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Effects of Mathematics Knowledge on Physics Students Performance in Electromagnetism

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Abstract The paper investigated the effects of Mathematics Knowledge on Physics Students Performance in Electromagnetism. A sample of two hundred students (200) Physics students in senior secondary school 2 (SS2) was randomly selected. The design adopted in the study was a quasi-experimental Pretest-posttest control type with each group treated differently. The instruments physics performance test in electromagnetism in (PPTE) and Mathematics ability test in electromagnetism concepts (MATEC) with reliability coefficient 0.74 and 0.94 respectively, were used to obtain performance data of students. The data were analysed using mean, percentages and the analysis of covariance (ANCOVA). The results of the study showed that students of high mathematical ability have greater mean percentage gain of 41.17% while those of low mathematical ability have 36.93%. Mathematics ability, instructional strategies, and gender have a positive joint relationship with students' performance in Physics (Electromagnetism) to a considerable extent 22.2% ($r^2 = 0.22$). It was recommended that Physics students should be properly groomed in mathematics, problem-solving schedules should accompany conceptual treatment of numerical problems in the Physics Classroom. Use of innovative teaching strategies would improve interactivity, understanding, and application of concepts (numerical and non-numerical) in the learning of electromagnetism.

Keywords Mathematics Knowledge, Physics Performance, Electromagnetism

1. Introduction

Physics as a science that involves the study of the physical properties of matter and its interaction with the energy a study of systematised knowledge produced by careful observation, measurement, and experiment in a view to establishing basic physical laws as well as give a scientifically reliable explanation of physical phenomena. The study of Physics has made significant contributions through advances in new technologies that arise from the theoretical breakthrough. For example, advances in the understanding of electromagnetism led to the development of new products which have contributed to the transformation of modern society, such as television, computers, domestic appliances, and nuclear weapons (Wikipedia, 2010).

Young and Freedman (2004) defined physics as an experimental science since its specialists observe the phenomena of nature and try to find patterns and principles that relate to those phenomena in the form of theories, physical laws or principles. Interestingly, the diversified concepts of the subject matter, have made its study relevant in many disciplines, such as engineering, medicine architecture, integrated science, chemistry, science education and mathematics.

Mathematics knowledge has become inseparable and a *sinequanon* in the learning of qualitative aspects of arts and science. In scientific discourse, mathematics knowledge is the "language of science" (Redish, 2005). Mathematical calculations occur at every step-in physics. It is only mathematics that gives form and definiteness to the properties of matter and harnessing of nature is possible only through quantitative interpretations of ideas and imaginations. Mathematics pervades physics so much that its impact and influence can be felt in every part of it. (Sidhu, 2006).

The effectiveness in student's understanding and application of concepts in electromagnetism can be guaranteed through adequate possession of mathematics knowledge hence students understanding of the basic mathematical concepts which influence greatly how they cope with higher level; materials where the application of these basic mathematical concepts is required. Physics students have difficulties with mathematics understanding of the concepts in physics which demands adequate mathematical knowledge. Osborne, Simon and Collins (2003), Lord and Jones, (2006) maintained that:

> *Physics students who lacked basic algebra performed poorly on mathematical problem-solving*

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tasks in physics due to students' lack knowledge of mathematical skills needed in problem-solving in physics or students do not know how to apply the mathematical skills they have to particularly solve the problems situation in physics. Although a wide conceptual difference exists between subjects (Physics and Mathematics) it is no longer history that mathematical knowledge is required to tackle numerical problems in physics, leaving much to be done in order to change students attitude towards mathematics and science.

