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Mathematics ability, performance and self-efficacy of secondary schools physics students

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Abstract
Mathematics is a language of science, explicitly in Physics at all levels of education. Students and teachers are rarely aware of this fact, to this end, this study sought to classify mathematics ability of physics students into levels to ascertain the influence on the performance. The study will find it inconclusive without investigating the influence of mathematics ability on self-efficacy of physics students. The study adopted descriptive survey research design on population of 1102 senior secondary schools (SSIII) students distributed in Ife Localities of Osun State, Nigeria. A sample of 260 physics students was randomly selected and used for the study from purposively selected ten schools in three local government areas from four in the locality. Three research instruments were developed and validated to elicit information on the variables of the study. They were administered to thirty students outside the study area for reliability measures. Mathematics ability and performance multiple choice items were fond reliable at 0.86 and 0.72 respectively by Kuder-Richardson Formula 21, while a four-point Likert-type scale of self-efficacy instrument yielded a reliability coefficient of 0.88 using Cronbach alpha analysis. One research question and two hypotheses guided the study. Data was analyzed using percentages, Anova and Post-hoc analysis. Findings showed that large percentage of physics students are within the average mathematics ability level; there was significant influence of mathematics ability levels on the performance and self-efficacy and students with high mathematics ability perform better and also possess high self-efficacy. It was concluded that high Mathematics ability is consequent to learning of Physics.

Keywords: Mathematics ability, performance, self-efficacy, secondary schools, physics

Introduction

Mathematics has evolved through ages and is a means of expressing and explaining concepts embedded in theory, laws, principle found in science, technology, business education, social and biological sciences and other related discipline. During Babylonian age, a system for writing down numbers was developed, the Sumerians, used sexageimal (base-60) to measure angle of 60 seconds in a minute, 60 minutes in an hour, and 360 (60 x 6) degrees in a circle, as well as the use of seconds and minutes of arc to denote fractions of a degree. In the Greek age, deductive geometry, Pythagoras, odd and even numbers, trigonometry, calculations of pie (π), area of an eclipse was discovered. The discoveries have made Mathematics an indispensable subject in the learning of sciences and other disciplines. In fact, it was with Greeks that Mathematics came into being as an area of study and ceased being a collection of techniques for measurement, counting and accounting but regarded as an intellectual pursuit having both aesthetic and religious elements (Devlin, 1998). The advance in knowledge has given wider scope to the extension and usefulness of Mathematics to all areas of study. The influence of Mathematics has gone beyond the wall of a classroom; it is life affairs' matters. Mathematics is not only concerned with everyday problems, but is also involving the use of imagination, intuition and reasoning to find new ideas and to solve puzzling problems (Liaqat, 2015) [23]. The use of imagination, intuition and rationality embedded in Mathematics has made it deductive inclined while ability to solve puzzling problems and discovery new things has made Mathematics to be inductive in its processes. With this, Mathematics is seen as all in all for all the aspects of human endeavours fused perfectly into empirical science, as a modeling art, as a factor in business transactions and a structure in engineering and a pivot in technology for the benefit of human comfort and satisfaction. Mathematics involves the usage of words or expression, notations and sign used in arrangement of facts to the learners. It informs us how to summarize observation with the help of numbers and make necessary rules to achieve life goal in a quantified means. Mathematics engenders feeling in individuals at various situations of life, it teaches us value and observable pattern of situations, accuracy or inaccuracy, structure, good or bad, more or less, high or depth, gain or loss which in summary is a science. It is therefore a science of behaviour, science of motivations, science of outcomes and science of numbers (Khan & Salman, 2020) [20]. This factored Mathematics into the process of development of cognition, attitudes and other forms of behaviour of the learners which are of positive value to skills acquisition in human development. So, it can be vividly concluded that Mathematics permeates all aspects of human endeavours.

The co-existing nature of Mathematics with empirical science brings it to a focal point in Physics learning to solve problems and explain exactness of theories and concepts. Mathematics in Physics explains both real and abstract concepts providing meaning to express quantities in measurable terms. The laws, theories and principles in Physics are mostly expressed and interpreted through notations, symbols and equations embedded in the domain of Mathematics and this made Mathematics a language of Physics. In the two subjects, numbers and numeration-fractions, logarithms, indices, algebraic processes -solution of equations, variation, graph, matrices, and differentiations are often used in solving problems, so Mathematics and Physics subjects are interrelated.

