and a specific understanding of various scientific aspects with clarity. From the reponses,87.2% correctly matched the vocabularies while 12.8% did not match the vocabularies correctly. On application of vocabularies to scientific contexts,68.1% and 31.9% correctly and incorrectly applied vocabularies respectively. Respondents were required to complete sentences focusing on quality of written scientific communication. From the responses,76.6% were able to correctly complete the given sentences while 23.4% gave incorrect responses. Additionally, respondents were asked to identify the correct term for supporting given descriptions. From the responses,89.4% correctly identified the terms while 10.6% were unable to identify the correct terms for use. Finally, respondents level of scientific knowledge was tested through the questionnaires given. From the analyzed results,66% responded positively to the questions testing their scientific knowledge while 34% gave incorrect responses to the tests for scientific knowledge.

4.0 Conclusion

i. Scientific Vocabulary and Academic Achievement

This study found a strong positive correlation between students' use of scientific vocabulary and their academic achievement in IGCSE Physics. Mastery of scientific terms helps students articulate complex concepts clearly, improving their understanding and communication. Proficiency in physics-related language aids in interpreting exam questions, avoiding distractors, and crafting precise answers. Regular use of scientific vocabulary also enhances learning and retention, deepening students' comprehension of difficult concepts.

ii. Scientific Knowledge and Academic Performance

The study revealed that a strong grasp of scientific concepts is crucial for academic success in IGCSE Physics. Students with a comprehensive understanding of scientific theories perform better academically, as they have enhanced problem-solving skills. A solid knowledge base also enables active participation in class activities, including experiments and scientific inquiries, which further solidifies their learning and improves performance in assessments.

iii. Scientific Attitudes and Academic Achievement

The research highlighted that positive scientific attitudes, such as curiosity, open-mindedness, and ethical conduct, significantly impact academic success in Physics. Students with these attitudes engage more deeply with tasks, exhibit greater curiosity, and are willing to research complex concepts. These attitudes foster a conducive learning environment, sustain interest, and ultimately contribute to higher academic performance.

5.0 Recommendations

i. Importance of Scientific Vocabulary

The research emphasizes that a strong foundation in scientific vocabulary significantly enhances academic achievement. Educators should integrate activities that build vocabulary, such as online resources, targeted lessons on key terms, classroom discussions using scientific terminology, and assessments focusing on important vocabulary. Interactive activities like vocabulary games, flashcards, and quizzes can make learning vocabulary engaging. Encouraging learners to read scientific texts, publications, and research journals can also help expand their vocabulary pool.

ii. Understanding Scientific Principles

A solid understanding of scientific principles is essential for academic success. The study showed a positive link between scientific knowledge and achievement. Teachers should focus on covering fundamental concepts comprehensively, using hands-on activities and inquiry-based learning to simplify complex ideas. Regular assessments can help identify knowledge gaps and guide timely interventions. Teachers can also use ICT-based resources and interactive simulations to reinforce classroom teaching and cater to diverse learning styles.

iii. Role of Scientific Attitudes

Scientific attitudes, such as curiosity, open-mindedness, and ethical conduct, significantly influence academic success. Schools should create environments that foster these attitudes. Curiosity can be encouraged through thought-provoking questions, while open-mindedness can be developed through collaborative projects and discussions. Ethical conduct is crucial, especially in research, ensuring safety and integrity. Pairing students with professional mentors can further reinforce positive scientific attitudes.

iv. Continuous Professional Development

For effective implementation of these recommendations, continuous professional development is essential. Teacher training programs should focus on building 21st-century skills in students. Educators need to adopt modern instructional strategies and develop effective assessment techniques that offer meaningful feedback.

v. Integration of Scientific Literacy in Teaching

Teachers should be creative in integrating scientific literacy aspects into their teaching, ensuring that students not only gain knowledge but also develop the skills to apply scientific concepts effectively.

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