In Nigeria, Adeyemi (2007) who had studied mathematics as a language for involving secondary school children in science and technology, indicated that their performance in West African schools Certificates Examinations (SSCE) mathematics also correlated significantly with their performance in Physics in the same examination, which remained generally poor. In order to improve students' understanding of mathematics, a lot of innovative strategies have been suggested and used, among mathematics majors - the use of interactive whiteboard for creative teaching and learning in literacy and mathematics: a case study (Wood and Ashfield, 2008), psycho- academic variables and mathematics achievement of 9th grade students in Nigeria (Joseph, 2012), play-way learning strategies involving use of games and the mathematics laboratory, among others. Brekke (2010) and Adegoke (2009) in assessing the Mathematics knowledge potential between two nations at the polar development of levels (developed or developing), in different research, lamented students continued difficulties in mathematics. While Adegoke observed that many students (Nigerian) appear to lack the reasoning ability involved in the study of physics, identified their problems as lack of logical-mathematics operations, Brekke lamented that a number of students (Americans) who come from elementary to high school is deficient in basic mathematics facts such as the result of dividing a number by zero. Obafemi and Ogunkunle (2014) stated that mathematics ability is significant in students' performance in sound waves when taught using collaborative, Demonstration and Guided-Discovery learning method; hence there exist evidence of inter-relatedness between Physics and Mathematics. The conceptual understanding of electromagnetism in particular and the subject matter, in general, is difficult without adequate mathematics knowledge. Hence the need to improve mathematics knowledge on physics students' performance in Electromagnetism.

Purpose of the Study

The purpose of this study was to investigate the effect of mathematics knowledge on physics students' performance in Electromagnetism. Specifically, the objectives of the study were to:

i. Evaluate student's general performance in electromagnetism using the instructional strategies.
ii. Investigate the intervening effects of instructional strategies on student's performance in electromagnetism given their mathematical abilities.
iii. Evaluate the intervening effect of instructional strategies on account of mathematical ability, and gender on students' performance on electromagnetism.

Research Questions

The following research questions were stated to guide this study:

I. What is the students' general performance in electromagnetism concepts?
II. How does the mathematics ability of students affect their performance in electromagnetism concepts?
III. How do mathematics abilities and gender jointly affect students' performance on electromagnetism?

Hypotheses

The null hypotheses tested in this study include:

Ho_1: There is no significant difference in performance of students in electromagnetism when taught using the instructional strategies.

Ho_2: No significant difference exists between the performances of students when electromagnetism is taught using the instructional strategies, on their mathematics abilities.

Ho_3: There is no significant joint effect of instructional strategies, mathematics abilities, and gender on students' performance in electromagnetism.

2. Methodology

The study adopted a quasi-experimental, pre-test, post-test experimental and control design. The control group was not presented with advance organisers while the experimental groups had advance organisers differently as a pictorial (group 1), written (group II) and verbal (group III) taught using the concept map strategy. Purposive sampling techniques were used to select a sample of two hundred SS2 students (200) for this study. The instruments Physics Performance Test on Electromagnetism (PPTE) and the Mathematics Ability Test on Electromagnetism Concept (MATEC) were used to elicit student understanding and application of the concepts of electromagnetism and their mathematics abilities.

MATEC consisted of 50 multiple choice questions on Mathematics based on mathematical concepts applicable in electromagnetism while PPTE consisted of 50 multiple choice questions in the concepts of electromagnetism based on the constructs of understanding and application. Difficulty indices of the instrument PPTE and MATEC are 33.3 and 50.0 respectively, and reliability coefficients calculated using Kuder-Richardson formula (K-R 21) as 0.74 and 0.99 respectively. The pre-test version of the PPTE and MATEC were administered to the students before instruction, at the end of 12 weeks of instruction, the post-test version of the PPTE and MATEC were administered. The scores of students were collated for data analysis. The statistical analysis tools for answering the stated research question were mean and percentages while Analysis of Covariance, (ANCOVA) was used for test of hypotheses.

3. Results

Research Question I: What are the student's general performances in electromagnetism concepts?

Table 1 shows that the mean percentage gain of students presented with the pictorial advance organiser is 40.54%, those presented with written advance organisers have mean percentage gain of 19.01%, those presented with verbal advance organiser have mean percentage gain of 29.96% while those without advance organisers have mean percentage gain of 16.57. This implies that the use of Pictorial advance organisers enhanced the performance of students in electromagnetism when taught using concept mapping strategy. Students performed poorly in electromagnetism when taught without the use of the organisers (gain; 5.60) but had improved performance due to the use of the strategies (14.32, 11.00, 6.42).