According to Khan and Saeed (2021) [21] conceptual knowledge plays a significant role in selecting procedures to solve problems in physics subject. Conceptual knowledge helps the students to understand and explain the phenomenal process at different situations. This conceptual knowledge is embedded in the concept of Mathematics. Ogunleye, Awofala and Adekoya (2014) [29] asserted that Mathematics and science at lower stage of education are sharing common objectives and the former is desirable, for a better academic performance in the latter. Performance is a desirable end of all academic pursuit at any level of education.

Academic performance refers to what students accomplish in the course of their studies and how they cope with or accomplish different learning experiences given to them by their teachers (Abubakar, 2020) [1]. Students' academic performance can be in form of grades, marks obtained in the subject areas but researches have shown some factors that are likely to determine academic performance of students in their studies. Grades or marks are criteria used to classify to high, average or low performers. This level of classification shows competence, concepts and skills differences (Khan & Saeed, 2021) [21]. Poor performance in Physics at secondary schools over the years has demanded attention from different stakeholders as a result of the outcomes in most external examinations in many countries. Evidences of poor performance in physical sciences over several years in the National Senior Certificate Examination results in Republic of South Africa was reported by Ayodele, Estelle and Salagaram (2019) [4]; also Physics performance at secondary schools is declining in external examination in Nigeria over the years.

From different researches, factors such as teachers' qualifications, gender influences, and instructional materials have shown to have significant effect on the performance in Physics (Onah & Ugwu, 2010) [30]. Further studies of recent showed that a number of factors are preventing good learning outcomes in Physics (Agbele, Oyelade, & Oluwatuyi, 2020; Bao & Koenig, 2019 & Burkholder, Blackmon, & Wieman, 2020) [3, 6, 9]. Some of the identified factors were highlighted as ineffective teaching methods, students believed that physics is a difficult subject and low motivation towards learning of physics, lack of facilities and laboratory. With the ongoing researches on the different strategies to enhance teachers' delivery of different teaching methods, there is a need to investigate further on inherent factor from the students' side. For the student to perform scholastically, students' factor is imperative as we considered teachers' factors consequential in the process of education to achieve curriculum objectives and goals. The teacher as such is expected to function not only as a purveyor of knowledge but also as a 'moulder' of child's total personality which is central for good performance (Onudibia, Okorie, Ewgu, Suleiman, & Amaitem, 2019) [31]. As the teachers are busy organising themselves in their methodology and assembling instructional materials, psychology factors of students have been considered important to learning, this is because development of scientific and mathematical reasoning cannot be separated from psychology perspectives. The consciousness of thought processes is very important to establish the self believe of an individual during active stage, therefore concept such as self-efficacy and self-concept among others psychology variables are germane to successful performance of students.

Self-efficacy is an important concept in social cognitive theory associated with human learning. According to Adebisi (2022) [2] self-efficacy is a motivational strength and belief about oneself; an inner drive that can out grown to form attitude of an individual. He therefore explained that self- efficacy is the belief that students have about their academic capabilities. To perform better and be motivated in Physics, self-efficacy in Mathematics is very important because enormous task of Mathematics concepts embedded in the subject and this might be considered insurmountable by many students. The students became scared and anxious of Mathematics and that have resulted into lack of confidence to complete the mathematical tasks (Medyasari, Zaenuri & Dewis, 2021) [25]. Therefore, self-efficacy helps the students to organize themselves, aids persistence to cope with seeming difficult subjects and arouse their emotional thinking.

The high level of self-efficacy can influence the positive attitudes to learning and low self-efficacy in science can lead to avoidance in science stream at upper secondary and tertiary level (Jamil, & Mahmud, 2019) [19] as well determine academic performance from reported studies (Nasir & Iqbal, 2019) [27].

According to Van Aalst (2005) students know that things are more complicated and they are often not satisfied with the level of understanding they achieve in Physics, as a result, they see Physics as a loose collection of facts and statements. That is, self-efficacy of the students described by Van Aalst is low in Physics. Self-efficacy of students in science is very important particularly in Physics that studies reality of the universe in microscopic and macroscopic levels and this demand that students are encouraged to stay close to learning of the subject. The belief that students hold is very germane to their psychology built up from their inner mind therefore what the students hold of themselves cannot be downplayed which can make them to be flexible and adaptable to the subject. Self-efficacy aids high level of psychodynamic activity and adaptability, self-regulation, flexibility and decrease in the level of emotionality and tolerance to unclear circumstances (Belykh, & Mayramyan, 2016) [7]. To every man here on earth our belief and motivation needs to be regulated to keep us going, so for every student the inner drive is crucial to his/her educational goal, this forms basis background to this study.

