RELATIONSHIP OF SOME VARIABLES IN PREDICTING PRE SERVICE TEACHERS' PROBLEM SOLVING PERFORMANCE IN CHEMISTRY

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ABSTRACT

The study examines the extent to which the relationship between pre-service Nigerian Certificate in Education (NCE) teachers' academic level, college specialization and gender could predict their problem solving performance in chemistry. The sample for the study involved two hundred and four, 200 and 300 level, chemistry major and non major pre service teachers drawn from eight colleges of education of Plateau and Six states of Northeast Nigeria. Three instruments were developed and used for data collection. Namely, chemistry problem-solving test (CPST); chemistry achievement test (CAT) and mathematics skill test (MST). Data were analysed using one-way ANOVA, t-test and multiple regression. The results showed that, based on academic level and college specialization, there was a significant difference between the mean problem-solving performances of the pre-service teachers at 0.05 α-level. However, there was no significant difference between the mean performance of male and female pre-service teachers. Academic level, college specialization, and gender taken together significantly predict pre-service teacher's problem solving performance. Among these three independent variables, academic level contributed most in the prediction. *[AJCE, 2(2), February 2012]*

INTRODUCTION

One of the important goals of chemistry education is the acquisition of problem-solving skills. Possession of superb problem-solving skills generates a sound base for good performance in different aspects of chemistry (1). Problem solving has been acknowledged as a paradigm of complex cognition that is part of our everyday experience (2). Danjuma (3) defines problem solving as a process whereby an individual or a group uses previously acquired knowledge and skill to meet (solve) the demand of a particular situation (problem).

Most researchers working on problem solving (4—8) agree that a problem occurs only when someone is confronted with a challenge for which an immediate answer is not available. Klein (6, p. 328) defines a problem as a situation in which a person is motivated to reaching a goal but attainment of the goal is blocked by some obstacle or obstacles. From this definition and those of other researchers, there appeared to be some commonality in ideas about the concept of a "Problem". First of all, for a question, a goal or an objective to be a problem it must be a challenge to the solver. Secondly, the solver must be willing to accept the challenge. Thirdly, the solver must have no readily accessible methods for obtaining the solution to the question, goal or objective. These three conditions have to be satisfied for a situation to be regarded as a problem. Many studies on problem solving in chemistry deal with a wide range of issues. Some (9—16) focused on the nature of problems and problem-solving processes whereas others (17—20) on instructional methods and strategies. Still other researchers have shown how certain variables relate to students' problem-solving performance. Examples of such variables include learner's cognitive style (21--22) and gender (22; 14). However, the results of some of these studies seem to suggest that students' success in problem solving depends on teachers' knowledge and disposition to problem solving. Bajah and Bello (18) report that teachers neglect the implementation of problem-solving instructional strategies during chemistry teaching. In an earlier work on recurrent difficulties in problem-solving, (10) had explained that many of the students' difficulties in chemistry problem-solving could be traced to the problem-solving behavior of the teacher. They add that teachers pay too little explicit attention to several phases of problem-solving processes that are essential to students.

It is against this background that the present study focused on investigating the chemical problem-solving behaviors of pre-service teachers. Relatively few papers have appeared in the chemistry education literature on problem-solving behaviors of pre-service chemistry teachers especially in Nigeria. Some of these few studies include the works of (23--24) on pre-service teachers' misconceptions in chemical equilibrium and chemical kinetics respectively. Another involves pre-service teachers' performance in stoichiometry (25). A more recent one is the results of part of a research (26) on problem-solving behaviors of pre-service teachers (that were considered in this study). He (26) found that, irrespective of their academic level and college specialization, the pre-service teachers used appropriate methods to solve chemistry problems. Method use was more pronounced among the chemistry majors. However, only few of them were successful in getting the correct answer.

PURPOSE OF THE STUDY

The main purpose of the study was to determine the relationship between three independent variables: pre service teachers' academic level, college specialization and gender in predicting their problem-solving performance in chemistry. The specific objectives are to:

a. examine pre service teachers' problem-solving performance
b. determine the extent to which pre-service teachers' academic level, discipline, and gender when taken together could predict their problem-solving performance
c. examine the relative contribution of each of the three independent variables of academic level, discipline and gender to the prediction of their problem-solving performance

METHODOLOGY

Design of the Study

The research was a descriptive study that employed ANOVA, Post Hoc comparison using Tukey's Honestly Significant Difference test (HSD) and t-test to examine the problem-solving performance of the pre-service teachers. A correlation methodology, specifically, multiple regression was used to determine the extent to which the three independent variables combined together could predict their problem-solving performance and also to find out the contribution of each variable to the prediction. All the statistical tests were done at 0.05α-level.

