

Determinants of Students' Achievements in Senior Secondary School Mathematics and Sciences: What is the role of Test Response Mode and Locus of Control?

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Abstract— This study investigated the effects of test response mode and locus of control on student's achievements in senior secondary school mathematics and sciences within the blueprint of casual-comparative research of an expost-facto type. The sample consisted of 240 senior secondary school year two students drawn from seven randomly selected senior secondary schools in Epe Local Government Area of Lagos State, Nigeria. Five instruments were used for data collection and data analysis was done using mean, standard deviation and t-tests (paired and independent samples). Results showed that there was a significant effect of test response mode on students' achievement in (a) Mathematics (b) Biology, (c) Chemistry, and (d) Physics. Students performed better in multiple-choice objective test than in constructed response test in each of the school subjects investigated. Also, there was a significant effect of locus of control on students' achievement in (a) Mathematics (b) Biology, (c) Chemistry, and (d) Physics in favour of the internals who recorded higher mean scores than the externals. Thus, recommendation based on the findings were made and science and mathematics teachers were implored to embrace effective teaching in the classrooms as a panacea for students to achieve better performance in science and mathematics.

Keywords— Test response mode, locus of control, mathematics, science subjects, achievement.

I. INTRODUCTION

In Nigeria and perhaps throughout the world, there is a well established tradition in secondary schools and that is once Mathematics and science subjects like Biology, Chemistry, and Physics have been taught, they have to be examined. Most times, these subjects are examined internally by the teachers who have been responsible for delivering the instructions. Sometimes, the subjects are examined by external bodies set up by Government for the purpose. Such external bodies in Nigeria include: the West African Examinations Council (WAEC), the National Examinations Council (NECO), the Joint Admission and Matriculation Board (JAMB), and the National Business and Technical Examinations Board (NABTEB). Each of these bodies assesses students' learning in a particular subject based on the prescribed syllabus. Learning defined as a relatively permanent change in a student's behaviour as a result of exposure to instruction can be inferred, measured and assessed. By assessment, a teacher finds out what changes

have occurred, thus helping the teacher to determine how much learning has taken place in students. Besides, assessment provides the teacher with that measuring rod of his/her success as a teacher at least with respect to his/her students learning. Since students' progress remains one of the main ways of judging the performance of a teacher, assessment must be at the centre of his/her strategy. Thus, for a teacher to ascertain if he/she has been successful in teaching, he/she needs reliable assessment methods. There are many ways by which a teacher can assess the degree to which a student has mastered the skills (in this case cognitive, affective, and psychomotor) integral to the acquisition of specialised knowledge as a result of planned instruction. Some of these methods include the use of essay (free-response) tests, objective (multiple-choice type) tests, projects, rating scales, sociometric technique, anecdotal reports, and biographical method. While the last four methods are more amenable to measuring a student social relationship with other students (affective skills) [1], the first two methods are needed for assessing students' level of cognition in a particular knowledge domain (cognitive skills) [3]. The project method may be required to assess manual skill (psychomotor skills) acquisition in a particular subject matter. Among the methods of probing into students' cognitive abilities, essay tests and multiple-choice object tests are particularly outstanding and popular considering the rate at which these two methods of assessments are being put to use in all levels of the educational system around the world.

In a constructed response item the testee is required to provide an original written response to a stimulus. Usually the testee is required to provide detailed information and to relate its specifics in a meaningful answer to a rather general question [4]. Essay questions can allow for the display of reasoning and the development of an argument [3] and at the same time encourage students to develop more desirable study habits [4] with special consideration for choice and flexibility of responses. This very flexibility has been the bane of essays and mathematics teachers employing this technique in assessing students' progress should consider how much structure they intend to impose when wording an essay item. Mathematics teacher should consider the fact that the more general the wordings, the greater the freedom and flexibility for the students, but the lower the possibility of standardized marking, for validity and reliability of the measure [3]. Apart from the fact that essay item is extremely difficult to score [4], a major defect is the subjectivity of the scoring of the markers, even when the examiner has a clear idea of acceptable answers in a standardized marking scheme [3, 5, 6].

