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Covariance Structure Modeling of Academic Performance on Mathematics Students in South-Western Nigerian Polytechnics

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Abstract Mathematics is a very important subject. It is the language of science and technology and so it is a force to reckon with in the development of any nation. Several studies on factors that affect mathematics achievement have been conducted. However, studies on factors that affect mathematics achievement among Polytechnics students in Nigeria seem to be rare. This study identified the variables that tend to affect academic performance among mathematics students and developed covariance structure model for examining the relationships between the variables. This was with a view to providing an appropriate frame work for predicting academic performance. Study participants were 240 students selected by convenience sampling from six Polytechnics (three State-owned and three Federal-owned) in the South-Western Nigeria. A self-report questionnaire was administered on participants to collect information on demographic factors, self concept, training environment and circumstances used to determine the academic performance of students. Data collected was analyzed using percentages and covariance structure model technique. It explained self-concept, training environment and circumstances affect academic performance, with a good model fit. The model supposes that the perceived attributes of self concept, training environment and circumstances in polytechnics predict the academic performance. The result showed that self-concept, training environment and circumstances has influences on students' academic performance in Nigerian polytechnic.

Keywords: *covariance structure modeling, academic performance, mathematics, students, LISREL*

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1. Introduction

Mathematics was originated in Egypt and Mesopotamia in the first era of civilization. Mathematicians of this time used a primitive geometry in determining land boundaries, building irrigation systems and other things, about 6th century BC. Mathematics was established as a logical deductive science and proofs was applied to geometic theorems Notably, Greek mathematics and such as Pythagoras, Thales, Archimedes and Apologies contributed a lot to the development of mathematics up to what it is today.

Definition according to international encyclopedia mathematics was defined as a study of points flintily, lines and figures in space but later enlarged to invade the study of more abstract and basic concepts. Broadly speaking, mathematics is divided into two main branches.

i. Applied mathematics; which deals with natural phenomena

ii. Pure mathematics; which deals with abstract phenomena. Its branches include geometry arithmetic's algebra, probability, statistics, deferential and integral calculus. The role of mathematics in economical, cultural, social agriculture, educational communication, scientific and technological development of a nation like Nigeria, cannot be fully appreciated unless their significance and nature are determined.

The study of mathematics for instance, has made significant contribution to medicine, agriculture science and technology consequently the study of medicine has improved the health of individuals worldwide and agriculture has enhanced economic development of many countries. Since the beginning of this century more economist have come to depend on mathematical tools for analyzing not only abstract economic problem but also real problems of economics planning and policy the computer revolution during the past few years was facilitated by the direct application of mathematics.

Reference [1] suggested that is by introducing mathematics as a compulsory subject at both primary and secondary levels will as by conducting mass science (mathematics) campaign among adults that Africans will be able to move rapidly from the static role of a spectator to that of action in the breath taking scientific age. Mathematics being the bedrock of all science is the key that leads to a better understanding of all other science and their relationship with the natural world as means toward economic survival. The subject teaches how to observe nature consciously and logically. The learning develops in the student both the skill of accuracy and a degree of honesty.

Reference [2] it brings to bear on the fear, being expressed today as regards the poor performances in mathematics being experienced in our secondary education today even higher institution of learning are out free from this dilemma. For some years now, most state secondary school students perform badly and quite below expectation in mathematics. Persistent poor performance in mathematics has been attributed to several factors including lack of interest, negative attitude by students, poor teaching methods etc. Mathematics is a tool for scientific and technological development and the environment has a significant role to play in this development.

Several studies have been conducted over the years to determine the predictors of mathematics achievement among various groups of individuals. Some of the predictors discovered are: socio- economic status [3], teaching methods [4], gender and continuous assessment [5]. Other factors found to affect achievement in mathematics are: self-concept and learning style [6], reading abilities, mathematics self-efficacy and teacher evaluation [7].