Participants

The population for the study comprised eight hundred and seventy nine, 200 and 300 levels pre-service Nigeria Certificate in Education teachers majoring in chemistry and those that have taken chemistry as a minor/non-major teaching subject from eight colleges of education located in Plateau and six states of the Northeast geopolitical zone of Nigeria. The sample for the study comprised two hundred and four pre-service teachers drawn from the population. Specifically, fifty seven 200 level chemistry majors, sixty six 300 level chemistry majors, forty 200 level non-majors and forty one 300 level non-majors.

The reasons for choosing these groups of pre service teachers as explained in (26) was that, at their present academic levels, they must have been offered enough chemistry courses that have equipped them with some basic knowledge and skill needed for solving the selected quantitative problems. Secondly, experience shows that after completing their studies, these categories of pre-service teachers are being employed (in place to supplement graduate teachers) to teach chemistry at the secondary schools in Nigeria because the number of chemistry teachers is grossly inadequate especially in the Northern part of the country. Thirdly, prior to the administration of the CPST, their performance on a chemistry achievement test (CAT) and a mathematics skill test (MST) has indicated that they have possessed an appreciable knowledge of chemistry and mathematical skills required for solving the CPST items.

Stratified random sampling technique was employed to select the sample. Four strata were formed based on their academic level and college specialization. A random sample of 10 pre-service teachers from each stratum from each of the eight colleges of education was drawn [except for one college where the population of 300 level chemistry majors was less than 10; in this case, the whole population (N = 7) was sampled].

Data Collection Instruments

For the purpose of this study, three instruments, namely, chemistry problem-solving test, chemistry achievement test, and mathematics skill test, were developed by the researcher. The chemistry problem-solving test (CPST) was a four-item free response test developed by the researcher (see Appendix A). Each item in the test represents one of the four topics in chemistry (i.e. composition of chemical substances, stoichiometry, gas laws, and electrolysis) found in the foundation chemistry courses of most of the colleges of education and at first-year undergraduate level of Nigerian Universities. The total score in the test was considered as a measure of the sample's problem-solving performance. The CPST was designed based on the measurement criteria for Problem-Solving Tests reported in the literature (27). In addition, a CPST scoring guide and a CPST model answer were developed and used for scoring the responses of pre-service teachers. As a problem-solving free-response test, the CPST has no time limit because they were required to record all the details of their thinking as they solved the problems.

The chemistry achievement test (CAT) was a 40-item multiple choice test with four alternative responses. The items were those selected out of the pool of the 60 that have been trial-tested. The content of the test covered the areas in chemistry judged by experts in chemistry education at the Abubakar Tafawa Balewa University, Bauchi, Nigeria as having provided the background knowledge for solving the problems contained in the CPST. The total score from the test was considered as a measure of the respondents' background knowledge in chemistry. The duration for the CAT was 60 minute.

The mathematics skill test (MST) was a 20-item multiple choice test with four alternative responses. The items were those selected out of the pool of 40 items that have been trial-tested and considered to be adequate for measuring mathematics skills. The items were drawn from mathematics topics that have applications in chemistry as judged by experts in chemistry and mathematics education. The total score in the test was considered as a measure of its respondents' mathematical skill necessary for solving numerical problems in chemistry. The duration for the test was 45 minutes.

Each of the three tests was pilot tested to obtain data for determining it's reliability. The CPST was subjected to an appropriate method of determining reliability of an essay test. That is, the inter-scorer method. The method involves correlating two sets of scores of the candidates obtained from independent scorers (28). Two experts, in chemistry education participated in this exercise. Each was given copies of participants test scripts obtained from two pilot trials. They scored the scripts using the CPST scoring guide and CPST model answers. The resulting two sets of scores obtained were correlated using Pearson's product- moment correlation formula and a correlation (reliability) coefficient of 0.62 was obtained. While the split-half method was used to establish the reliability values for the CAT and MST which were 0.71 and 0.77 respectively.

