A path analytical study of Nigerian senior secondary school students' characteristics and their academic performance in physics

Estudio analítico sobre el rendimiento académico en física en una escuela secundaria nigeriana

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Abstract

The study constructed and tested a ten-variable model for providing a causal explanation of senior secondary students' academic achievement in physics in terms of ten variables are: physics learning resources, student's gender, school type, school principal area of specialization, physics teacher's qualification, problem solving skills, practical skills, student's attitude towards physics, physics general aptitude and achievement in physics (the dependent variable). The study is of the ex-post factor type that utilized a multi-stage stratified sampling technique consisting of two stages. A stratified random sampling was used to select 22 schools, 22 school principals and 22 physics teachers. Purposive sampling technique was employed to select 15 physics students from each school totalling up to 330 (167 males and 163 females). Data collection involved the use of eight valid and reliable instruments (Tests and Questionnaires) whose reliability indices range between 0.53 and 0.90. The data were subjected to multiple regression and path analysis procedure in order to estimate the coefficient of structural equations of the proposed model. The results indicate that the most meaningful causal model emerged with four (4) direct and eight (8) indirect significant pathways. The predictor variables correlate positively with the dependent variable (R = 0.541) The nine-predictor variables account for 27,2% of the variability in the criterion ($p < 0.05$). The relative order of importance of the predictor variables with respect to their influence on physics achievement (from the most to the least important) are physics general aptitude, student's gender, student's attitude, school type, physics practical skills, physics teacher's qualification, problem solving skill and school principal's area of specialization. The implications of these findings for parents, practicing teachers, education policy makers and curriculum developers are discussed.

Key words*: skills, school factors, student factors, causal modeling, physics.*

Resumen

El estudio construyó y probó un modelo de diez variables para proporcionar una explicación de logros académicos de los estudiantes de la escuela secundaria en física. Un muestreo al azar estratificado fue utilizado para seleccionar a 22 escuelas, 22 directores de escuela y a 22 profesores de física. La técnica de muestreo fue empleada para seleccionar a 15 estudiantes de física de un total de 330 (167 varones y 163 mujeres). La colección de datos implicó el uso de ocho instrumentos válidos y confiables (las pruebas y los cuestionarios) con un índice de confiabilidad que se extiende entre 0.53 y 0.90. Los datos fueron sujetos al procedimiento del análisis de la regresión múltiple y de la trayectoria para estimar el coeficiente de ecuaciones estructurales del modelo propuesto. Los resultados indican que el modelo causal más significativo emergió con cuatro directos y ocho caminos significativos indirectos. Las variables correlacionan positivamente con la variable dependiente (R = 0.541). Se encontró que la orden relativa de importancia con respecto a su influencia en los logros en física (de mayor a menor importancia) es: aptitud general de la física, el género del estudiante, tipo de escuela, habilidades prácticas de la física, calificación del profesor de física, habilidad al solucionar problemas y área de especialización de directivos de la escuela. Las implicaciones de estos resultados para proceso docente se discuten.

Palabras clave*: habilidades, escuela, estudiantes, modelo causal, física.*

INTRODUCTION

The scientific and technological revolutions of the seventeenth and eighteenth centuries, have brought many profound social, economic, and cultural changes in society (AHMED, 1985; PROCTER, 2005). Science and

technology have brought immense benefits to humanity in the form of raising standards of living and expansion of mental horizons (Bruce, 2006). In addition, industrial and agricultural productions in nations have owed more and more to knowledge made available by science. In Nigeria, the role of science in the development of technology has been stressed (Emovon, 1985). This concern arises from the increasing awareness that Nigeria cannot develop as rapidly as she aspires to, without creating an adequate pool of scientific and technical manpower at all levels of its working population (Ozoro, 1977). It was as a result of the recognition given to the subject (physics) in the development of individuals and the nation, that its teaching is accorded a prominent position at the senior secondary level of education as contained in the Nigerian National Policy of Education (Federal Republic of Nigeria, 2004). The importance of physics cannot be overemphasized. The day-to-day modern lighting system, cooling system, heating system and conveniences of life can be traced to the contribution of physics technology. Even in our classrooms and homes we see physics phenomena and products, which attend to human conveniences and security (Ariyo, 2006). As important as physics is, secondary education in Nigeria is associated with unfavorable performance of students in physics. Evidence abounds from past studies carried out in Nigeria that secondary school students often show negative attitude to physics and this negative attitude has been found to reduce students interest towards physics enrolment and poor performance in the Senior Certificate Examinations (Iroegbu, 1998; Oyekan 1993). This situation is not peculiar to Nigeria alone; other researches outside the country have also reported poor performance and low enrolment among secondary school students in such subjects as physics and chemistry (Farmer, 1990; Kempa, 1991; Meester & Maskell, 1995; Coutinho & Santos, 2001). The issue of secondary school students low and under performance in physics is a cause for worry.