Furthermore, the mean percentage gain of the experimental group (29.84%) is greater than the control group (16.57%). This implies that the use of advance organisers enhanced the performance of students in electromagnetism when taught using concept mapping strategy.

Research Hypothesis I: (HO_1) there is no significant difference in performance of students in electromagnetism taught using the instructional strategies.

As indicated in Table 2, the calculated $F_{3,195}$ value is 5.532 at the degree of freedom of 3,195 and Probability level of 0.05 against the $F_{3,195}$ critical value of 3.89.

This shows that there is no significant difference between the performance of students in the concept of electromagnetism who were presented with advance organisers (pictorial, written and verbal) and those without the advance organisers when taught using concept map strategy.

Table 1. Gain scores of students' performance in the concepts of electromagnetism

Groups	**Performance**				
		$PPTE\ (pre)$ $\bar{x}$	$PPTE\ (post)$ $\bar{x}$	Gain	Gain%
Experimental	PAO	10.52	24.82	14.32	40.54
	WrAO	13.68	20.10	6.42	19.01
	VAO	12.86	23.86	11.00	29.96
Control	WAO	14.10	19.70	5.60	16.57

PRT- Pre-test Post-test, PAO- pictorial Advance organiser.
WrAO- written Advance Organiser, VAO- verbal Advance organiser.
WAO- Without Advance organiser.

Table 2. Summary of Analysis of covariance of students' performance in electromagnetism based on the four instructional strategies using pre-test as a covariant

Dependent Variable: post-test scores of performance					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	724.876[a]	4	181.219	4.499	S
Intercept	9079.451	1	9079.451	225.429	S
PRETESTTO	0.021	1	0.021	0.001	Ns
Instructional strategies	668.453	3	222.818	5.532	S
Error	7853.879	195	40.276		
Total	105071.000	200			
Corrected Total	8578.755	199			
a. R Squared = .084 (Adjusted R Squared = 0.066)					

Research Questions II: How does mathematics abilities of students affect their performance in Electromagnetism?

Table 3 indicates that students of high mathematics ability have mean percentage gain of 41.17% while those of low mathematical ability have 36.93% in their performance in the concept of electromagnetism, when presented with pictorial advance organizers and taught using concept mapping, this implies that average mathematical ability is required for tackling numerical problems in electromagnetism.

Moreover, students' who learned using written advance organisers have high mathematics ability of 26.62%, those with average mathematics ability have mean percentage gain of 18.06 while those students with low mathematics ability had mean percentage gain of 22.06 in their performance of the concepts of electromagnetism.

Furthermore, the mean percentage gain in students with high mathematics ability presented with verbal advance organiser is 35.40%, those students with average mathematics ability have mean percentage gain of 30.59% while those of low mathematics ability have 15.87. This implies that students of high mathematics abilities contributed to high performance in the concepts of electromagnetism' while those of low mathematics ability performed poorly.

However, those students, who learned without advance organisers with average mathematics ability have mean percentage gain of 18.65% on their performance in the concepts of electromagnetism, while those of high mathematics ability have to mean percentage gain of 16.00% and those of low mathematics ability have 12.29%.

Finally, the mean percentage gain of the experimental group (30.57%) is less than the mean percentage gain of the control group (15.65%) in their performances in the concepts of electromagnetism classified by high, average and low mathematics when taught using concept mapping strategy.

Research Hypothesis II: (HO_2)

No significant difference exists between the performance of students in electromagnetism taught using the instructional strategies, given their mathematics abilities.

Table 4 shows that the main effects (Group and MATA) are non-significant. The calculated F-value is 2.310 and 1.550 respectively at the degree of freedom of 3,187 and a probability level of 0.05, the critical value is 3.04. Since the critical value is greater than the calculated value in both cases, the null hypothesis is retained. No significant main effect exists between the performance of students presented with advance organisers (Pictorial, written and verbal) and those not presented with the advance organisers when taught the concept of electromagnetism using concepts mapping strategy, given their mathematical abilities.

