EFFECT OF STUDENTS' BACKGROUND KNOWLEDGE OF MATHEMATICS ON SENIOR SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN PHYSICS

Ayodele Ogunleye, Adeneye O. A. Awofala, Emiola A. Adekoya
University of Lagos, Nigeria

Abstract. The study investigated the effect of students' background knowledge of mathematics on academic achievement in physics. The moderating effect of gender was also examined. The sample consisted of 300 senior secondary school year one science/mathematics students in Lagos State. The study adopted pre-test and post-test control group non-equivalent quasi-experimental design using a 2×2 factorial matrix with one experimental group and one control group. Five research questions and three null hypotheses were raised, answered, and tested in the study. Two research instruments, Mathematics Achievement Test (MAT) (r = 0.82) and Physics Achievement Test (PAT) (r = 0.78) were administered on the sample and data gathered were analysed, using Mean, Standard deviation, Independent Samples t-test statistic and analysis of covariance. Results showed that there were no statistically significant differences in the mean pre-test achievement scores in mathematics (t=1.426, p=0.155) and physics (t=0.416, p=0.667) between the treatment groups prior to the intervention. Results also revealed that there was no statistically significant difference in the mean pre-test achievement scores in mathematics (t=-1.63, p=0.103) and physics (t=0.356, p=0.722) based on gender. However, there was a statistically significantly positive relationship between achievement score in physics and mathematics prior to the intervention (r=0.602, p=0.002). Treatment and gender had statistically significant main effects on students' posttest achievement score in physics ($F_{(1, 299)}$=440.413, p=0.000, η^2_p=0.599; $F_{(1, 299)}$=9.611, p=0.002, η^2_p=0.032) respectively. There was no statistically significant interaction effect of treatment and gender on students' post-test achievement score in physics ($F_{(1, 299)}$=0.52, p=0.820, η^2_p=0.000). Based on the results, the study recommended that the teaching of prerequisite mathematics concepts in physics before physics teaching should be adopted as instructional technique for enhancing meaningful learning in physics.

Keywords: students' background knowledge of mathematics, physics achievement

Introduction

Physics as one of the physical science subjects plays an important role in the technological development and industrial revolution of any nation. The knowledge of scientific skill in physics is of tremendous use in solving diverse problems of humanity and providing solution to natural and artificial problems in the world at large. According to Esiobu (2005) and Akinyemi & Orukotan (1995), Science, Technology and Mathematics (STM) education play a dominant role in the developmental effort of nations. Science and technology are seen as the foundation of national power and productivity. Technological advancement seems to be the gateway to present day economic growth, social well- being, political power and military superiority. It means that the knowledge of physics contributes to the cognitive reservoir that facilitates the sustenance and advancement of technologically oriented society. Physics links the principle learnt and the phenomena observed in the classroom to applications in engineering and allied fields.

The importance of physics cuts across human endeavour such as medicine, pharmacy, agriculture, petroleum engineering, geology, engineering, industries and computer. The feats of science and technology are in every facet of human endeavour. It could be rightly said that every sector of the society now depends on science and technology for proper functioning and mathematics as the creation of human mind (Awofala et al., 2013) is the universal language used to describe the problems arising in most branches of science and technology.

Mathematics, the creation, representation analysis, interpretation of numbers and symbols affects all aspects of the human environment significantly but at varying degrees. The social, economic, political, geographical, scientific and technological aspects of man's life centre on number. One very important fact is that all other disciplines of numbers- Arithmetic, statistics, accounts etc. are integral parts of mathematics.