A principal goal of experimentation in education is to provide a basis for inferring causation [8]. Among the tools used to achieve this goal are the active manipulation and control of independent variables, random assignment to experimental treatments, and appropriate methods of data analysis. Causal inferences are difficult to support without true experimentation. Nevertheless, social and behavioral scientists often make such inferences in the context of non- experimental and quasi-experimental research. A variety of sophisticated methods for multivariate data analysis have been developed and used in these situations many of which fall into the general category of covariance structure modeling.

Covariance structure modeling (CSM) is a collection of statistical methods for modeling the multivariate relationship between variables. It is also called structural equation modeling or simultaneous equation modeling and is often considered an integration of regression and factor analysis. CSM incorporates several different approaches or frameworks to representing these models. In one well-known framework (popularized by Karl Joreskog, University of Uppsala), the general CSM can be represented by three matrix equations:

$$\eta_{(mx1)} = B_{(mxm)} * \eta_{(mx1)} + \Gamma_{(mxn)} * \xi_{(nx1)} + \zeta_{(mx1)}$$

$$y_{(px1)} = \Lambda_{y(pxm)} * \eta_{(mx1)} + \varepsilon_{(px1)}$$

$$x_{(qx1)} = \Lambda_{x(qxn)} * \xi_{(nx1)} + \delta_{(qx1)}.$$

As CSM is a flexible and powerful technique for examining various hypothesized relationships, it has been used in numerous fields, including marketing (e.g., [9,10]), psychology (e.g., [11]), and education (e.g., [12,13,14,15]). For example, educational research has benefited from the use of CSM to examine (a) the factor structure of the learner traits assessed by tests or questionnaires (e.g., [16]), (b) the equivalency of models across populations (e.g., [17,18]), and (c) the effects of learner variables on proficiency or academic achievement at a single point in time (e.g., [15,19]) or across time (e.g., [13,20,21]).

CSM can be used to test whether a hypothesized causal structure is consistent or inconsistent with the data. Applications of covariance structure modeling are still rare in Nigeria, but several criteria suggest rapidly increasing use in educational data [8]. Recent textbooks on multivariate analysis have included chapters on CSM (e.g., [22]). The purposes of this article are to show how covariance structure modeling is currently being applied to investigate the reasons behind unhealthy performance of mathematics students in southwestern polytechnics in Nigeria and give possible recommendations on how to solve the problem.

The conceptual framework or model of the study distinguishing three types of factors that may likely affect academic performance are the self-concept in which factors like self-description and self-criticism will be considered. We have the following intervening variables in the model; life's circumstances will be considered from the perspective of loss, threat, fear, disappointment, rejection, travesty, training environment will reveal the kind of school and availability of boarding facilities. The dependent (response) variable will be the academic performance which will be considered through GPA at the end of the first session and the aptitude test.

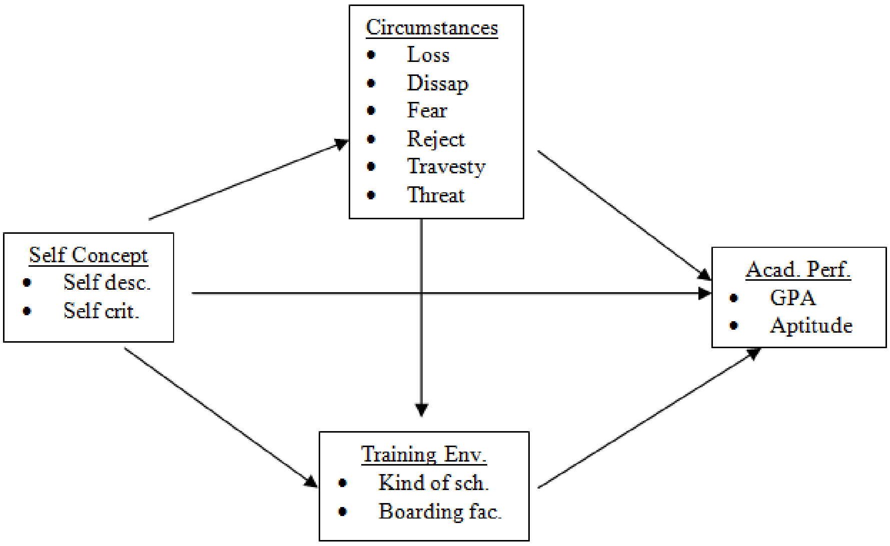

Figure 1. Conceptual framework showing the interrelationship of some variables on academic performance

