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## MATHEMATICS AND CHEMISTRY SENIOR SCHOOL CERTIFICATE RESULTS, GENDER AND ATTITUDE AS PREDICTORS OF ACHIEVEMENT IN A PHYSICAL CHEMISTRY COURSE

By

Toyin Eunice Owoyemi

### Abstract

The research work examines the extent to which mathematics and chemistry senior secondary school certificate (SSCE) results, gender and attitude of students can predict student achievement in physical chemistry course. An ex post-facto research design was adopted since there was no manipulation of the independent variables. Results of fifty-seven National Certificate in Education (NCE) chemistry students in Ekiti State College of Education were collated for analysis. A regression model was used to determine whether there is a linear relationship between physical chemistry result and the independent variables and to ascertain which of the variables can be used to predict achievement in physical chemistry course. This study shows that mathematics and chemistry SSCE results are the most important predictors of achievement in the course while attitude and gender do not influence the performance. The relative predictive power of SSCE Mathematics to the students' achievement in Physical Chemistry doubles that of SSCE Chemistry. The relative explanatory importance of SSCE Mathematics obtained is 0.755 when controlling Chemistry knowledge whereas that of Chemistry is 0.350 when Mathematics is controlled. Specific recommendations are given curriculum planners and policy makers to make achievement in mathematics and chemistry prerequisites to offering chemistry in higher institutions so as to improve student learning.

### Introduction

Chemistry is the study of composition, structure property of matter including the changes that matter undergoes and the related energy changes that accompany material changes. This subject can be categorized into: Organics Chemistry (which involves the study of living sources) and Physical chemistry (which is the main part that involves calculation involving energy changes, mole concepts, electrolysis and equilibrium).

The birth of this third category of chemistry called "physical chemistry" is sometimes related to the names Ostwald, Arrhenius and Van't Hoff and dated back to the year 1887, when Ostwald founded the Zeitschrift Fur Physikalische Chemie (Barkan, 1990). But as many historians have pointed out, the phrase "Physical chemistry" was widely used before that time. But there is no doubt that in the late nineteenth century there was a rapid growth of research in the field now understood as Physical chemistry.

A review of the chemical education literature indicates that many teachers of physical chemistry believe that their students find this sub-discipline of chemistry to be 'hard' (Sozibilir, 1992; Karen and William, 2004), and this has prompted some researchers to investigate the reasons why students find physical chemistry difficult (Nicoll and Francisco, 2001; Hahn and Polik, 2004). A number of factors appear to contribute to this perception. Perhaps surprisingly, these are not simply limited to students' abilities in

mathematics, despite physical chemistry having such a high mathematical component. Factors such as motivation, logical thinking and prior knowledge are also important.

Certainly, physical chemistry is in a sense related to mathematics as well as to chemistry establishing some reaction between the fields.

A lot of the familiar names of the scientist who came up with innovations during the industrial revolution of the 17<sup>th</sup> century were mathematicians. Examples of such people are Kepler, Pascal, Newton, Galileo etc. Infact, most of their studies revolved around mathematics and science. It is not surprising therefore that mathematics features prominently in the school curricula and it is made compulsory for all students up to secondary level. The bedrock of the physical sciences such as chemistry is mathematics.

Determining the factors that influence performance in physical chemistry can attract efforts to improve teaching methods and increase student understanding by the teachers. Many studies have examined factors that influence performance in general chemistry courses. For instance, research into factors contributing to success in general chemistry courses, has shown that improved student performance is correlated in varying degrees with higher reasoning ability, better mathematical skills and logical thinking ability (Bunce and Hutchinson, 1993), previous chemistry background, better attitudes about the course, as well as higher placement exam scores. The introduction to the article by Hahn and Polik (2004) also cites the past work on general chemistry and extends that research to physical chemistry.

In physical chemistry, logical thinking ability (Nicoll and Francisco, 2001) as well as previously successful courses in mathematics, physics and chemistry, were shown to be predictors of success: these conclusions are also supported by Derrick and Derrick (2002). Zielinski

(2003) also asserted that using symbolic mathematics software appropriately, we can effectively implement the physical chemistry curriculum, bringing about even more comprehensive chemistry teaching and learning.

Research by House (House, 1995) has also shown students' initial attitudes to be significant predictors of performance in introductory college chemistry, among those students with the requisite mathematics skills. Effects on learning because of various types of 'chemistry anxiety' have also been reported by Eddy (2000).