As a solution to the inconsistencies in the relative judgment of essay questions, many test constructors have advocated for the adoption of multiple-choice test items. The multiple-choice item consists of a stem, in which the problem or question is posed; followed by a number of distractors, options, responses or the wrong answers; one of which is the key or correct answer. The incorrect options or alternatives are called the distractors or foils. The stem of the item may be posed either as a question or as an incomplete statement.

Multiple choice questions require testees to choose a correct response from about four or five options that are provided for each item. This assessment technique can measure any subject-matter area, all levels of ability, especially the conceptual, interpretative, and critical levels [3] and the test is objectively score-able and no human judgment is needed [6]. Aside the fact that multiple-choice question is difficult to construct, a major disadvantage is that the student's response gives no evidence of his/her originality or ability to respond without being given a choice of responses.

In secondary schools, both internal and external examinations conducted for students lend themselves well to the adoption of multiple-choice and essay tests and students' performance has been graded using these tests. Aside the fact that essay tests lack objectivity in scoring, anti-essayists have attributed the continued poor performance of students in mathematics as well as the persistent low enrolment ratio in mathematics departments in institutions of higher learning to the undue emphasis placed on the use of essay tests to assess students' performance/achievement in mathematics. Based on this, the anti-essayists posit that the public examining bodies should desist from using essay test as an instrument for grading students' performance.

Contributing to the debate, [7] maintained that the educational system may run into problems if too much emphasis is put on any one such method of assessment without taking cognizance of the fact that each assessment technique has its own distinctive characteristics. He declared further that a teaching learning system that relies entirely on the multiple-choice test for instance might suffer the side effect of students learning to scan materials for factual testable items, gobbets of details or technical terms, rather than looking for clues that might be demanded of them in essay tests. Also, the multiple-choice test is subject to student guessing when scoring system that corrects guessing is not applied [4] and the score that is obtained is quite likely to be prone to error. In view of the above, the study sought to investigate the extent to which test response mode determines students' cognitive achievement in senior secondary school Mathematics, Biology, Chemistry, and Physics.

The achievements of students in Mathematics, Biology, Chemistry and Physics (MBCP) may be moderated by the extent to which students attribute success or failure to internal or external factors, i.e., factors under or not under their control. This attribution, called locus of control, has been extensively investigated using [2] that identifies respondents as either "internals" or "externals". Internals believe that events primarily results from their own behaviour and generally perceive themselves as having a high degree of control over their lives. For instance, success on a mathematics test is attributable by internals to their effort or hardwork. Externals believe that events primarily are the result of chance or someone else's actions and perceive themselves as being influenced largely, if not wholly, by external factors. In an academic setting, an external would likely consider failure on a mathematics test to be the result of an unfair test (teacher's fault, for example). Studies have

tended to confirm a positive relationship between internal locus of control and academic achievement [12, 13, 14] and [8] demonstrated this relationship to be independent of socio-economic status, though ethnic origin appeared to have a modulating effect. More recent studies have found that college freshmen who were identified as internals obtained significantly higher grade point averages (GPAs) [24] and that internals showed significantly lower academic procrastination, debilitating test anxiety, and reported higher academic achievement than externals [23]. Students with internal locus of control earn better grades and work harder [9] and include spending more time on homework as well as studying longer for test. External locus of control may be caused by continued failure in spite of continued attempts at school tasks [22] and a high external locus of control, in turn, leads to a lack of motivation for study and school in general [9]. Externals are more likely to respond to failure by given up hope and not trying harder [10] and may feel that working hard is futile because their efforts have only produced disappointment and ultimately may perceive failure as being their destiny [9]. This study therefore, investigated the effects of test response mode and locus of control on students' achievements in MBCP.

II. RESEARCH QUESTIONS

1. Is there any significant effect of test response mode on students' achievement in (a) Mathematics, (b) Biology, (c) Chemistry, and (d) Physics?
2. Is there any significant effect of locus of control on students' achievement in (a) Mathematics, (b) Biology, (c) Chemistry, and (d) Physics?