The earliest civilization of mankind came through mathematical manipulation. The pyramid of Egypt constructed several years ago still remains tourist attraction to date. The construction of the pyramids involved sound and intelligent mathematical calculation. The marriage of mathematics to the evolution and development of the civilization and overall advancement of human world confirms its importance. Owing to its numeral and symbolic nature, it is more married to the scientific and technology facets of our world than to any other aspect. It occurs and reoccurs in physical and natural sciences which are mainly represented by physics and chemistry in our secondary schools. Based on this circumstance, it is an established fact that mathematics is and remains a dominant contributing factor to the performance of student in physics and chemistry and the control tool of mathematics remains the basic skills underlying all scientific and technological skills. Mathematics is a subject that is related to other science subjects such as physics and chemistry in areas like Number and numeration–fractions, logarithms indices, Algebraic processes – solution of equations, variation, graph, and also in volume and students often perform poorly in the sciences (Jegede et al., 1992; Mkpananga, 2005).

Although, science has been accepted by many people including students as the bedrock for technological development they still feel that mathematics is not necessary for achieving good performance in science. The reason for this can be attributed to the controversy surrounding the nature of mathematics (Hailikari et al., 2007) and one question beckoning for answer is under what branch of studies should mathematics be classified? While one school of thought agrees that mathematics is a science another argues that mathematics must be an art. This later school of thought is based on the fact that mathematics, in its application is purely an art. On the other hand students view mathematics as a difficult school subject and so many of them try to avoid it.

The physical sciences (Physics, Chemistry and Mathematics) are studied in our secondary schools as separate subjects having little or no direct relationship with one another even when the same teacher teaches the two or more of these subjects. The lack of coordination, integration and purposeful planning makes students fail to understand the interrelatedness among the various subject fields in mathematics and physics.

Mathematics and science in primary and secondary schools share common objectives and it is desirable, for a better academic achievement, for those who major in science to select mathematics as their minor as this will be of immense benefit. Physical sciences are deeply rooted in mathematics, and as such they should not be studied in isolation of mathematics.

The poor approach of teachers to the inter-relatedness of these subjects or the total lack of it makes the students believe that mathematics is not necessary for them to perform well in physics. Unfortunately for them mathematics has been accepted as the compulsory pre-requisite for admission into universities. In addition, poor grounding in mathematics is manifested in their overall performance in physics which over the years have faced a continuous downward trend in Senior Secondary School Certificate Examination results.

In Nigeria, students' poor performance in physics have been attributed to poor teaching methods, unqualified and inexperienced teachers, poor student attitude toward physics, poor learning environment and gender effect (Ogunleye, 2000; Jegede et al., 1992; Owolabi, 2004). In spite of all the advantages derived and the recognition given to physics as one of the core science subjects and as a pivot upon which technological and economic development rest, there are wider gaps between curriculum planner intention, the implementers, that is, physics classroom teachers and what goes on in the classroom. This has led to the negative perception of students that physics is a difficult school subject. More often than not the interrelatedness of mathematics and physics is not always emphasised in physics teaching.

What students *already know* about the content is one of the strongest indicators of how well they will learn new information relative to the content. Commonly, researchers and theorists refer to what a person already knows about a topic as "background knowledge." Numerous studies have confirmed the relationship between background knowledge and student achievement (Nagy et al., 1987; Dochy et al., 1999; Tobias, 1994). In these studies the reported average correlation between a person's background knowledge of a given topic and the extent to which that person learns new information on that topic is .66.

Prior research has attempted to measure the impact of high school physics courses on students' success in undergraduate physics (Hart & Cottle, 2003; Alters, 1995). These American studies generally found that students who performed well in high school mathematics and physics subjects also did well in undergraduate physics. However, Tai & Sadler (2001) point out that these conclusions were reached by examining only a few variables and forming simple correlations.