School is regarded as crucial in the academic upbringing of a child. School performance depends upon the effect of school inputs, students' characteristics and the effect of a change in combination of these inputs. Prominent among the factors that have been identified to be responsible for poor learning outcomes in physics include the following: improper exposure to laboratory activities (Akpan, 1986; Ibeagha-Jonathan, 1986), poor science background at the Junior secondary school (Bello, 1985), lack of problem solving abilities (Onwiodwokit, 1989), failure to read and understand questions before rushing to answer (West African Examinations Council, 1994), students' poor attitude and self esteem (Daniel, 1993), gender stereotyping (Okpala & Onocha, 1986), nature of physics perceived as difficult (Akinwumi, 1986; Egbugara, 1993; Okpala & Onocha, 1988; Dickson, 1995), incoherent science curriculum (Pattanayah, 2003), dearth of qualified teachers, lack of teaching facilities, poor teaching-learning processes, lack of equipped laboratories, inadequate coverage of syllabus, and population explosion (Obanya, 1982; Adeyegbe, 1991; Imogie, 1993; Nwana, 1994; Salami, 1994; Orji, 1998; Bilesanmi-Awoderu, 2000; O'Conor, 2001, Lenga, 2001 & Wenning, 2004). It is thus explicable that some Nigerian educators (Ibeagha-Jonathan, 1986; Okpala and Onocha, 1988; Iroegbu, 1998) had directed their research studies towards improving the students' academic performance in physics at the senior secondary school level in the country. However, these studies, despite their scope and perhaps depth, only focus on availability of physics laboratory equipment, utilization of laboratory equipment, teacher's qualification, classroom interaction patterns of teacher trainees, and students' problem solving skills. None of the studies provided any information on skills needed for students' success in physics practical problem solving and other factors that influence their achievement in physics in relation to the present study. Furthermore, none of the previous studies have combined the nine factors in this present study to provide a causal explanation for students' achievement in physics. The available literature thus reveals that much is yet to be done by way of research, to explore all the school and students' factors that could maximize students' academic performance in physics at the senior secondary school level. It is against this background that the investigators designed the present study.

Problem

The study sought to construct and test a ten-variable model for determining the extent to which some student and school factors (practical skills, problem solving skills, gender, physics aptitude, students' attitude towards physics, school types, school principal's area of specialization, learning resources and teacher's qualifications) provide a causal explanation on students' academic achievement in physics amongst senior secondary three (SS 3) students in Oyo state of Nigeria.

Methodology

(a) Sample

The study is of the ex-post-facto type, utilizing a multi-stage stratified sampling technique consisting of two stages. A stratified random sampling was used to select 22 schools from two educational zones in Oyo state, Nigeria that has the Federal, State and Privately owned school type represented. Twenty-two (22) School Principals (21 Males and 1 Female) and twenty-two (22) physics teachers from the participating schools were selected. Purposive sampling technique was employed to select 15 physics students from each school, totaling up to 330 students (males and females).

(b) Instrumentation

Data collection involved the use of eight valid and reliable instruments. They are:

(i) Physics Attitude Scale Questionnaire, Cronbach alpha value = 0.63;
(ii) Physics Practical Skills Observational Instrument (PPSOI), Scott pi inter-rater reliability value = 0.53;
(iii) Physics Achievement Test (PAT), Test-retest value = 0.78;
(iv) Problem Solving Skills Questionnaire (PSSQ), Test-retest value = 0.79;
(v) Physics General Aptitude Test (PGAT), Kuder Richardson formular 21 value = 0.90;
(vi) Physics Teacher Questionnaire (PTQ);
(vii) Principal Area of Specialization Questionnaire (PAOSQ); and
(viii) Physics Learning Resources Questionnaire (PLRQ), Cronbach coefficient value = 0.74.

DATA COLLECTION AND ANALYSIS

The investigator and two research assistants were involved in the process of data collection, which lasted for seven weeks after due permission had been sought from the school principals.

The data were analysed using a confirmatory causal modeling technique, which involved multiple regression (backward solution), and path analysis. Thus, the investigators had to (i) build a hypothesized causal model involving school and students factors and students' achievement in physics at the senior secondary school level (Figure 1) on the basis of temporal order, research findings and theoretical grounds as suggested by Kerlinger & Pedhazur (1973); (ii) identify the paths of the model through eight structural equations (not shown); (iii) trim the paths of the model (based on statistical significance and meaningfulness); and (iv) validate the new model by reproducing the zero order correlation matrix of the variables from a set of normal equations (not shown) using the path coefficients in the new model.