Theoretical Framework

The theoretical framework for the research makes use of Bandura's (1997) [5] self-efficacy of social cognitive theory. The theory posits towards giving a more comprehensive overview of learners' cognition in the context of social learning. The crux of this theory is that human behavior learned observationally through dynamic interaction on social basis which prompts behavioural capabilities, social capabilities and cognitive skills. Considering the factor of self-efficacy in this study, according to Bandura (1997) [5], Self-efficacy is centred on beliefs and once it is formed it can be difficult to be changed, he therefore proposed the theory of reciprocal determinism. The dynamic and reciprocal interaction keeps ongoing in the learning of Physics in senior secondary schools through interaction of

students with their teachers, the environment, or external social context, and response to stimuli to achieve educational goals. The social interactions among the learners have been supported to precede development and cognition positioned by Social Development Theory. Vygotsky (1978) [38] felt social learning precedes development. He states that every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; then, between people (inter-psychological) and then inside the child (intra-psychological).

Statement of The Problem

The obvious fact over the years has shown that among the sciences studied at secondary schools Physics as a subject has recorded low enrolments and poor performance. Besides, external examination has evidently revealed unimpressive academic performance in Physics which researchers and examiners are constantly pondering at. Although findings from the general perspectives to proffer solutions have not yielded the desired results but there is a need to look at it contribution from psychology point of view. In the Bruner's instructional model to achieve the desired goals in education, readiness, intuition, and motivation are essentials (Bruner, 1960) [8]. These are underlying factors in actualising self-efficacy which from social cognitive theory point of view can be referred to as internal focus of control. However, there is need to investigate this on external focus of control (Mathematics which is a language of Physics) to ascertain the influence of mathematics ability as the source of reinforcement to perform better in Physics. Therefore, the study was conducted.

Research Methods

1. Research Question

The study raised this research question:

a. what distribution pattern of Mathematics ability level exists among Physics students in Secondary schools in Osun, Nigeria?

2. Research Hypotheses

Two hypotheses were tested in this study at 0.05 level of significance, they are:

a. there is no significant influence of Mathematics ability level on performance of Physics students in secondary schools in Ife localities of Osun State, Nigeria; and
b. there is no significant influence of Mathematics ability level on self-efficacy of Physics students in secondary schools in the study area.

3. Research Design

The descriptive survey research designed was adopted for the study. The descriptive survey research design was adopted for this study because it involves with the collection of data for the purpose of describing and interpreting prevailing conditions. According to Egbule and Okobia (1998) [13] the design is economical for independent researcher as it has a wide range of scope, great deal of information as well as representative samples, which allows for inferences and generalization to an entire population. Therefore, the design enabled the researcher to obtain the opinion of students on Mathematics ability, performance and self-efficacy in secondary schools Physics.

4. Participants

The population for the study consisted of 1,102 secondary schools (SSSIII) students in Ife localities in Osun State, Nigeria. A representative of 260 physics students from SSSIII were randomly selected and used for the study, the sample represents 23.6% of the entire population. From the four local government areas in the study area, three local government areas were purposively selected on criteria that they are readily available for the study. Ten schools were randomly selected from the local government areas out of which the students were randomly selected for the study.

5. Research Instrument

Three instruments used for data collection are:

Mathematics Ability Test (MAT): This test is made up of twenty multiple items. The test was subjected to the scrutiny for contents validity by two experienced Mathematics teachers in secondary schools who have physics background knowledge. The experts verified questions that are applicable to physics solving questions. MAT was administered to thirty students outside the research areas to determine the reliability. The data collected was analyzed using Kudar Richardson 21 and reliability of 0.86 was obtained, considered and appropriate for the study.

Physics Performance Test (PPT): Physics Performance Test (PPT) was used to ascertain students' knowledge in Physics. PPT is made of fifteen multiple items. The content validity of the instrument was established by a Physics teacher in secondary school in the state. PPT was also administered to thirty students to obtain the reliability coefficients of 0.72 using Kuder Richardson 21.

Self-efficacy Questionnaire (SeWQ): Self-efficacy Questionnaire (SeWQ) used for the study was a self-constructed questionnaire of 10 items from the relevant literature, SeWQ was validated by an expert in education psychology. The expert made necessary corrections to address self -efficacy of students towards Physics. The items in the instrument were structured on four-point likert ratings scale of Moderately True, MT; Exactly True, ET; Hardly True (HT); Not at All); (NA), scored for positive items (3,4.2,1) and negative items (2,1,3,4).