Studies of students' Background knowledge in science and mathematics began in the 1970s and have since produced a voluminous literature (Dochy et al., 1999). Interest in prior knowledge began with the careful documentation of common errors made by students in solving physics and mathematics problems. Analysis of interviews with these students reveals that the errors are not random slips, but rather derive from underlying concepts. The learner will formulate existing physics structures only if new information or experiences are connected to knowledge already in memory. It is evident that it is from experiences that students develop a cognitive structure which may be valid, invalid or incomplete (Dresel et al., 1998). Prior knowledge is defined as a multidimensional and hierarchical entity that is dynamic in nature and consists of different types of knowledge and skills (Dochy, 1992; Hailikari et al., 2007). Prior knowledge has long been considered the most important factor influencing learning and student achievement (Dochy & McDowell, 1997; De Corte, 1990; Dresel et al., 1998; Tobias, 1994).The amount and quality of prior knowledge positively influence both knowledge acquisition and the capacity to apply higher-order cognitive problem-solving skills (Dochy & McDowell, 1997; De Corte, 1990; Dresel et al., 1998; Tobias, 1994) irrespective of gender.

World-wide gender has often been a variable of interest in most research works in Education and in this study it was included as a moderator variable of interest because past studies in Nigeria had indicated gender as one of the most important variables in science/mathematics education (Abakpa & Iji, 2011; Abiam & Odok, 2006) with inconclusive report findings (Abakpa & Iji, 2011; Akinsola & Awofala, 2009). Reported findings in gender had been mixed with some claiming that males performed better on achievement measure in mathematics and science than their female counterparts (Awofala, 2011a; Awofala, 2010; Ogunneye, 2003; Akinsola & Awofala, 2009) while others (Abakpa & Iji, 2011; Ogunleye & Babajide, 2011; Arigbabu & Mji, 2004; Agommuoh & Nzewi, 2003) observed no significant effect of gender on students' achievement in science and mathematics thus concluding that gender differences in achievement/performance might be disappearing. The present study was undertaken to investigate the effect of students' background knowledge of mathematics on senior secondary school students' achievement in physics. It also examined the influence of gender on students' achievement in physics.

Research questions

The research sought answers to the following questions: (1) Will there be any statistically significant difference in achievement mean score in physics between the experimental (teaching of prerequisite mathematics concepts in physics before real physics teaching) and control (physics teaching only) groups prior to the intervention? (2) Will there be any statistically significant difference in achievement mean score in mathematics between the experimental (teaching of prerequisite mathematics concepts in physics before real physics teaching) and control (physics teaching only) groups prior to the intervention? (3) Will there be any statistically significant difference between male and female students in achievement mean score in physics prior to the intervention? (4) Will there be any statistically significant difference between male and female students in achievement mean score in mathematics prior to the intervention? (5) Is there any statistically significantly positive relationship between students' pretest achievement score in mathematics and physics?

Null hypotheses

The following hypotheses were formulated and tested at 0.05 level of significance:

H_{01}: There is no significant main effect of treatment on students' achievement in physics.

H_{02}: There is no significant main effect of gender on students' achievement in physics.

H_{03}: There is no significant interaction effect of treatment and gender on students' achievement in physics.

Methodology

Research design

The study employed a quantitative research within the blueprint of pretest-posttest non-equivalent control group quasi-experimental design to contrast the treatment's (at two levels) with gender (at two levels) using a 2×2 factorial matrix.

The research design is symbolically presented below:

$O_1\ X_1\ O_2$	gain = $O_2 - O_1$	$O_1\ O_3$ = pre-tests
$O_3\ C\ O_4$	gain = $O_4 - O_3$	$O_2\ O_4$ = post-tests

X_1 and C represent teaching of prerequisite mathematics concepts in physics before lecture in physics and conventional teaching method without teaching of prerequisite mathematical concepts respectively. The mean gain scores between O_1 and O_2 and O_3 and O_4 were tested for statistical significance using the Analysis of Covariance (ANCOVA) in which pre-test score in physics was used as covariate.