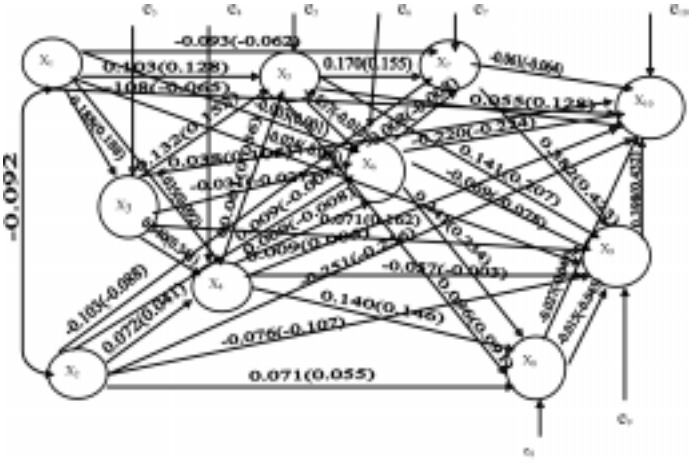

Figure 1. Hypothesized recursive path model (37 paths) of a - ten - variable system.

Key

X_1 = School type
X_2 = Gender
X_3 = Teacher's qualification
X_4 = Principal's area of specialization
X_5 = Learning resources
X_6 = Student attitude
X_7 = Practical skill
X_8 = Problem solving
X_9 = Physics General aptitude
X_{10} = Achievement in physics

RESULTS

The most meaningful causal model involving nine predictor variables and students' achievement in physics is shown in figure 2, based on significance and meaningfulness.

To verify the tenability of the new model (figure 2) the original correlation was reproduced using the new path model. This correlation is presented in table 1.

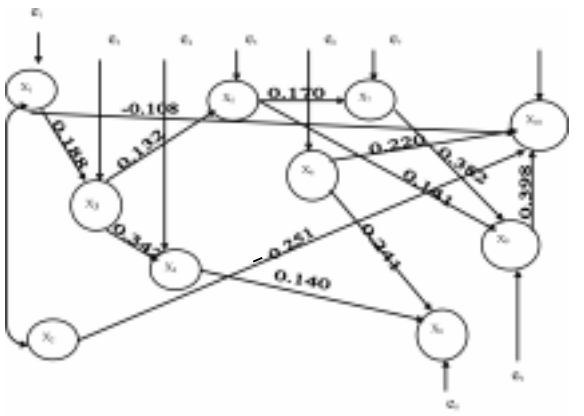

Figure 2. The new path model (12 paths) of a ten-variable system.

The discrepancies between the original and the reproduced correlation are considered very minimal (since the discrepancies are less than 0.05). Thus, the pattern of correlation in the data is considered tenable with the new model (figure 2). In consequence, figure 2 is considered to be the most meaningful causal model.

The direction of the causal paths of variables in the model is shown in the pathways, which are (i) significant, (ii) meaningful, and (iii) have a link with the criterion variable- achievement in physics. The paths are twenty-four (24). The beta weights of the paths (path coefficients) that give the estimate of the strengths of causation are shown in Figure 2 as the path coefficient from the new model. From these weights, the actual values of the indirect paths were obtained simply by multiplying the component single paths.

Out of a total of the 24 significant and meaningful pathways through which the predictors cause variation in the criterion, only 4 are direct paths, while 20 are indirect. The four direct paths are associated with school type (var. 1), student gender (var. 2), student attitude (var. 6), and physics general aptitude (var. 9). The total effects (direct plus indirect) of all the seven predictor variables are shown in table 2 below.

Table 1
Correlation matrix for the model

Variable	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
X1	1.000	-0.092	0.188	0.092	0.128	0.081	-0.062	-0.021	-0.086	-0.065
X2	-0.092	1.000	-0.002	0.041	0.033	-0.098	- 0.008	0.055	-0.187	-0.256
X3	0.188	-0.017	1.000	0.341	0.152	-0.027	0.202	-0.079	0.362	0.105
X4	0.064	0.066	0.348	1.000	0.056	-0.006	0.071	0.146	-0.083	0.005
X5	0.025	-0.002	0.152	0.0448	1.000	-0.060	0.155	0.081	0.207	0.128
X6	0.000	-0.000	0.008	0.000	0.000	1.000	-0.008	0.234	-0.078	-0.224
X7	0.064	- .0004	0.022	-4.0E16	0.130	0.000	1.000	-0.023	0.423	0.155
X8	0.009	0.008	0.048	0.140	0.0063	0.247	0.0011	1.000	-0.045	-0.049
X9	0.085	-0.0005	0.0195	0.0092	0.0092	0.000	0.486	0.081	1.000	0.432
X10	-0.063	-0.2438	0.0082	0.0016	0.135	0.220	0.161	-0.055	0.398	1.000

• **Note:** Entries above the diagonal are original correlation coefficients while entries below are reproduced correlation coefficients.