All these research efforts were done in the developed countries therefore, the purpose of the current study is to extend this idea to developing countries especially Nigeria.

The study is therefore concerned with explaining and predicting student's achievement in physical chemistry course in terms of their mathematics and chemistry SSCE results, gender and attitude.

#### **Statement of the Problem**

The study sought to determine the extent to which SSCE mathematics and chemistry results, gender and attitude could predict achievement of students in physical chemistry course.

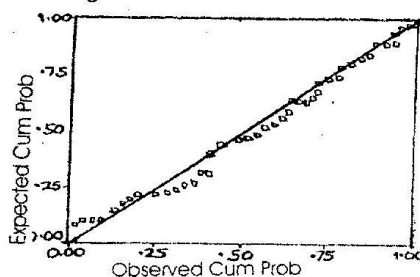
#### **Research Questions**

Based in the stated problem, the study provided answers to three questions.

1. To what extent would the independent variables (mathematics and chemistry SSCE results, gender and attitude), when taken together, predict achievement in physical chemistry?
2. What are the relative contributions of the independent variables to the predictions?
3. Which of the independent variables will predict achievement of students in physical chemistry course?

conforms to normality. That is the error is normally distributed.

Fig 1 Normal Probability Plot



Also the simple plot of residuals on Y-axis against predicted values on the X-axis reveals a cloudy of dots. Thus the error variance is constant (homoscedastic). The correlations between the independent variables are very small (Table 1). The highest correlation is between School Certificate Chemistry results and gender ( $r = 0.05$ ) and the least is  $r = -0.179$  which is between attitude towards physical chemistry and gender. Moreover the coefficient of determination  $R^2 = 0.663$ , thus, there is no perfect collinearity between the independent variables. From Table 2, the tolerance coefficients are generally high ( $\geq 0.954$ ) for all the variables, which further reinforced the assumption of non-multicollinearity.

Table 1: Pearson Correlations

	PHCHEM	GEMDER	SCMATHS	ATTITUDE	CCHEM
PHCHEM	1.000	.214	.718	.020	.272
GENDER	-.214	1.000	-.104	-.179	.051
SCMATHS	.718	-.104	1.000	-.046	-.103
ATTITUDE	.020	-.179	-.046	1.000	-.050
SCCHEM	.272	.051	-.103	-.050	1.000

The variance-inflation factor (VIF),  $(1.015) < VIF < 1.048$ , are sufficiently low, hence the regression coefficients (B) and beta ( $\beta$ ) coefficients are very stable. Furthermore, the collinearity diagnosis shows that the condition indices 9CI)

flag no excessive collinearity in the model. The five factors produce  $(1.00 \leq CI \leq 27.718)$ , the Durbin-Watson Coefficients  $d = 1.819$  indicates no serial autocorrelation. All the data series are independent of each other.

Table 2: coefficients

Model	Correlations			Collinearity Statistics	
	Zero-order	Partial	Part	Tolerance	VIF
Constant					
Gender	.214	-.239	-.143	.954	1.048
SCMATHES	.718	.784	.733	.975	1.026
ATTITUDE	.020	.078	.045	.961	1.040
SCCHEM	.272	.523	.56	.985	1.015

Dependent variable: PHCHEM

### Research Question I

To what extent will the independent variables (Mathematics and Chemistry SSCE results, gender, attitude) when taken together predict achievement in physical Chemistry course?



**Table 3a:** Composite Effect of the Independent Variables SSCE Mathematics and Chemistry Results, Gender and Attitude on Physical Chemistry

R	R <sup>2</sup>	Adjusted R	Standard Error of the Estimates
0.814	0.663	0.637	0.870

**Table3b: ANOVA**

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	77.497	4	19.374	25.606	.000
Residual	39.345	52	.757		
Total	116.842	56			

a Predictors: (Constant), SCCHEM, ATTITUDE, SCMATHS, GENDER

b Department Variable: PHCEM

**Table 4: Regression Coefficients of Independent Variables**

Model	Unstandardized Coefficients		Standard Coefficients	T	Sig.	95% Confidence Interval for B	
	$\beta$	Std. Error	$\beta$			Lower Bound	Upper Bound
(Constant)	-.749	1.225		-.612	.534	-3.206	1.708
GENDER	-.500	.281	-.146	-1.778	.081	-1.064	.064
SCMATHS	-.566	.062	.742	9.108	.000	.442	.691
ATTITUDE	.154	.275	.046	.562	.577	-.397	.705
SCCHEM	.387	.088	.399	4.427	.000	.212	.563