Furthermore, the interaction between instructional strategy and Mathematical ability shows no significance. The calculated F-value at the degree of freedom of 6,187 is 1.126 while the critical value is 2.140 at 0.05 significance levels. Therefore, the null hypothesis is retained. No significant interaction effect exists between the performance of students presented with advance organisers (Pictorial, written and verbal) and those not presented with advance organisers when taught the concept of electromagnetism using concept mapping strategy, given their mathematical abilities.

Table 3. Gain scores of performance in electromagnetism by students of high, average and low mathematics abilities

		Performance				
Groups		MA	$PPTE\ (pre)$ $\bar{x}$	$PTE\ (post)$ $\bar{x}$	Gain	Gain%
Experimental	PAO	H	9.88	23.88	14.00	41.47
		A	8.55	24.44	15.89	48.17
		L	10.93	23.73	12.80	36.93
	WrAO	H	12.75	22.00	9.25	26.62
		A	13.25	19.09	5.84	18.06
		L	12.86	20.14	7.28	22.06
	VAO	H	11.75	24.63	12.88	35.40
		A	12.87	24.00	11.13	30.59
		L	13.73	18.91	5.18	15.87
Control	WAO	H	16.14	22.29	6.15	16.00
		A	13.03	52.17	7.03	18.65
		L	15.27	19.55	4.28	12.29

MA- Mathematical ability
H- High (24-34) A- Average (14-23) L – low (4-13)
PAO- Pictorial Advance organisers, WrAO- written Advance organiser
VAO- Verbal Advance Organisers, WAO- without Advance Organiser

Table 4. Summary of 4x3 Analysis of Covariance of students' performance, in the concept of electromagnetism classified by instructional strategies and mathematics abilities using pretest scores as a covariant

Dependent Variable: PPTE POSTTEST(T)					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1091.966[a]	12	90.997	2.273	s
Intercept	8281.471	1	8281.471	206.849	s
PRETESTTO	0.114	1	0.114	.003	ns
Main Effect					
Instructional strategies	277.420	3	92.473	2.310	ns
MATA	124.080	2	62.040	1.550	ns
Interactions					
Instructional strategies * MATA	270.527	6	45.088	1.126	Ns
Error	7486.789	187			
Total	105071.000	200	40.036		
Corrected Total	8578.755	199			

Table 4.1. MATA-Mathematics Ability, Group-instructional strategies

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.222[a] (0.195)	0.049	0.035	6.45005
a. Predictors: (Constant), MATA, gender, group				

Table 5. Summary of 4x3x2 analysis of covariance of students performance in the concept of electromagnetism classified by instructional strategies mathematical ability and gender using pretest scores as a covariance

Dependent Variable: post-test scores of performance					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1696.646[a]	23	73.767	1.886	s
Intercept	7982.512	1	7982.512	204.141	s
PRETESTTO	.267	1	0.267	0.007	ns
Instructional strategies	280.058	3	93.353	2.387	ns
MATA	43.617	2	21.809	0.558	ns
GENDER	169.403	1	169.403	4.332	s
Instructional strategy * MATA	144.425	6	24.071	0.616	ns
Instructional strategy * GENDER	229.510	3	76.503	1.956	s
MATA * GENDER	39.387	2	19.693	.504	ns
Instructional strategy * MATA * GENDER	386.508	5	77.302	1.977	ns
Error	6882.109	176	39.103		
Total	105071.000	200			
Corrected Total	8578.755	199			
a. R Squared = .198 (Adjusted R Squared = 0.093) MATA- Mathematics Ability					

Research Question III: How do mathematics abilities, instructional strategies, and gender jointly affect students' performance on electromagnetism?

Table 4.1 shows an index of the relationship of r= 0.222. This indicates that the advance organisers, gender and mathematical ability of students' jointly have a positive relationship with the students' performance in electromagnetism when taught using concept mapping strategy. This implies that it is only to a considerable extent (22.2%) that the advance organisers, gender and mathematics ability of students jointly influenced positively, students' performance in electromagnetism.