Participants

The participants comprised 300 Senior Secondary School year one science/mathematics students (145 males and 155 females). A combination of purposive and simple random sampling techniques was used. First, purposive sampling was used to select six senior secondary schools offering science/mathematics field in education districts three and four. Second simple random sampling was used to select one intact class each from six equivalent coeducational secondary schools that were distantly located from one another in education districts three and four in Lagos state, Nigeria. Three schools were randomly assigned to the experimental group and the remaining three schools to the control group. The mean ages of the students in the experimental schools and control schools were 14.2 years and 14.3 years respectively.

Instrumentation

Two research instruments were used to collect data in this study and they are: Mathematics Achievement Test (MAT) and Physics Achievement Test (PAT).

Mathematics Achievement Test

The MAT was designed in two main parts. Part 'A' contained the Bio-data of the respondents such as sex, age, religion, class level, and school and part 'B' consisted of 10 items, multiple-choice objective test of five options A to E developed based on the prescribed senior secondary school year one mathematics curriculum covering the following topics: Angles, sequences and series, quadratic equation, approximation and percentage error, simultaneous equation and surd. Participants were expected to encircle the option bearing the answer. To determine the validity of MAT, copies of the MAT were given to a panel of three experts (two in mathematics education and one in test and measurements) to carefully assess areas covered by the test and/or to remove potential or biased invalid items from the instrument. The face and content validity of the MAT were also ascertained by this panel of experts by (a) checking the clarity of the directives, the questions, as well as the sufficiency of the possible answers and (b) evaluating the appropriateness of the test. The face and content validated 10-item MAT was pilot tested on a sample of 30 senior secondary school year one mathematics students that were not part of the study sample and using Kuder-Richardson Formula (KR-20), an estimated reliability coefficient of .82 was determined. The maximum score obtainable on the MAT was 10 while zero was the minimum score a participant could obtain.

Physics Achievement Test

The PAT was designed in two main parts. Part 'A' contained the Bio-data of the respondents such as sex, age, religion, class level, school and gender and part 'B' consisted of 10 items, multiple-choice objective test of five options A to E developed based on the prescribed senior secondary school year one physics curriculum covering the following topics: Derivation of equation of linear motion and motion under gravity, projectiles and falling bodies, equilibrium of forces, Newtons laws of motion, and machines (Obioha, 2006). Participants were expected to encircle the option bearing the answer. To determine the validity of PAT, copies of the PAT were given to a panel of three experts (two in physics education and one in test and measurements) to carefully assess areas covered by the test and/or to remove potential or biased invalid items from the instrument. The face and content validity of the PAT were also ascertained by this panel of experts by (a) checking the clarity of the directives, the questions, as well as the sufficiency of the possible answers and (b) evaluating the appropriateness of the test. The face and content validated 10-item PAT was pilot tested on a sample of 30 senior secondary school year one physics students that were not part of the study sample and using Kuder-Richardson Formula (KR-20), an estimated reliability coefficient of .78 was determined. The maximum score obtainable on the PAT was 10 while zero was the minimum score a participant could obtain.

Procedure for data collection

The study made use of six willing physics graduate teachers. At the outset of the study, the teachers made the students respond to two instruments i.e. Mathematics Achievement Test (MAT) and Physics Achievement Test (PAT). The scores on the MAT administered before the treatment were used to ascertain the background knowledge of the participants in the six schools earmarked for the study while the scores on the PAT prior to the treatment served as the covariates. After this, the teachers provided the treatment conditions, which lasted four weeks. This involved the teaching of prerequisite mathematics concepts in physics before lectures in physics in three schools (experimental group) and the teaching of physics without any attempt to teach the prerequisite mathematics concepts in the remaining three schools (control group). Thereafter, the PAT was also administered as post-test.

In the experimental group (n=154) students were taught the prerequisite mathematics concepts before given lectures in physics. The instruction involved lessons with lecture and questioning methods to teach prerequisite mathematics concepts and physics concepts. All the mathematics concepts associated with the physics topics earmarked for the study were first treated with the students before embarking on physics teaching using the conventional teaching method. The only difference in the instruction between the experimental and control groups was that in the experimental group, participants were first taken through the associated mathematical concepts in the physics topics while in the control group the physics teachers taught physics without any recourse to teach the associated mathematical concepts.