From table 4, the regression equation is

$$\text{PHCEM} = -0.7149 + 0.566\text{SCMATHS} + 0.387\text{SCCHEM} - 0.500\text{GENDER} + 0.154\text{ATTITUDE}$$

The coefficient of multiple determination (Table 3a)  $R^2 = 0.663$  indicates that 66.3% of the variance in the achievements in physical chemistry (PHCEM) are jointly explained by the variations in mathematics and chemistry, the gender of the students and attitude towards physical chemistry. On the other hand it means that the proportionate condition in error in estimating achievement in physical chemistry is 0.663 (R<sup>2</sup>) when all the independent variables are known.

When all the independent variables assume the value of zero the intercept value is -0.749. the meaning of this is not very clear. However, it is not expected that the achievement in physical chemistry can be extrapolated to the negative axis of Y (i.e. the 4<sup>th</sup> quadrant of the graph). Moreover some of the independent variables, gender

and attitude, cannot take the value zero.

The ANOVA is given in table 3b. The results show that the F-test ( $F=25.606$ ) is significant, that is at 5% level the  $R^2$  is significant; the regression coefficients (B) are significantly different from zero which implies that there is a linear relationship of physical chemistry to the independent variables.

Furthermore, the standard error mean prediction (confidence interval) for the achievement in physical chemistry is  $\pm 1.96(0.838)$  i.e. (-1.6425, + 1.6425) where 0.838 is the standard deviation (SD) of the residual. The mean of the dependent variable is 3.05, which is greater than 1.6425 while SD (0.838) is markedly less than the standard deviation (1.444) of the dependent variable (PHCEM). These further reinforce the goodness of the model.

### Research Question 2

*What are the relative contributions of the independent variables to the prediction?*

The unstandardized coefficients in Table 4 show that mathematics result produces the highest amount of increase in the dependent variable per unit increase ( $B=0.566$ ). This is followed by SSCE chemistry result ( $B=0.387$ ). While the coefficient of variation for attitude is closer to zero (0.154) than others, gender has  $B= -0.500$ . From Table 1, the Pearson correlations ( $r^2$ ) shows that 51.55% variance in the dependent variable is explained by School Certificate mathematics, 7.4% by chemistry, 0.04% by attitude towards physical chemistry and 4.58% by gender.

Since the units and grading techniques are not the same, our discussion shall make use of the standardized

coefficients  $\beta$  (Beta). The school certificate results are based on 9-point weighted scores while physical chemistry results is based on 5-point weighted scores and attitude towards physical chemistry is scored using 4-point Likert Scale.

From the t-test results in Table 4 it could be seen that only SSCE mathematics and Chemistry are statistically significant. Thus the unique variance accounted for by Gender ( $t=-1.778$ ) and attitude ( $t = 0.562$ ) are not statistically significant.

The confidence intervals in Table 4 include the value zero for gender ( $-1.064 \leq \mu \leq 0.064$ ) and attitude ( $-0.397 \leq \mu \leq 0.705$ ). This confirms further that gender and attitude toward physical chemistry cannot be used to predict achievement in physical chemistry course.

**Table 5: Level - Importance (LI)**

Independent Variable	Mean	B coefficients	Level-Importance (LI)
GENDER	1.7700	-5.500	-0.885
SCMATHS	4.3333	0.566	2.4526
ATTITUDE	3.1474	0.154	0.4847
SCCHEM	4.5088	0.387	1.7449

Level-importance (LI) is the actual influence of the independent variable on the dependent variable. The LI for SSCE mathematics and chemistry are relatively higher than others. Gender and attitude have low influence on the Physical Chemistry result. That of SSCE

mathematics is 40.56% higher than SSCE Chemistry. Both the potential influence (-0.500) and actual influence (-0.885) of gender are negative while the potential influence of attitude towards Physical Chemistry (0.154) and actual of 0.484) are closer to zero than one.