The following hypotheses are proposed for the direct path:

H_{01}: There is no significant relationship between self-concept and students' academic performance.

H_{02}: There is no significant relationship between self-concept and students' circumstance.

H_{03}: There is no significant relationship between self-concept and training environment

H_{04}: There is no significant relationship between students' circumstance and training environment.

H_{05}: There is no significant relationship between training environment and students' academic performance.

H_{06}: There is no significant relationship between students' circumstance and students' academic performance.

2. Materials and Methods

Study participants were mathematics students selected by convenience sampling from six Polytechnics (three State-owned and three Federal-owned) in the South-Western Nigeria. To qualify for inclusion in the survey, participants must be currently in Higher National Diploma II (HND II) and have their Cumulative Grade Point Average (CGPA). Using these criteria, an initial sample of 300 students was approached by the researcher and trained research assistants in their assigned Polytechnics. The students were asked to volunteer to participate in the study. Volunteers were used to facilitate data collection as issues of CGPA and 'Circumstances' among students are usually considered sensitive and personal. All participants were guaranteed complete anonymity and confidentiality with respect to their written responses. From the initial sample, 240 students, representing 80%, returned the survey questionnaire. The survey questionnaire was a self-report instrument, which sought information on demographic factors, self concept, training environment and circumstances used to determine the academic performance of students. The questionnaire had been pilot-tested on a sample of 45 students of the Obafemi Awolowo University, Ile-Ife, South-Western Nigeria to ensure content validity, readability and ease of understanding. Reliability analysis showed that the instrument had moderate internal consistency (Cronbach's alpha 0.67).

Since Maximum Likelihood Estimation (MLE) is a common estimation procedure used in CSM software, [23] recommends that the minimum sample size to use MLE appropriately is between 100 to 150 participants. As the sample size increases, the MLE method increases its sensitivity to detect differences among the data (this is the justification for the sample size of 240 students).

Many software programs are used for CSM estimation, including *LISREL* (Linear Structural Relationships; [24]), *AMOS* (Analysis of Moment Structures; [25]), *SAS* [26], *EQS* (Equations; [27]), and *Mplus* [28]. These software programs differ in their ability to compare multiple groups and estimate parameters for continuous, binary, ordinal, or categorical indicators and in the specific fit indices provided as output. In this research, data analysis was done using descriptive and the *LISREL 8.80* package for CSM to estimate the parameters.

3. Results

3.1. Respondents' Characteristics

Data collected on demographic characteristics of respondents (Table 1) showed that 66.3% were male respondents while 33.7% were female. Most respondents (58.0%) were within the 22-26 years age group, 27.1% aged above 27 years, 14.1% were within 17-21 years, while only 0.8% were below 16 years. On religious preference, the majority (72.9%) of the students were christian, 24.2% were muslim, while only 2.9% were traditionalist. Majority (66.3%) of the students came from a monogamous marital relationship, while 33.7% were from a polygamous relationship.

Table 1. Respondents' Characteristics (*n = 240*)

Characteristics	Frequency	Percent
Respondents' gender		
Male	159	66.3
Female	81	33.7
Respondents' age		
Below 16 years	2	0.8
17 – 21 years	34	14.1
22 – 26 years	139	58.0
More than 27 years	65	27.1
Respondents' religious preference		
Christianity	175	72.9
Muslim	58	24.2
Traditionalist	7	2.9
Respondents' type of family		
Monogamy	159	66.3
Polygamy	81	33.7

3.2. Analysis of the Structural Model

A CSM technique was used to test the model with LISREL 8.80 statistical package was employed for this purpose. The parameters of the model were estimated with the Maximum Likelihood (ML) procedure. The goodness-of-fit was evaluated with indicators; x^2/df comparative fit index (CFI), non-normed fit index; (NNFI), goodness of fit index (GFI) criterion, among others.