RESULTS AND DISCUSSION

Pre service Teachers' Problem-Solving Performance

Table1 presents the analysis of variance (ANOVA), testing whether there was significant difference among the problem-solving performance among 200 level majors and non-majors and 300 level majors and non-majors. From the table, the F-value of 3.62 was obtained which was found to be significant at 0.05 α-level. This implies that differences existed among the means problem-solving performance of the pre-service teachers, that is, they performed differently in the chemistry problem-solving test. The effect size f of the F-value from the ANOVA results was also determined using the formula developed by (29). Effect size gives an indication of the strength of the influence of the independent variables on the dependent variable which, in this case, were academic level and college specialization.

Developments on the use and reporting of statistical techniques (30--32) have emphasized that when a mean difference was found to be significant in a statistical analysis, an accompanying effect size statistic and/or a statistic demonstrating the amount of variance accounted for by the observed difference should be included to support the main statistical results. An effect size of 0.23 was determined for the F-value from the ANOVA test presented in Table 1. This value was considered to be small based on Cohen's scale, implying that, although the independent variables had significant influence on the dependent variable (problem-solving performance). However, the value of the effect size was too low to inform a decision on pedagogical practice.

TABLE 1: The ANOVA Results of the Problem-Solving Performance of the Pre-service Teachers

Source of Variation	SS	Df	MS	F	P
Between Groups	1471	3	490		
Within Groups	27110	200	136	3.62	0.014
Total	28581	203			

From Table 1 at the 0.05 α - level, the $F_{calculated} = 3.62 > F_{critical} = 2.65$.

The effect size for the F-ratio, f was determined using the formula developed by (14),

$$f = \sqrt{\frac{\eta^2}{1-\eta^2}} \qquad \text{where} \qquad \eta^2 = \frac{\text{SS between}}{\text{SS total}}$$

SS between and SS total are obtained from the ANOVA Table

$$\eta^2 = \frac{1471}{28581} = 0.051$$

Therefore $1-\eta^2 = 1 - 0.051 = 0.949$

So,

$$f = \sqrt{\frac{0.051}{0.949}}$$

$$f = \underline{0.23}$$

TABLE 2: The Means of the Pre-service Teachers in the CPST

Statistic	NCE II Chemistry Majors ($\overline{X}_1$)	NCE III Chemistry Majors ($\overline{X}_2$)	NCE II Non-Majors ($\overline{X}_3$)	NCE III Non-Majors ($\overline{X}_1$)
Mean ($\overline{X}$)	31.46	33.41	25.98	32.34

TABLE 3: Pair wise Comparisons Between All Means Using the Tukey's HSD Test

Comparisons	Difference	HDS Value	Decision
$\overline{X}_1 - \overline{X}_2$	1.95	6.06	Not Significant
$\overline{X}_1 - \overline{X}_3$	5.48	6.06	Not Significant
$\overline{X}_1 - \overline{X}_4$	0.88	6.06	Not Significant
$\overline{X}_2 - \overline{X}_3$	7.43	6.06	Significant
$\overline{X}_2 - \overline{X}_4$	1.07	6.06	Not Significant
$\overline{X}_3 - \overline{X}_4$	6.36	6.06	Significant

HSD 0.05/3 = 6.06

As mentioned earlier, a pair wise Post Hoc comparison of the mean problem-solving performance was also made using Tukey's Honestly Significant Difference Test (HSD) and presented in Table 3. The purpose of this comparison was to ascertain where the significant difference that existed among the means from the ANOVA. The results obtained revealed that, there existed significant differences between the means of 300 level majors and 200 level non-majors, and that between 300 level non-majors and 200 level non-majors respectively. The result still indicated that, among the independent variables considered, academic level of the pre-service teachers seems to have greater influence on their problem-solving performance. The influence of college specialization was not much. The result presented in Table 4 indicates that, there was no significant difference between the mean problem-solving performance of male and female pre-service teachers. This result was contrary to the finding of (22) who reported a differential performance in chemistry problem-solving tasks, with the girls significantly performing better than the boys. Ajagun attributed the differential performance to the fact that a larger number of the female subjects in her study were drawn from single-sex schools.