• **Key**

X_1	=	School type	X_2	=	Gender
X_3	=	Teacher's qualification	X_4	=	Principal's area of specialization
X_5	=	Learning resources	X_6	=	Student attitude
X_7	=	Practical skill	X_8	=	Problem solving
X_9	=	Physics General aptitude	X_{10}	=	Achievement in physics

DISCUSSION

From the available data of this study, it is evident that 27,2% of the variability of Nigerian Students' achievement in physics (var. 10) is accounted for by all the nine-predictor variables when taken together. The contribution of all the nine-predictor variables to achievement in physics when taken together consists of 21,33% (absolute value) and 48,50% direct and indirect components respectively. Also, since the magnitude of beta weights is assumed to be directly proportional to the degree of the effects of the influencing variable, it could be seen from Table 2 that four out of the nine variables, that is: Physics general aptitude (var. 9); Student gender (var. 2); Student attitude (var 6); and School Type (var.1), have direct causal influence on the students' achievement in physics.

More specifically, Physics general aptitude (var. 9) has the most causal influence on the Students' achievement in physics. As shown in Table 2, var. 9 has a path coefficient of 0.432, significant ($p<0.05$), and accounts for 50,87% of the total effect of the nine-predictor variables (46,86% and 4,00% indirect) on the criterion variable – achievement in physics. It thus seems that students' physics general aptitude score influenced their achievement in physics.

Student's gender (var. 2) is the next important variable that has direct causal influence on students' achievement. It has a path coefficient of (-0.251) and accounts for 30,14% (absolute value) of the total effect. This empirical finding is not unexpected considering the fact that other researchers in the region (Erinosho, 1992; Mbano, 1997; O'Counor, 2001; Lenga, 2001) have shown that gender had a significant effect on students' achievement in physics. It thus follows that teachers, guidance counsellors, parents and guardians should endeavour to encourage girls to study science. Presently, male students outnumber their female counterparts in physics enrolment, as the investigator had observed from the field of study. The government could motivate females by providing scholarship grants for those of them who desire to offer physics or related courses at the tertiary level.

The third most important cause of variation in Students' achievement in physics is Students attitude towards physics (var. 6). As shown in Table 4.6, var. 6 has a path coefficient of (-0.224) and accounted for 26,38% (absolute value) of the total effect. This finding supports those of Okpala (1985), Agbadiuno (1992), Umoinyang (1999), Onafowokan & Okpala (1999). The result supports the reported effects of attitude on achievement. For instance, Emina (1986) submitted that attitude towards a subject seems to be the very basis of cognitive development in the subject as well as other positive correlates of achievement in the subject.

The fourth most important cause of variation in achievement in physics is School type (var.1). It has a path coefficient of (-0.065) and accounts for 7,65% (absolute value) of the students' achievement in physics. According to the findings of this study, School type has causal direct effect on the students' achievement. This finding is in line with the findings of Erinosho

Table 2
Proportion of total effects of the predictors that are direct and indirect

CRITERION VARIABLE	PREDICTOR VARIABLES	TOTAL EFFECT (A)	% (C)	DIRECT EFFECT (B)	% (D)	INDIRECT EFFECT (A-B)	% (E)	(F)
V 10	1	-0.065	-7.65	-0.108	-12.72	- 0.043	5.0660	-28.13
	2	- 0.256	-30.14	-0.251	-29.56	-0.005	-0.5900	- 110.60
	3	0.105	12.36	-	-	0.105	12.360	45.44
	4	0.005	0.5900	-	-	0.005	0.5900	2.17
	5	0.128	15.07	-	-	0.128	15.0780	55.40
	6	- 0.224	- 26.38	-0.220	-25.91	- 0.004	- 0.4700	-96.99
	7	0.155	- 18.25	-	-	0.155	18.2580	67.10
	8	- 0.049	- 5.77	-	-	- 0.049	- 5.7700	- 21.21
	9	0.432	50.87	0.398	46.86	0.034	4.0000	187.02
TOTAL		0.231	27.2	-0.181	-21.33	0.412	48.508	100.00

• **NOTE:** **(C)** = (A/T_A) X 27,2% **(D)** = (B/T_A) X 27,2% **(E)** = $(A\text{-}B/T_A)$ X 27,2% **(F)** = (C/T_C) X 100
Total effect = Original correlation coefficient.
Direct effect = Path coefficient.
Indirect effect = Total effect – Direct effect.