III. METHODOLOGY

This study adopted causal-comparative research of an expost-facto type. In such a research design, the investigators do not have a direct control of independent variables because their manifestations have already occurred or because they are inherently nor manipulable. What the researchers did in the present study was to examine the effects of independent variables (test response mode and locus of control) on dependent variables (achievements in MBCP) as it occurred rather than creating these manifestations. 240 senior secondary school year two students from senior secondary schools in Epe Local Government Area of Lagos State, Nigeria took part in the study. There were 51 senior secondary schools in this local government area out of which eighteen schools had facilities and manpower that supported the teaching and learning of the sciences. Six schools out of the eighteen schools were selected through simple random sampling. This was achieved by writing the initials of each school on a slip and deposited all the slips in a box. After they had been thoroughly reshuffled, a lad was asked to draw a slip out of the box without looking at it for the first selection and this procedure was repeated five other times until the sample size of six was chosen. One intact class of senior secondary school year two science students was then randomly selected

using a flip of coin in case there were more than one arm for science class in the school. All students in the selected classes participated in the study and the distribution of students according to the six intact classes chosen is presented in Table 1 together with the age range, mean age of students and standard deviation in each intact class where IC, N, AR, MA, and SD connotes intact class, number of students, age range, mean age and standard deviation respectively.

TABLE I
DISTRIBUTION OF SCIENCE STUDENTS ACROSS THE SAMPLED SIX INTACT CLASSES

IC	1	2	3	4	5	6	Total
N	42	41	38	43	36	40	240
AR	14-17	15-18	14-18	14-17	15-18	14-17	14-18
MA	16.64	17.28	17.14	16.96	17.16	16.87	17.04
SD	0.68	0.87	0.84	0.72	0.85	0.70	0.78

Five research instruments (four developed and one adapted) were used for data collection in the study. They were: (i) Locus of Control Scale (LCS) (ii) Mathematics Achievement Test (MAT), (iii) Physics Achievement Test (PAT), (iv) Chemistry Achievement Test (CAT), and (v) Biology Achievement Test (BAT). The locus of control scale based on [2] was used to categorise the science students into internals and externals. It consists of 29 items and the instrument according to [21] using a sample 122 Botswana in-service teachers recorded a coefficient alpha of 0.82. The MAT, PAT, CAT and BAT separately consists of two parts, A and B. Part A contains age, class level and gender as demographic variables while Part B contains 40 multiple-choice objective questions and five constructed-response questions of moderate difficulty. For MAT, the questions were drawn from the concepts of trigonometry, latitudes and longitudes and Bearings and distances. These topics have been perceived difficult by students and a vast majority of them often skip questions on these mathematical concepts during external examination [16, 17, 18]. For PAT, the questions were drawn from the concepts of temperature, heat energy and humidity and measurement. Evidence suggests that teachers, perceived difficulty in teaching these topics and students often demonstrate poor performance on them [25]. Items on the BAT were drawn from the biology concepts of photosynthesis, heredity and evolution. These concepts were part of the biology concepts on which students often exhibit weak performance. For the CAT, the questions were drawn from the concepts of atomic structure, electronic energy levels, and orbital, periodic classification of elements and its relationship to their electronic configurations. These chemistry concepts prove more challenging to students and students often show poor performance on them. The researchers' constructed instruments (MAT, BAT, CAT and PAT) were face and content validated by experts in various

subject disciplines in terms of content coverage, language clarity to the target audience and relevance of test items to the stated objectives. Minor amendments were made to the four instruments. For the multiple-choice aspects of the MAT, BAT, CAT and PAT, the internal consistency reliability coefficients 0.93, 0.94, 0.89, and 0.90 were computed respectively using Kuder-Richardson formula 20. The Kendall tau inter-rater reliability coefficients for the constructed response aspect of the MAT, BAT, CAT and PAT were 0.92, 0.93, 0.90, and 0.89 respectively and the average item difficulty computed for the MAT, BAT, CAT and PAT were 0.50, 0.52, 0.49 and 0.51 respectively. An examination of the scheme and records of work of all schools that participated in the study showed that the topics from which MAT, BAT, CAT and PAT items were constructed had been taught. In the locus of control scale, one point was awarded for certain answers on 23 of the statements. Thus, higher scores correspond to external locus of control. A score of 13 or less is considered internal, above 13 is external. To ensure the suitability of the instrument for the present study however, students' responses on the LCS were subjected to Cronbach's alpha analysis and the obtained internal consistency reliability coefficient was 0.89. The administration of the instruments on the participants was carried out by one of the investigators with the assistance of the mathematics/science teachers in each of the sampled schools. Data collection lasted four days and students' results were collated for analysis. The descriptive statistics of mean and standard deviation and inferential statistics of paired and independent samples t-test were employed.