TABLE 4: Summary of Analysis for the t-test for Gender Difference in Problem-Solving Performance

Variable	N	Mean	SD	SE	Df	t_{cal}	P
Male	153	31.80	12.10	0.98	203	1.52	0.13
Female	51	29.10	10.60	1.50			

$t_{critical} = 1.96$

Using the Independent Variables to Predict Problem-Solving Performance

The results presented in Table 5 showed the extent to which the independent variables when combined together could predict pre-service teachers' problem-solving performance in chemistry. The table showed the coefficient of multiple-regression (R) of 0.22 and R^2 of 0.048 were obtained, all low indicating a weak relationship. However, the ANOVA for the multiple-regression produced an F value of 3.33 that was significant at 0.05 α - level indicating that the effectiveness of the joint contributions of the three independent variables mentioned in predicting pre-service teachers' problem-solving performance could not have occurred by chance. The magnitude of the relationship under consideration is reflected in the values of the coefficient of multiple-regression (R) where a value of 0.22, and a multiple regression square (R^2) with 0.048 (4.8%) and multiple regression square adjusted of 0.033 (3.3%) obtained. These results are indications that pre-service teachers' academic level, specialization and gender taken together accounted for only 4.8% of the total variance in their problem-solving performance. That is, we have got 4.8% of the variance to make prediction about their problem-solving performance and 3.3% of the variance to make correct prediction.

To ascertain the contribution of each of the independent variables in making the prediction, the regression weights (β) of the independent variables were computed and tested by converting them to t-values. These results were presented in Table 6.

TABLE 5: The Results of Multiple Regression for Pre-service Teachers' Academic Level, Discipline, and Gender against their Problem-Solving Performance.

Multiple R = 0.22
Multiple R^2 = 0.048 = 4.8%
R^2 (adjusted) = 0.033 = 3.3%
SE = 11.60

Analysis of Variance for the Multiple Regression

Source	SS	Df	MS	F_{cal}	F_{crit}	P
Regression	1343.9	3	448.0	3.33	2.65	0.05
Residual	26916.5	200	134.6			
Total	28260.4	203				

TABLE 6: The Regression Weights of the Three Independent Variables and their corresponding t-values in Predicting Pre-service Teachers' Problem-Solving Performance.

Predictor	Coefficient of regression weights (β)	SD	t-ratio	P	Decision
Constant	28.895	2.071	13.95	0.00	-
Academic Level	3.468	1.627	2.13	0.034	Significant
Specialization	2.987	1.661	1.80	0.074	Not Significant
Gender	2.676	1.876	1.43	0.155	Not Significant

$t_{critical}$ = 1.96 at 0.05 α-level

The results from Table 6 showed the contribution made by each of the three independent variables to the prediction of the problem-solving performance. The extent of contribution includes 3.468, 2.987, and 2.767 for academic level, discipline and gender respectively. These are the regression weights (β) for these independent variables. Also from the table, the t-values associated with the regression weights indicated that only academic level contributed significantly to the predictive value of the pre-service teachers' problem-solving performance. It implies that it was the only independent variable that contributed most to the prediction. The result seems to support those of Table 3 whereby, only pair wise comparison of means involving the academic levels were found to be significant in post Hoc comparisons. Those involving specialization were not.

The reason for the influence and contribution of academic level in predicting problem-solving performance may not be far from the fact that the pre-service teachers at level 300 must have had more experience with the contents of the chemistry courses than those at level 200, making them to perform better than on problem-solving tasks. Psychologists such as (5) and (6) and also researchers on problem-solving in science such as (33—35) have shown that experience was a very important factor for success in solving problems.

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APPENDIX ‘A

CHEMISTRY PROBLEM SOLVING TEST (CPST)

INSTRUCTION

Attempt all questions. You are expected to show clearly all the steps you have taken to arrive at your answer, including all rough works. You should also show how you have confirmed that your answer to each of the question is the correct answer. Direct all enquiries to your invigilator. Do not take away this question paper.

Q1. A gas at a pressure of 5.00 atm was heated from 0^oC to 546^oC and simultaneously compressed to one third of its original volume. What will be the final pressure in atm?

Q2. When aqueous copper (II) tetraoxosulphate (VI) was electrolyzed between copper electrodes, masses in grams of the electrodes before experiment were the anode 9.20g and the cathode 7.75g. After the experiment, it was found that the mass in grams of copper anode was 6.00g. Calculate the mass in grams of copper cathode at the end of the experiment.

Q3. Given the equation below, what mass of ammonia would be produced from 1.0 mole of H_2 and excess nitrogen?

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

Q4. A strip of pure copper having a mass of 3.178g was strongly heated in a stream of oxygen until it was converted to the black oxide. The resultant black oxide has a mass of 3.978g. Calculate the percentage composition of the black oxide?