In the control group (n=146) no attempt was made to first teach the prerequisite mathematics concepts associated with the physics concepts. The teacher taught physics using the conventional teaching method of chalk and talk. The conventional instruction involved lessons with lecture and questioning methods to teach the topics earmarked for the study. The teacher posed problems on the chalkboard and solved them with explanations. In the better part of the instruction time, the students received instruction and engaged in discussions arising from the teacher's explanations and questions. Thus, in the control group, teaching was teacher dominated with students listening and copying notes.

Data analysis

The post-test physics scores were subjected to analysis of covariance (ANCOVA) using the pre-test physics scores as covariates. An independent samples t-test was used to ascertain differences in pre-test mathematics scores between the two groups prior to the treatment. All statistical tests were carried out at alpha (α) level of 0.05.

Results

Answering of research questions

Research Question One: Will there be any statistically significant effect of treatment on students' pretest achievement score in physics?

Table 1. Means, standard deviations, and t-test value on pretest achievement score in physics for experimental and control classes

Group	N	Mean	SD	df	t	p
Experimental group	154	4.5260	.97148	298	.416	.667
Control group	146	4.4795	.96289			

Prior to treatment in both the experimental and control groups the researchers tested for difference in pre-test achievement score in physics of the two groups. Results in Table 1 showed that the experimental group recorded slightly higher mean score (M=4.45260, SD=0.97148) in pre-test achievement in physics than their control group counterparts (M=4.4795, SD=0.96289). This difference was however not statistically significant (t=0.416, df=298, p=.667) based on an independent samples t-test. Thus, it was concluded that there was no statistically significant difference in achievement mean score in physics between the two groups prior to the intervention.

Research Question Two: Will there be any statistically significant effect of treatment on students' pretest achievement score in mathematics?

Table 2. Means, standard deviations, and t-test value on pretest achievement score in mathematics for experimental and control classes

Treatment	N	Mean	SD	df	t	p
Experimental group	154	4.2013	.71747	298	1.426	.155
Control group	146	4.0822	.72879			

Prior to treatment in both the experimental and control groups we tested for difference in pretest achievement score in mathematics of the two groups. Results in Table 2 show that the experimental group recorded slightly higher mean score (M=4.2013, SD=0.71747) in pretest achievement in mathematics than their control group counterparts (M=4.0822, SD=0.72879). This difference was however not statistically significant (t=1.426, df=298, p=.155) based on an independent samples t-test. Thus, it was concluded that there was no statistically significant difference in achievement mean score in mathematics between the two groups prior to the intervention.

Research Question Three: Will there be any statistically significant effect of gender on students' pretest achievement score in physics?

The results in Table 3 below show that female students recorded slightly higher mean score (M=4.5226, SD=0.96924) in pre-test achievement in physics than their male counterparts (M=4.4828, SD=0.96540). This difference was however not statistically significant (t=0.356, df=298, p=.722) based on an independent samples t-test. Thus, it was concluded that there was no statistically significant difference between male and female students in achievement mean score in physics prior to the intervention.

Table 3. Means, standard deviations, and t-test value on pretest achievement score in physics for female and male groups

Gender	N	Mean	SD	df	t	p
Female	155	4.5226	.96924	298	.356	.722
Male	145	4.4828	.96540			

Research Question Four: Will there be any statistically significant effect of gender on students' pretest achievement score in mathematics?

The results in Table 4 below show that male students recorded slightly higher mean score (M=4.2138, SD=0.71866) in pre-test achievement in mathematics than their female counterparts (M=4.0774, SD=0.72556). This difference was however not statistically significant (t=-1.63, df=298, p=.103) based on an independent samples t-test. Thus, it was concluded that there was no statistically significant difference between male and female students in achievement mean score in mathematics prior to the intervention.