Research Hypothesis III: (HO_3)

There is no significant joint effect of instructional strategies, mathematics abilities, and gender on student performance on electromagnetism.

Table 5 shows that the main effect of instructional strategies, mathematics ability, and gender. At 0.05 significant level and degree of freedom (df) of 3,199, the calculated F-ratio is 2.387 for instructional strategies, 0.558 for mathematics ability and 4.332 for gender. The critical values at df of 3,199 are 2.65, therefore, the main effect of group and gender is non-significant since the critical value is greater than the calculated values (no significant difference). There exists a significant difference in mathematical ability since, at 0.05 significant level and df of 3,176, the F-ratio calculated is less than the F-critical value.

Furthermore, the interaction effects of instructional strategies and mathematics ability are 0.616 which is less than the critical values hence there is a significant difference in students' performance in electromagnetism due to the interactive effect of group and mathematical ability.

The F-ratio calculated for the interaction of group, mathematics ability and gender is 1.977 at 0.05 significant level and degree of freedom of 5,176 while the critical value at 0.05 significant level and degree of freedom of 5,176 are 2.26. Since the F-calculated is less than F-critical, the null hypothesis is retained. This shows that there is no significant joint effect in the instructional strategies on performance in electromagnetism by students of high, average, and low mathematics abilities, whether male or female.

4. Summary of Findings

- Students of high mathematics ability have mean percentage gain of 41.17% while those of low mathematical ability have 36.93% in their performance in the concept of electromagnetism taught using pictorial advance organiser (PAO).
- Mean percentage gain of the experimental group (30.57%) is greater than the mean percentage gain of the control group (15.65%) in their performance in Electromagnetism classified by high, average and low mathematical abilities.
- Mathematics ability, instructional strategies, and gender have positive joint relationship with students' performance in Physics (Electromagnetism) to a considerable extent of 22.2% ($R^2 = 0.222$).
- There is no significant difference between the performance of students in the concept of electromagnetism who were presented with advance organisers (PAO, WrAO, VAO) and those without the organisers when taught using concept map strategy.
- At 0.05 significant level and degree of freedom df (3,197), there exist significant interaction effects of instructional strategies and mathematical ability on students' performance in electromagnetism. Students of high mathematics ability contributed mostly to the high performance in electromagnetism concepts.

5. Discussion

The performance of students was affected according to their mathematical abilities in the understanding and application of the concepts of electromagnetism. However, students taught with the pictorial advance organisers, of low mathematical abilities had a higher mean performance in the concepts (36.93%). This may have resulted from the interactive effect of the pictorial organizers and the realm of understanding is at a lower level in the cognitive domain of the taxonomy of educational objectives where much of mathematics skills may not be required and that an average mathematical ability is required for problem-solving in mathematical concepts in electromagnetism.

Mathematics ability interacted favourably with the instructional strategies used for this study and accounted for a significant performance in the concepts of electromagnetism. Students of high mathematics ability contributed immensely to their high performance in electromagnetism taught using concept map strategy irrespective of their gender. These findings agreed with the view of Adeyemi (2007) that the performance of students in Mathematics and Physics correlate significantly, and the teaching of students using innovative strategies such as the use of concept map strategy and intervention of pictorial organisers contributed to a better in the corporation and retention of the concepts of electromagnetism.

6. Conclusions

Adequate knowledge of mathematics is compulsorily required for the understanding and application of the concepts of electromagnetism hence effort has to be made in order to improve students' acquisition of mathematics skills if they expect a positive learning outcome in Physics.

7. Recommendations

Based on the findings of this research, the following recommendations are made.

1. Students who offer Physics have a need for the proper inculcation of the basic mathematics principles, laws, and theories, especially as needed in the understanding and application of the Physics concepts.
2. Students-centred interactive/innovative strategies such as the use of Advance Organizers and concept map strategy should be used in teaching electromagnetism concepts.
3. Teachers of Physics should engage students with problem-solving schedules for familiarisation and retention of approaches to numerical problems in electromagnetism.

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