SeWQ was also administered to thirty students to obtain the reliability coefficients of 0.88 using Cronbach alpha analysis.

6. Procedure for Data collection

The research instruments were administered by the researcher with assistance from science teachers under the supervision of the researcher. The aim of the research was explained to the students. The respondents were randomly selected into three classes for the purpose of administering the three instruments simultaneously. The students considered for the study meet the criteria that they are regular in schools and they attended Mathematics and Physics classes confirmed by their teachers.

Results

The results of the research question and the null hypotheses test are as follows:

Research Question: What distribution pattern of Mathematics ability level exists among Physics students in Secondary schools in Osun, Nigeria?

Table 1: Mathematics Ability of Physics Students

Mathematics Score	Frequency (F)	Percentage (%)	Ability
0-6	79.0	26.9	Low
7-13	163.0	55.4	Average
14-20	18.0	6.1	High

Table 1 shows the distribution pattern of Mathematics ability level of Physics students in secondary schools in Ife localities of Osun State, Nigeria. The number of students who scored between 0 to 6 is79.0 representing 26.9% indicating low Mathematics ability while the number of students who scored between 7 to 13 is 163.0 representing 55.4% indicating average Mathematics ability and number of students who scored between 14 to 20 is 18.0 representing 6.1% indicating high Mathematics ability.

Hypothesis One: There is no significant influence of Mathematics ability level on performance of Physics students in secondary schools in Ife localities of Osun State, Nigeria.

Table 2: One-way Analysis of Variance of Physics Performance Test of Low, Average and High Mathematics ability levels of the Students

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	230.278	2	115.139	37.576	0.000
Within Groups	787.487	257	3.064		
Total	1017.765	25			

Table 2 shows that there is a statistically significant influence of Mathematics ability levels on the physics performance for the three groups (Low, Average and High) at the $p< 0.05$ level, [F (2,257) =37.576, p=0.00]. The null hypothesis is therefore rejected. Table 3 shows the results of Tukey multiple comparison tests to determine pair-wise difference among the groups.

Table 3: Turkey test analysis showing multiple Comparison of Performance among Mathematics ability levels

Mathematics Ability (I)	Mathematics Ability (J)	Mean Difference (I-J)	Std. Error	Sig.
Low	Average	-1.83265	0.23997	0.000
	High	-2.98875	0.45718	0.000
Average	Low	1.83265	0.23997	0.000
	High	-1.15610	0.43477	0.023
High	Low	2.98875	0.45718	0.000
	Average	1.15610	0.43477	0.023

From Table 3 shows significant mean difference in the performance among students with different mathematics ability levels. The results suggested that students of high ability levels performed best among the three levels while low mathematical level performs least.

Hypothesis Two: There is no significant influence of Mathematics ability level on self-efficacy of Physics students in Secondary schools in the study area.

Table 4: One-way Analysis of variance of self-efficacy of Low, Average and High Mathematics ability levels of Physics students

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	156.855	2	78.427	3.363	0.04
Within Groups	5993.130	257	23.320		
Total	6149.985	259			

Table 4 shows that there is statistically significant influence of Mathematics ability levels on the self-efficacy for the three groups (Low, Average and High) at the $p< 0.05$ level, [F (2,257) =3.363, p=0.04]. The null hypothesis is therefore rejected. Table 5 shows the results of Tukey multiple comparison tests to determine pair-wise difference among the groups.

Table 5: Tukey test analysis showing multiple Comparison of Self-efficacy of Mathematics ability levels of Physics students

Mathematics Ability (I)	Mathematics Ability (J)	Mean Difference (I-J)	Std. Error	Sig.
Low	Average	-0.36957	0.66200	0.842
	High	-3.23699	1.26124	0.029
Average	Low	0.36957	0.66200	0.842
	High	-2.86742	1.19942	0.046
High	Low	3.23699	1.26124	0.029
	Average	2.86742	1.19942	0.046

Table 5 above shows significant mean difference in self-efficacy among students with low, average and high mathematics ability levels. The results suggested that students of high mathematics ability level had high self-efficacy, students of average mathematics ability correspond to average self-efficacy while low mathematics ability level had least self-efficacy.