Table 4. Means, standard deviations, and t-test value on pretest achievement score in mathematics for female and male groups

Gender	N	Mean	SD	df	t	p
Female	155	4.0774	.72556	298	-1.63	.103
Male	145	4.2138	.71866			

Research Question Five: Is there any statistically significant relationship between students' pretest achievement score in mathematics and physics?

The result of the Pearson product moment correlation shows that there was a statistically significant positive relationship between students' achievement score in mathematics and physics (r=0.602, p=0.002) prior to the intervention. This result showed that any increase in achievement scores of students in mathematics may lead to an increase in their physics achievement scores.

Null hypothesis testing

Table 5 below showed the results of statistical analysis of post-test achievement scores between the experimental and control groups according to gender. The mean of the posttest achievement scores for the experimental group *(M=8.8636, SD=0.96384)* was higher than the mean of the control group *(M=6.3699, SD=1.11426).* This result connotes that the students in the experimental group performed better in physics than their counterparts in the control group.

Table 5. Results of mean achievement post-test scores in physics based on treatment and gender

Treatment	Gender	Mean	Std. Deviation	N
experimental group	Female	8.6709	1.03430	79
	Male	9.0667	.84363	75
	Total	8.8636	.96384	154
control group	Female	6.2105	1.02392	76
	Male	6.5429	1.18793	70
	Total	6.3699	1.11426	146
Total	Female	7.4645	1.60469	155
	Male	7.8483	1.62588	145
	Total	7.6500	1.62366	300

Thus, the teaching of prerequisite mathematics concept in physics before real teaching in physics might improve the achievement score of students in physics. This result linked the null hypothesis one stated below.

Null Hypothesis One (H_{01}): There is no significant main effect of treatment on students' posttest achievement score in physics.

Further analysis of the post-test achievement scores of the students in the experimental and control groups using the analysis of covariance as contained in Table 6 showed that the difference in means between the two groups was statistically significant ($F(1,299)=440.413$, $p=0.000$, $\eta^2_p=0.599$). Thus, the null hypothesis one was rejected and it was upheld that there was a statistically significant main effect of treatment on students' achievement in physics.

Null Hypothesis Two (H_{02})*:* There is no significant main effect of gender on students' posttest achievement score in physics.

Further analysis of the post-test achievement scores of the male and female students using the Analysis of Covariance as contained in Table 6 showed that the difference in means between the male and female students was statistically significant ($F(1,299)=9.611$,

$p=0.002$, $\eta^2_p=0.032$). Thus, the null hypothesis two was rejected and we upheld that there was a significant main effect of gender on students' achievement in physics.

Table 6. Summary of analysis of covariance of post-test physics scores by treatment and gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Non-cent. Parameter	Observed Power[a]
Corrected Model	478.057[b]	4	119.514	113.660	.000	.606	454.642	1.000
Intercept	690.377	1	690.377	656.562	.000	.690	656.562	1.000
Covariates	1.920	1	1.920	1.826	.178	.006	1.826	.270
Treatment (T)	463.095	1	463.095	440.413	.000	.599	440.413	1.000
Gender (G)	10.106	1	10.106	9.611	.002	.032	9.611	.871
T*G	.055	1	.055	.052	.820	.000	.052	.056
Error	310.193	295	1.052					
Total	18345.00	300						
Corrected Total	788.250	299						

a Computed using alpha = .05; b R Squared = .606 (Adjusted R Squared = .601)

Table 5 showed the results of statistical analysis of post-test achievement scores based on treatment and gender. In the control group, the male students recorded higher posttest achievement mean score in physics (*$M=6.5429$, $SD=1.18793$*) than their female counterparts (*$M=6.2105$, $SD=1.02392$*) while in the experimental group, male students obtained higher post-test achievement mean score in physics (*$M=9.0667$, $SD=0.84363$*) than their female counterparts (*$M=8.6709$, $SD=1.03430$*). This result connotes that in both the experimental and control groups male students seemed to display achieve better in physics than their female counterparts. This result linked null hypothesis three stated below.

