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Correlations Among Jamaican 12th-Graders' Five Variables and Performance in Genetics

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This study was aimed at finding out if the level of performance of selected Jamaican Grade 12 students on an achievement test on the concept of genetics was satisfactory; if there were statistically significant differences in their performance on the concept linked to their gender, self-esteem, cognitive abilities in biology, school-type and socioeconomic background (SEB); and if there were significant correlations among the five variables and the students' performance. The sample (n = 357, 102 males and 255 females) was chosen from two all-boys' schools, four all-girls' schools, and 13 mixed schools in rural and urban Jamaica. The results indicated that the students' level of performance (mean = 22.81 or 45.62%) was unsatisfactory; there were statistically significant differences in the students' performance on the genetics test based on their self-esteem, cognitive abilities in biology and school-type in favour of students with a high self-esteem, high cognitive abilities, and students in the coeducational schools respectively; there was a positive, statistically significant but weak relationship between the students' (a) self-esteem, (b) cognitive abilities, and (c) school type and their performance on the genetics test.

Keywords: Correlations, Gender, Genetics Achievement Test, School-type, Socioeconomic Background

INTRODUCTION

In 1999, the Caribbean Examinations Council (CXC) - the regional body which examines Caribbean 11th-graders on all school subjects - got the approval of the UK's National Academic Recognition Information Centre to offer the Caribbean Advanced Proficiency Examinations (CAPE) to replace the GCE advanced level examinations that UK's examinations boards had been conducting in the Caribbean. The CAPE was instituted to offer Caribbean students the opportunities to sit examinations that Caribbean educators set with a view to improving the students' pass rate. But, the fact that 954 (69%) of the 1383 Jamaican students who wrote the CXC CAPE in biology from 1999 to 2003 got the passing Grades 1-5, while 429(31%) of them obtained Grades 6-7 and failed the examinations is a cause for concern.

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One of the justifications for this study was that genetics is one of many biology concepts in the CAPE biology curriculum that present students with high cognitive challenges. Indeed, some studies have shown that many students perceived genetics to be difficult to learn (Longden, 1978; Woolley, 1979), while ample evidence indicated that many students performed poorly on genetics tests (Walker, Mertens & Hendrix, 1979). Yet, genetics is widely recognised as the conceptual foundation for the understanding of biology itself (Deadman & Kelly, 1978). A review of the reports on candidates' work in the CAPE in biology since 1999 revealed that many candidates did not perform well on questions set on genetics although the topic is taught fully in Grades 10 and 11. We considered it worthwhile to explore the possible links among selected Jamaican

12th-grade CAPE students' gender, self-esteem, cognitive abilities in biology, school-type and socioeconomic background (SEB) and their performance on a test on genetics. This was because it has been shown in many studies that these five variables did contribute to students' poor performance in science generally, but the topic of this study had not been investigated in previous studies. We also conjectured that the five variables were likely to be significantly correlated to the participants' performance on the genetics test in this study, although the findings of previous studies on the five variables were conflicting.

The findings of many of the international studies conducted between the 1970s and 1990s showed that gender differences in high school students' performance in mathematics and science achievement tests were in the males' favour (Forrest, 1992; Third International Mathematics and Science Study, TIMSS, 1997). But recent evidence from Northern Ireland revealed that boys received lower grades than girls in all science subjects at both the "O" and "A" levels (Millar, 1999). Many local studies' findings on gender differences in students' performance in biology are also inconclusive. For example, while no gender differences in high school students' performance in biology had been documented in some studies (e.g., Greenfield, 1996), Jegede and Okebukola (1991) reported that male Nigerian 10th-graders significantly outperformed their female counterparts in biology. Moreover, whereas Soyibo and Ishola (1986) found no significant gender differences in selected Nigerian 11th-graders' performance in genetics, Woolley (1979) reported that male British "A"-level students performed significantly better in genetics than their female peers.

The positive evaluation that individuals make and maintain about themselves is termed self-esteem, while the evaluated beliefs which individuals have about themselves are referred to as self-concept (Cooper-Smith, 1967). In this study, self-concept and self-esteem are considered as synonyms. The findings of several studies have revealed that students with a high self-esteem performed significantly better in science than their classmates with a low self-esteem (Brookover, LePere, Hamilton & Erickson, 1965; Ugwu & Soyibo, 2004). However, Soyibo and Pinnock (2005) recorded no significant self-esteem differences in Jamaican 11th-graders' performance in respiration.

Whereas many researchers have demonstrated that students' cognitive ability is a most valuable asset in their learning of science and mathematics (Bennet, Seashore & Wesman, 1966; Soyibo & Pinnock, 2005), research findings on the link between students' cognitive ability and performance in genetics are mixed. Lawson and Thompson (1988) contended that students' solutions and interpretations of genetic problems required formal level operations such as combinatorial, proportional and probabilistic reasoning. But, Smith and Sims (1992) asserted that combinatorial, proportional and probabilistic reasoning was not demanded in students' solutions of typical genetic problems.