Discussion of Findings

The study was aimed at finding out the influence of mathematics ability on the students' performance and self-efficacy in Physics. The result of research question one shows the distribution patterns of mathematics ability of Physics students with high percentage clustering around the average and few students are represented with high ability in Mathematics. The findings is in support of Fuentes (2021) [16] who sought Mathematical ability level of science students from 71 respondents, 52 representing 73% are "fairly able" indicated low ability, 17 representing 24% are "able" indicated average ability and only 2 representing 3% are "highly able" indicated high ability. This shows that Mathematics knowledge of Physics students is found wanting, a situation that is contrary to what is expected

among Physics students because Mathematics is the language of science that is needed ultimately to explore or solve problems. The report of findings of Pospiech, Lehavi, Bagno and Eylon, (2019) [34] indicated that some physics teachers perceived the role of mathematics in teaching physics as an "auxiliary science" while others see it differently. It is however a matter of great concern for researchers because there is no common agreement to their belief which could affect student's inclination to Mathematics in some quarters. It is therefore necessary that every physics student is accorded the opportunity to acquire concepts, principles and skills of Physics (Macmillan and Celin (2019) [24] in which Mathematics concepts and skills should not to be trivialized for a good and basic background.

The result of the first hypothesis shows there is a significant influence of Mathematics ability on the performance in Physics. The result of Post -hoc analysis shows that level of Mathematics has direct influence on their performance in Physics. The result of the findings is in support of Charles-Organ and Okey (2017) [11] who investigated the effect of Mathematics ability on students' performance in Physics and found out that a positive relationship between the two subjects exits in their findings. The striking fact is that application of Mathematics to the knowledge acquisition in Physics creates the physics-mathematics interface, the extent of the association in the interface in the elementary, secondary, and advanced levels could determine the physics performance of learners because there are elements of Mathematics at every stage of Physics (Sanchez & Ponce, 2020) [35]. To science education experts and other experts in science and engineering, mathematical concepts are a prerequisite and determinant to solving physics problems (Burkholder, Murillo-Gonzalez, & Wieman 2021) [10] and the difficulty encountered in learning Physics are often linked to the inadequacies of learners in mathematics (Yuliati, Yogismawati, & Nisa 2018; Nakakoji & Wilson, 2018) [39, 26].

The result of the second hypothesis shows there is a significant influence of mathematics ability on self-efficacy of Physics students. This result is in support of the findings of Negara, Nurlaelah, Wahyudin, Herman.and Tamur (2021) [28] and that of Hackett (1985) [17]; Lent and Hackett (1987) [22]; Pajares (1996) states that there was a positive relationship between self-efficacy and mathematics performance. This corroborated the fact made known by Garfield and Ben-Zvi (2009) [14] that to be able to do Mathematics it is not enough to know how to do it, but it must be accompanied by self-efficacy about the correctness of its concepts and procedures. This invariably justify why self-efficacy of physics students is imperative to their learning because what affect the mathematics ability or performance is bound to affect the performance in physics and motivation to pursue the subject for the fact that self-efficacy helps the students to have confidence in himself to face challenges, tasks and examinations (Hamann, Pilotti, & Wilson, 2020; Tan, Jain, Obaid, & Nesbit., 2020) [18, 36], a factor that develop the capabilities in students to perform better (Flores-Rivas & Marquez, 2020; Ramírez-Coronel, Martinez-Suarez, Minchala-Urgiles,.& Contrras-Sanango, 2020) [15, 33]. Focusing attention on self-efficacy on mathematics knowledge is as well on the other hand shifting our attention on Physics.

Conclusion and Recommendations

It is evidenced from the study that Mathematics ability is an essential knowledge to be possessed in enhancing the good performance in Physics at the secondary school's education. In conclusion, Mathematics is seen to be a sine qua non to Physics and this could be traceable to the nature and laid down activities of the subject in the curriculum itself. In the study, mathematics ability influenced students' performance and self-efficacy of Physics students.

Based on the findings of the study, it was recommended that the underlying factor to enhance performance in Physics is self-efficacy, so there is a need to boost it through good teaching strategy which is inquiry-mathematical based.

Physics students are to offer Further Mathematics subject as a compulsory subject at secondary schools to help the students to be mathematics inclined and teachers should patiently explain concepts in Physics through mathematical procedures for the students to adhere to the fact that there is no hiding place for Mathematics in relation to Physics. It is imperative for all hands to be on deck to help the students to develop high self-efficacy from the view of social cognitive theory of Bandura of social interaction with the environment. This can be enhanced through the teachers, good instructional materials, extensive collaborative strategy and scaffolding

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