### Research Question 3

*Which of the independent variables will predict scores of students in Physical Chemistry course?*

**Table 6a: The Coefficient of Multiple Correlations of SSCE mathematics and Chemistry**

R	R <sup>2</sup>	Adjusted R	Standard Error of the Estimates
0.789	0.638	0.624	0.890

**Table 6b: Change Statistics**

R <sup>2</sup> Change	F-Change	df1	df2	Sig. F Change	Durbin Watson
0.638	47.486	3	54	.000	1.820

a Predictors: (Constant), SCCHEM, ATTITUDE, SCMATHS, GENDER

b Department Variable: PHCEM

Table 7: Analysis of Variance

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	74.489	2	37.244	47.486	.000
Residual	42.353	54	0.784		
Total	116.842	56			

a Predictors: (Constant), SCCHEM, ATTITUDE, SCMATHS, GENDER  
 b Dependent Variable: PHCEM

From table 6a the coefficient of multiple determinant is  $R^2 = 0.638$ . Thus 63.8% of the variance in achievement in Physical Chemistry course is jointly explained by SSCE mathematics and chemistry. Table 3a indicates that all the independent variables, SSCE mathematics, chemistry results, gender and attitude towards physical chemistry jointly contribute 66.3% of the variance in the achievement in Physical Chemistry course. This shows that the

contributions of gender and attitude are very minimal. The  $R^2$  change 0.638 does not reveal a significant change from the  $R^2$  change (0.663) when all the independent variables are regressed on Physical Chemistry result.

The ANOVA shows that the F-ratio is significantly different from zero at 5% level of significance. In the ANOVA prob ( $F$ ) < 0.05,  $R^2$  is significant.

Table 8: Regression Coefficients of Mathematics and Chemistry

Model	Unstandardized Coefficients		Standard Coefficients	T	Sig.	95% Confidence Interval for B	
	B	Std. Error	$\beta$			Lower Bound	Upper Bound
(Constant)	-1.148	.521		-2.204	.032	-2.192	-.104
SCCHEM	.378	.089	.350	4.253	.000	.200	.557
SCMATHS	.576	.063	.755	9.161	.000	.450	.702

The model obtain from Table 8 is as follows

$$\text{PHCEM} = -1.148 + 0.378\text{SCCHEM} + 0.576\text{SCMATHS}$$

The regression coefficients show that SSCE mathematics has a higher contribution per unit increase (0.576). The t-tests confirm that all the regression coefficients are statistically significantly different from zero at 0.05 level. The beta ( $\beta$ ) weight of SSCMATHS (0.755) shows that Mathematics is the most important predictor of achievement in Physical Chemistry course. While achievement in Physical Chemistry will increase by 0.350 if SCCHEM is increased by one standard deviation, the same one standard deviation increase in SCMATH will produce a corresponding 0.755 increase in Physical Chemistry results. This means that relative predictive power of

School Certificate mathematics to the students' achievement in Physical Chemistry doubles that of School Certificate Chemistry. In order words, the relative explanatory importance of school certificate Mathematics is 0.755 when controlling Chemistry knowledge whereas that of Chemistry is 0.350 when Mathematics is controlled.

The intercept value is -1.148 with 95% confidence interval of (-2.192, -.104). This is expected to be the achievement of the student in Physical Chemistry when the performance in both mathematics and Chemistry are zero. The upper bound is -0.104 that means there is no way a student can perform

well at all without good performance in Mathematics and Chemistry ordinary levels. This is in agreement with the findings of Nicoll & Francisco (2001) and Derrick & Derrick (2002).

#### Conclusion and Recommendation

There is a linear relationship between Physical Chemistry, School Certificate Chemistry and Mathematics results, gender and attitude towards Physical Chemistry. However, the actual influence of gender and attitude towards Physical Chemistry is very low and negligible. In effect, attitude and gender as independent variables could not be used to predict the results of students in the course. That is student's achievement in physical chemistry course has nothing to do with attitude or whether the student is male or female. The result of the study showed that SSCE mathematics and chemistry results could be used to predict the performance of student in physical chemistry course. Moreover, school certificate Mathematics has greater influence than school certificate Chemistry in predicting the performance of students in Physical Chemistry course. Hence, it is very appropriate to lay emphasis on school certificate because of the importance of SSCE mathematics and chemistry results in the prediction of achievement of students in physical chemistry course. It is therefore recommended that curriculum planners and policy maker should make achievement in mathematics and chemistry prerequisites to offering chemistry in higher institution.

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