IV. RESULTS

The results of this study are presented according to research questions asked.

1) *Research Question One:* Is there any significant effect of test response mode on students' achievement in (a) Mathematics, (b) Biology, (c) Chemistry, and (d) Physics?

Table 2 below provides mean scores for the constructed response and multiple choice tests according to subject discipline. In Mathematics, students' scores for constructed response questions were 3.82 points lower than for multiple-choice questions, a significant difference ($t = -52.43$, $p = .000$). In Biology, students' scores for constructed response and multiple-choice questions differed by 3.78 points, also favouring multiple-choice questions. A paired-samples t-test showed that this difference was significant ($t = -53.33$, $p = .000$). In Chemistry, student's scores for constructed response questions were 3.99 points lower than for multiple-choice questions, a significant difference ($t = -52.01$, $p = .000$). In Physics, students' scores for constructed response and multiple-choice questions differed by 3.83 points, in favour of multiple-choice questions. A paired-samples t-test indicated that this disparity was significant ($t = -52.26$, $p = .000$). Thus, it is concluded that there was a significant effect of test response mode on students'

achievement in (a) Mathematics, (b) Biology, (c) Chemistry, and (d) Physics

TABLE 2
PAIRED-SAMPLES t-TEST FOR CONSTRUCTED RESPONSE AND MULTIPLE-CHOICE QUESTIONS IN MATHEMATICS, BIOLOGY, CHEMISTRY, AND PHYSICS

Constructed response				Multiple-choice		
Subject	N	$\bar{X}$	SD	$\bar{X}$	SD	t
Mathematics	240	9.51	2.59	13.33	2.47	-52.43*
Biology	240	9.53	2.56	13.31	2.43	-53.33*
Chemistry	240	9.57	2.56	13.36	2.44	-52.01*
Physics	240	9.57	2.57	13.40	2.43	-52.26*

*Significant at $p < .05$

2) *Research Question Two:* Is there any significant effect of locus of control on students' achievement in (a) Mathematics, (b) Biology, (c) Chemistry, and (d) Physics?

Table 3 below shows the means and standard deviations of the students' overall achievement scores between internal and external locus of control in Mathematics, Biology, Chemistry, and Physics. In Mathematics, the internals obtained higher mean achievement score ($\bar{X} = 14.24$; $SD = 3.00$) than their external counterparts ($\bar{X} = 11.56$; $SD = 2.96$), a significant difference ($t = 6.90$, $p = .000$). The internals recorded higher mean achievement score in Biology ($\bar{X} = 13.13$, $SD = 3.08$) than the externals ($\bar{X} = 11.56$; $SD = 2.96$), and the difference was significant ($t = 3.96$, $p = .000$). In Chemistry, the internals recorded higher mean achievement score ($\bar{X} = 13.57$, $SD = 3.39$) than external ($\bar{X} = 11.51$, $SD = 3.27$), a significant difference ($t = 4.75$, $p = .000$). The internals obtained higher mean achievement score in Physics ($\bar{X} = 12.94$; $SD = 3.73$) than their external counterparts ($\bar{X} = 11.16$; $SD = 3.33$). An independent samples t-test indicated that this difference was significant ($t = 3.84$, $p = .000$). Hence, it is concluded that there was a significant effect of locus of control on student's achievement in (a) Mathematics, (b) Biology (c) Chemistry, and (d) Physics.