Null Hypothesis Three (H_{03}): There is no significant interaction effect of treatment and gender on students' posttest achievement score in physics.

Further analysis of the post-test achievement scores of the interaction of treatment and gender using the Analysis of Covariance as contained in Table 6 above showed that the interaction effect of treatment and gender was not statistically significant *($F_{(1,299)}=0.52$, $p=0.820$, $\eta^2_p=0.000$)*. Thus, the null hypothesis three was not rejected and we upheld that there was no significant interaction effect of treatment and gender on students' achievement in physics.

Discussion

The results of the present study showed that there was no statistically significant difference in achievement mean score in physics between the experimental (teaching of prerequisite mathematics concepts in physics before real physics teaching) and control (physics teaching only) groups prior to the intervention. This finding indicates that the two groups entered the experiment/instruction on equal strength. This result corroborates the findings of previous studies in mathematics (Fatade et al., 2014; Awofala et al., 2012). This is also in consonance with this study finding that there was no statistically significant difference in achievement mean score in mathematics between the experimental (teaching of prerequisite mathematics concepts in physics before real physics teaching) and control (physics teaching only) groups prior to the intervention.

On gender differences in achievement in mathematics and physics, the present study showed that there was no statistically significant difference between the male and female students in achievement mean score in physics and mathematics prior to the intervention. This is an indication that male and female students recorded comparable achievement mean scores in mathematics and physics prior to the intervention. Previous studies on gender differences in science and mathematics have recorded equivocal findings with some claiming that male performed better in mathematics and science than their female counterparts (Awofala, 2007; Awofala et al., 2013) while others found no significant gender differences in mathematics and science (Awofala & Nneji, 2012; Fatade et al., 2012; Ogunleye & Babajide, 2011; Arigbabu & Mji, 2004).

The present study showed that there was a statistically significantly positive relationship between students' pretest achievement scores in mathematics and physics. This result indicated that there was a direct relationship between achievement in physics and mathematics. Thus, students with high performance in physics were expected to record high performance in mathematics and vice versa. This finding agreed with the findings of previous studies (Awofala et al., 2012) in which significantly positive relationship was found between achievement in mathematics and physics.

With respect to hypotheses testing, the results showed that there was a significant main effect of treatment on students' achievement in physics. This meant that students that were taught the prerequisite mathematics concepts in physics before real physics teaching performed better in physics than those students that were taught physics without any recourse to the teaching of prerequisite mathematics concepts in physics. This finding indicated that the knowledge of mathematics should be taken as a prerequisite for effective teaching and learning of school physics. Thus, mathematics should be seen as a formidable anchor for physics teaching and learning. This is in line with the theory of meaningful learning by Ausubel (1990) that students' prior knowledge of a subject should serve as a formidable anchor to learning new knowledge in the subject.

The amount and quality of prior knowledge positively influence both knowledge acquisition and the capacity to apply higher-order cognitive problem-solving skills (Dochy & McDowell, 1997; De Corte, 1990; Dresel et al., 1998). Meltzer (2002) in a study of the relationship between mathematics preparation and conceptual learning gains in physics found out that students' pre-instruction algebra skills might be associated with their facility at acquiring physics conceptual knowledge in a physics course. This result further indicated that 59.9% of the variance in students' achievement in physics could be explained by the treatment alone.