Table 2. Associated Latent Variables vs Manifest Variables

Latent Variable	Manifest Variable	Acronym
Self-concept	Self description	SFDC
	Self criticism	SFCT
Training environment	Kind of school	KDS
	Boarding facilitation	BDF
Circumstances	Loss	LOSS
	Rejection	REJT
	Disappointment	DISP
	Fear	FEAR
	Travesty	TRSY
	Threat	THR
Academic performance	GPA	GPA
	Aptitude	APT

Hypothesis testing was transformed on various models. The observed (manifest) variables were used to predict the latent variables of self-concept, training environment, circumstances and educational performance. In structural equation modelling, we obtained by processing the data in the instrument. Table 2 revealed the manifest variables as against the corresponding latent variables.

The variables "GPA" and "Aptitude", which predict the latent variable "Academic Performance", were calculated using the relevant items in the questionnaire. The covariance matrix of the model to be analyzed before getting the estimation is given in Table 3:

Table 3. Covariance matrix of the model to be analyzed

	APT	GPA	KDS	BDF	LOSS	DISP	THR	TRSY	FEAR	REJT	SFDC	SFCT
APT	1.24											
GPA	-0.03	0.67										
KDS	-0.05	-0.03	0.97									
BDF	0.05	-0.10	0.37	0.78								
LOSS	-0.03	-0.22	-0.02	0.17	2.09							
DISP	-0.06	-0.08	0.06	0.10	0.64	2.43						
THR	0.05	-0.05	-0.01	0.00	0.13	0.15	0.22					
TRSY	-0.02	-0.05	0.05	0.05	0.51	0.50	0.05	1.09				
FEAR	0.03	-0.04	-0.04	-0.06	0.09	0.06	0.07	0.09	0.70			
REJT	0.19	-0.22	-0.11	0.19	0.82	0.38	0.19	0.35	0.20	2.08		
SFDC	0.86	-1.48	1.26	3.24	3.62	1.28	0.38	1.78	0.30	7.78	171.87	
SFCT	-0.06	-0.27	0.61	0.68	0.16	0.00	0.12	-0.08	0.27	0.73	16.84	10.63

3.3. Test of Model Fit Using Sample Model

Seven fit indexes which are commonly used in the literature (χ^2/df, GFI, AGFI, NNFI, CFI, SRMSR and RMSEA) were employed to text model fit. These model fit indices represent the three fit indices categories absolute fit, comparative fit, and parsimonious fit. It is often the case that the fit indices contradict each other. The commonly used measures of model fit, based on results from an analysis of the structural model, are summarized in the Table 4. In comparison to the recommended values (see [29,30,31]), our values show chi-square/degree of freedom is less than 3, GFI greater than 0.9, NNFI is closer enough (0.89) to the recommended value of 0.90, CFI greater than 0.90, an AGFI greater than 0.8, SRMSR less than 0.1 and RMSEA less than or 0.06 or 0.08 are considered indicators of good fit.

Table 4. Summary Statistics of Model Fit

Fit index	**Recommended Value**	**Observed Value**	**Reference**
χ^2/df	$\leq$ 3.00	1.66	Hair *et al.* (2006)
GFI	$\geq$ 0. 90	0.95	Schumacker and Lomax (2004)
AGFI	$\geq$ 0. 80	0.91	Schumacker and Lomax (2004)
NNFI	$\geq$ 0. 90	0.89	Schumacker and Lomax (2004)
CFI	$\geq$ 0. 90	0.92	Schumacker and Lomax (2004)
SRMSR	$\leq$ 0. 10	0.056	Hu and Bentler (1998)
RMSEA	$\leq$ 0. 60 $\leq$ 0.08	0.082	Hair *et al.* (2006)

Note:χ^2/ df = Chi-square / Degree of freedom; GFI = Goodness-of-fit index; CFI = Comparative fit index AGFI=Adjusted goodness-of-fit index; SRMSR=Standardized root mean square residual; NNFI=Non-normed fit index; RMSEA=Root mean square error of approximation.