TABLE 3
INDEPENDENT SAMPLES t-TEST FOR OVERALL ACHIEVEMENT SCORES BY LOCUS OF CONTROL IN MATHEMATICS, BIOLOGY, CHEMISTRY, AND PHYSICS

Subject	Locus of control group	N	$\bar{X}$	SD	t	p
Mathematics	Internal	135	14.24	3.00	6.90*	.000
	External	105	11.56	2.96		
Biology	Internal	135	13.13	3.08	3.96*	.000
	External	105	11.56	2.96		
Chemistry	Internal	135	13.57	3.39	4.75*	.000
	External	105	11.51	3.27		
Physics	Internal	135	12.94	3.73	3.84*	.000
	External	105	11.16	3.33		

*Significant at $p < .05$

V. DISCUSSION AND CONCLUSION

The results of this study suggest that students are more successful answering questions in Mathematics, Biology, Chemistry and Physics when the questions are in multiple-choice objective format than when the questions are in constructed response format. Science and mathematics students who were identified as internals obtained significantly higher mean achievement scores than externals. The significant effect of test response mode on students' achievements in favour of multiple-choice objective test format corroborates similar result obtained by [6] in physics in which they found that students' performed better in multiple-choice objective test than in constructed response test. A constructed response test by its nature demands higher level of reasoning and allows the development of an argument. It is a means of assessing students' creativity and ability to organize, analyze, integrate and synthesise ideas in a subject domain. Constructed response tests are more likely to encourage thoughtful and reasonable answers containing analysis and applied knowledge. Thus, for students to record success in constructed response tests, they are not only required to recall the principles and concepts they have been taught, but that they have to analyse and integrate these concepts and principles and find a reasonable way of synthesizing them to get the correct answers. From the results of this study, students performed better in multiple-choice objective tests which may not necessarily demand higher reasoning ability and creativity. In fact, multiple-choice objective test may predispose students to factual answers. Evidence suggests that it is difficult to test higher mental processes such as analysis, synthesis and evaluation with objective tests [4]. In general, students need higher mental processes before they can do well in science and mathematics essay (constructed-response) tests. A certain minimal level of reasoning ability may predispose students to better performance in science and mathematics constructed response tests. This is in consonance with the assertion that there exists a positive correlation between formal reasoning and science achievement [11] and that increase in mental ability is associated with increase in science achievement [15]. However, it appears many students lack this reasoning ability [6] which cuts across locus of control. This is in support of the general comments of the Chief Examiners, WAEC that (i) many candidates were only good in rote memorization, but very poor in application of knowledge; (ii) many candidates could not express their ideas logically and in clear terms [17, 18, 19, 20]. The other result in this study relates to the significant effect of locus of control on students' achievement in science and mathematics. This result is in agreement with the outcome of similar studies conducted by [23, 24] in which they found that internals obtained significantly higher GPAs and showed significantly lower academic procrastination, debilitating test anxiety and reported higher academic achievement than externals. Locus of control, which is the tendency for students to ascribe achievements and failures to either internal factors that they can control (effort, ability, motivation) or external factors that are beyond control (chance, luck, fate, other' actions) is a vital factor that could influence the ways students engage in the

learning of science and mathematics. This is because students who have the conviction that effort and ability are vital ingredients in the learning of science and mathematics are likely to be intrinsically motivated and encouraged to engage in science and mathematics tasks thus improving their future expectation and performance. On the other hand, if students attribute their performance in science and mathematics to external and uncontrollable factors such as luck, fate, chance or powerful others, then their expectations for a successful education in science and mathematics may be minimal and they might be less favourably disposed towards engaging in science and mathematics tasks and the result may be nothing but poor performance.

The results of this study have implications for science and mathematics instructions, test construction, writing and curriculum development. No doubt, the type of testing procedure adopted in assessing students' level of cognition in a particular knowledge domain (subject) could drastically influence the performance of students in the subject. Since good results in tests and examinations are more likely to predispose students toward high engagement in science and mathematics, it is hereby recommended that in setting questions for tests and examinations, senior secondary school science and mathematics teachers should give priority to setting relatively easy and relatively difficult test items for both multiple-choice objective test and constructed response test. By this, low achieving students will be able to attempt some items while the high achieving students will be able to demonstrate their academic prowess in the knowledge of science and mathematics. Besides the fact that science and mathematics teachers should aim at effective teaching in their classrooms, internal locus of control is an essential factor for students to have a thorough understanding of science and mathematics. Internals are more likely to develop an intrinsic orientation in which participation in the science and mathematics task presents or because participation brings feeling of competence, mastery, control, and self-determination.

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