The significant main effect of gender on students' achievement in physics recorded in the present study showed that gender differences in science and mathematics might not have all disappeared (Awofala et al., 2013) and the differences still show the existence of gender stereotype teaching in science. The present study result on gender differences in achievement in physics also supported the work of researchers who believe that gender stereotyping is still dominant in the Nigerian educational system (Awofala, 2011b; Awofala, 2007; Erinosho, 1997). Gender based differences are due to the individual's perception of own abilities and the sex role (Schiefele & Csikszentmihalyli, 1995). However, the result is at variance with the findings of some previous studies (Awofala & Nneji, 2012; Fatade et al., 2012; Ogunleye & Babajide, 2011; Arigbabu & Mji 2004) that reported no significant main effect of gender on students' performance in science and mathematics. The result further indicated that 3.2% of the variance in students' achievement in physics could be explained by gender.

The results of the present study showed that there was no significant interaction effect of treatment and gender on students' achievement in physics. The non-significant interaction effect of treatment and gender recorded in this study showed that gender seemed not to interact with instruction to produce results, meaning that the treatment conditions did not discriminate across gender in this study. Similar studies have found non-significant interaction effect of treatment and gender on students' learning (Awofala et al., 2013).

Conclusion

In the course of the present study, it can be asserted that the teaching of prerequisite mathematics concepts in physics before physics teaching could be a way of improving students' performance in school physics. The present study showed that effective teaching and learning of physics could be achieved through the teaching of mathematics concepts that serve as anchors to physics contents. Thus, physics should not be taught in isolation but in conjunction with mathematics and better still further mathematics which seems to have more connections with school physics as Hudson & Rothman (1981) and Awofala et al. (2012) found a strongly positive relationship between (further) mathematics and physics. As shown in this study the teaching of prerequisite mathematics concepts in physics before physics teaching made students more confident in learning physics thereby improving achievement in physics. The teaching of prerequisite mathematics concepts in physics assisted physics teachers through diagnostic testing to ascertain the students' level of preparedness before the teaching of physics. The teaching of prerequisite mathematics concepts in physics could be adopted as a viable strategy for strengthening the students' cognition in physics thereby lessening the general perception that physics is a difficult school subject.

Based on the findings of this study and the discussion that followed, the following recommendations were made: (A) Physics teachers should adopt the principle of Ausubel theory of meaningful learning in the teaching of school physics. Students' previous knowledge in mathematics should be used as a template for meaningful physics teaching and learning; (B) Physics teachers should endeavour to teach prerequisite mathematics concepts in physics before engaging in real physics teaching as this will allow for meaningful understanding and integration of mathematics concepts embedded in physics contents; (C) The state government should make all effort to recruit qualified and experienced teachers to teach Physics in all the public schools in the state; (D) There should be an increased instructional supervision in Physics and Mathematics education in the state. This should be undertaken by knowledgeable supervisors in the subjects. Where the personnel are not available, knowledgeable supervisors could be engaged on consultancy; (E) Since it is revealed that mathematics has positive influence on the achievement of students in physics, it is therefore recommended that all science students should be mandated to take further mathematics for at least the first two years of the Senior Secondary School; (F) Mathematics and physics teachers should endeavour to make the teaching and learning of mathematics and physics interesting to the students.

In view of the limitations of this study, suggestions were made for further studies: (i) It may be a worthwhile effort for future researchers to engage in a longitudinal study of the effect of background knowledge of mathematics on students' achievement in physics; (ii) One of the limitations of the present study was that it did not consider the effect of treatment on attitudes toward physics. Future studies may consider the effect of background knowledge of mathematics on this dependent variable; (iii) The teaching of prerequisite mathematics concepts in physics could be supplemented with cooperative learning and its effects found on students' learning outcomes in physics.

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✉ **Dr. Ayodele Ogunleye**
Department of Science and Technology Education,
University of Lagos,
Lagos, Nigeria
E-mail: aogunleye@unilag.edu.ng

✉ **Dr. Adeneye O.A. Awofala**
Department of Science and Technology Education,
University of Lagos,
Lagos, Nigeria
E-mail: aawofala@unilag.edu.ng

✉ **Mr. Emiola A. Adekoya**
Department of Science and Technology Education,
University of Lagos,
Lagos, Nigeria
E-mail: jibowest@yahoo.com