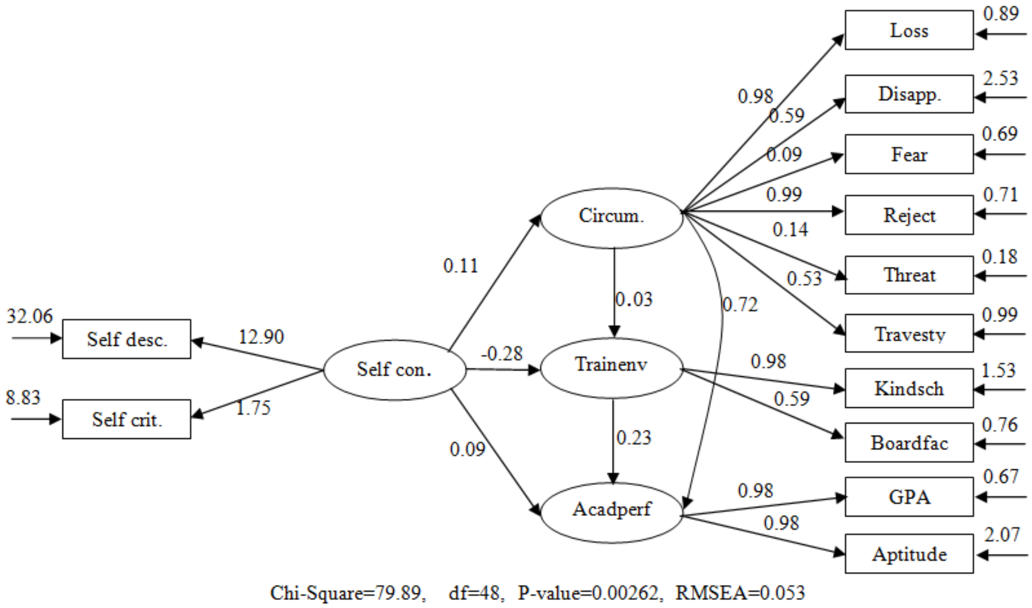

Figure 2. The computed estimates for the model

Figure 2 reveals the computed estimates for the conceptual framework. The regression coefficient (β) for the direct path of self-concept → academic performance is 0.09 with t-value = 0.35, while that of self-concept → circumstances is 0.11 with t-value = 1.21.Moreso, β is -0.28 with t-value = 1.49 for the direct path of self-concept → training environment, while that of direct path of circumstances → training environment is 0.03 with t-value = 0.35. Furthermore, the value of β for direct path of training environment → academic performance is 0.23 with t-value = 0.96, while that of the direct path circumstance → academic performance is 0.72 with t-value = 1.21.

Therefore the null hypotheses of independence are not supported in any of the cases at p<.00262.

4. Conclusion/Summary

The paper attempted to identify the variables that tend to affect academic performance among mathematics students and developed covariance structure model for examining the relationships between the variables. Covariance structure modelling offers a means of developing and evaluating ideas about multivariate relationships; and this property makes CSM of interest to the practitioners of science, psychology, education, among others [8,10,15]. As seen in this paper, self-concept, training environment and circumstances affect academic performance, with a good model fit. The model supposes that the perceived attributes of self-concept, training environment and circumstances in polytechnics predict the academic performance. The result showed that self-concept, training environment and circumstances has influences on students' academic performance in Nigerian polytechnics.

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