Note: Absolute values of the total effect and direct effects are used for computation.

(1992), ARIYO (1995), and NJOKU (1999) whose results documented students' differences in performance based on school type. This suggests in general that nature of school type has influence on students' achievement in physics. Students from schools that are privately owned enjoy the monitoring services of their founders or board of trustees, unlike the schools that are owned by the State Government or by the Federal Government, where monitoring services are weak. The result is an eye opener to the needs of monitoring services in all Nigerian schools, especially at the senior secondary level, which is a pivot to tertiary education. This also calls for accountability in the education sector whereby justice demands that teachers should deliver the goods they are paid for.

However, variables: Teacher's Qualification (var.3), School Principal's area of specialization (var.4), Learning Resources (var.5), Practical skills (var.7), and Problem Solving Skills (var.8) show only indirect effect on the criterion variable (var.10). In other words, in the presence of the potent factors, the direct effect of variables 3,4,5,7and 8 would be low and not statistically significant and meaningful.

Findings of this study thus reveal that physics general aptitude has the highest causal influence on senior secondary school students' physics achievement. This is in line with previous research findings, whereby a positive link had already been established (GRONLUND, 1981; AIKEN, 1988; THORNDIKE and HAGEN, 1969; GAGNE & BRIGGS, 1979). The major finding of this study is that four out of the nine predictor variables (Physics general aptitude, Student gender, Student attitude and School type) had both direct and indirect effects on students' achievement in physics, while the remaining five (Teacher's Qualification (var.3), School principal's area of specialization (var.4), Learning resources (var.5), Practical skills (var.7), and Problem solving skills (var.8)) only had indirect effect. The result documents the relative order of importance of the variables as follows:

$$X_9 > X_2 > X_6 > X_1 > X_7 > X_5 > X_3 > X_8 > X_4.$$

The main contributions of this study reveal that physics general aptitude, Student gender, Student attitude and School type variables are good predictors of students' achievement in physics. The implication is that parents should encourage their children to develop physics general aptitude by not discouraging them from playing with scientific gadgets such as radios, fans, personal computers and handsets, among others. Physics Teachers should be gender sensitive in their teaching methodology and learning style. The result should also be communicated to the policy makers and stakeholders to accommodate individual learning differences that are gender associated as a key policy issue. Positive students' attitude towards physics can also be encouraged by school principals at the senior secondary school level by motivating and rewarding students' achievement in physics periodically. The Evaluation unit of Federal Ministry of Education in the region could yearly compare and publish physics students' senior certificate achievement in physics on school type basis for the purpose of ranking and competition. This may help to close the gaps that are presently existing within the different school types in the region.

CONCLUSIONS

The main findings of this study are summarized as follows:

- All the nine predictor variables; school type, gender, physics general aptitude, physics practical skill, physics problem skills, student attitude towards physics, teacher's qualification, school principal's area of specialization and physics learning resources are effective in predicting achievement in physics.
- A new model (the most meaningful causal model) involving the listed schools, students and students' achievement in physics variables with twelve (12) significant pathways (4 direct and 8 indirect) was produced. The pattern of correlation in the observed data was found to be consistent with the new model.
- Out of the nine predictor variables, hypothesized to exert causal influence on achievement in physics, four variables: school type, student gender, student attitude to physics and physics general aptitude significantly exert such causal influence directly and indirectly while five (teacher's qualification, principal area of specialization, learning resources, practical skills and problem solving skill) only indirectly exert causal influence on physics achievement.
- Out of the total effects of 27,2% exerted by the nine – predictor variables on achievement in physics, 21,33% (absolute value) are direct while 48,50% are indirect.
- The relative order of importance of the nine predictor variables with respect to their influence on the criterion variable (from the most to the least importance) are; physics general aptitude > gender > attitude> school type > physics practical skill > physics learning resources > teacher's qualification > problem solving skill > school principal's area of specialization.

Conclusively, these results should be communicated to teachers during seminars and workshops so that they encourage and help their students to develop positive attitudes towards physics by their teaching methodology and relationship. The results of this study might be an eye opener to readers for the sake of comparison in different regions and as a pivot for methodological approaches to similar problems.

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