Whilst some researchers have reported that students in mixed schools significantly outperformed students in boys' and girls' schools in biology (Clayton-Johnson & Soyibo, 2004), several studies have shown that girls' schools performed better in many school subjects including science than boys' and mixed schools (e.g., Forrest, 1992). While some research findings have shown that boys in all-boys' schools statistically significantly outscored students in all-girls' and mixed schools in biology (e.g., Soyibo & Pinnock, 2005), Field (1998) found no significant school-type differences in high school students' biology performance. Nevertheless, Soyibo and Ishola (1986) reported that Nigerian 11th-graders in a mixed high school significantly outperformed their counterparts in all-boys', and all-girls' schools on a genetics test.

Again, the findings of many studies on the relationship between students' SEB and their academic achievement are mixed. Several research findings have demonstrated that students from a high SEB significantly outperformed their peers from a low SEB in science (Field, 1998; Flemming & Malone, 1983; Ugwu & Soyibo, 2004). But, a few studies' findings indicated no significant SEB differences in students' science performance (Blair-Walters & Soyibo, 2004; Houtz, 1995). Whereas, Clayton-Johnson and Soyibo (2004) reported that some Jamaican 11th-graders from a high SEB performed significantly better in biology than their peers from a low SEB, Soyibo and Pinnock (2005) reported the absence of significant SEB differences in the biology performance of some Jamaican 11th-graders.

PURPOSE OF THE STUDY

Based on the foregoing review of cognate literature, this investigation was aimed at finding out if the level of performance of some Jamaican 12th-grade CAPE biology students on a genetics achievement test (GAT) was satisfactory; if there were significant differences in their performance based on their gender, self-esteem, cognitive abilities in biology, school-type, and SEB; and if any significant relationships existed among the five independent variables and the students' performance on the GAT.

METHODOLOGY

Research Design

We used an *ex post facto* research design because the five independent variables (the differences in the students' gender, self-esteem, cognitive abilities in biology, school-type, and SEB) had existed already and the observations were made on their possible relationships with the dependent variable (the students' performance on the GAT) (Weirsma, 1995).

Sample

The sample consisted of 357 12th-grade students (102 males and 255 females) conveniently selected from 2 out of the 3 all-boys' schools (52 students), and 4 out of the 7 all-girls' schools (109 students), and 13 coeducational schools (196 students) offering the CAPE in rural and urban areas of Jamaica in the 2003/2004 academic year. The participants - who were chosen from 14 traditional high schools, 3 nontraditional high schools and 2 community colleges - represented 56% of Jamaican 12th-graders (N = 641) enrolled for the CAPE in biology in the 2003/2004 academic year. See Table 3 for the detailed composition of the study's sample.

In this study, the traditional high schools were the long-established, "academic-oriented" high schools, while the nontraditional schools, and (now called 'new secondary schools') were founded in the 1970s as junior secondary schools. The two types of schools had similar curricula but the weaker students were placed in the latter. However, the selected schools in this study had trained biology teachers with a BSc degree in biology. The community colleges were post-secondary institutions that offered pre-university programmes (e.g., CAPE and A-level subjects), and professional certificate and diploma programmes.

Instrumentation

The two instruments we utilised to collect data were: the Cooper-Smith (1967) Self-Esteem Scale (CSSES) – used to measure the students' self-esteem and the Genetics Achievement Test (GAT) – employed to assess the students' knowledge of genetics. In Section A were the students' demographic variables, while the GAT and self-esteem scale were in Sections B and C; and the three sections were combined as one instrument.

The CSSES adopted for this study is a commercially produced self-report inventory with 26 statements that describe how the respondents felt. Students responded to each statement that best described them by inserting a tick under the column "Like me" or "Unlike me." There were 10 positive and 16 negative statements. A score of 5 was given to the respondent who chose each positively-worded item, whereas zero was given for a negative response. For the negatively-worded items, the scoring was reversed. The maximum score on the CSSES was 130. The reported test-retest reliability coefficient of the CSSES ranged from .70 (after 3 years) to .88 (more than 5 weeks) (Rublin, 1978), while Soyibo and Pinnock (2005) recorded a Cronbach alpha coefficient of .81 with Jamaican 11th-graders.

The students' raw scores on the CSSES ranged between 10 and 130; their mean was 97, while their standard deviation was 25. Based on their scores, the students were grouped into three categories: high self-esteem (scores between 122 and 130 - i.e. one standard deviation above the sample mean 97 + 25); average self-esteem (scores between 72 and 121- i.e. one standard deviation below the mean and 121); and low self-esteem (scores between 10 and 71).

The GAT consisted of five structured questions which one of the authors set using the CXC (2003) CAPE unit 1, paper 1 biology examination as a guide. The questions were based on the genetics contents and ten specific objectives prescribed for the CXC (2002) CAPE biology.

Displayed in Table 1 are the major contents that the five questions set on the GAT covered. In preparing the test, a table of specifications was constructed to ensure that each of the main questions contained items that tested the students' knowledge, comprehension and application levels on Bloom's (1956) taxonomy of educational objectives in the cognitive domain. Each question was allotted 10 marks, and the maximum score was 50. Multiple-choice items were not used because the CXC does not offer such items to its CAPE candidates. Two university senior lecturers (a PhD holder in biology, and the other a PhD holder in biology education with expertise in test construction), the 19 biology teachers in the sampled schools (each with a BSc in biology and more than three years of teaching A-level biology), validated the GAT items. There was a 100% agreement among the validators on the four validation criteria given to them. The inter-rater reliability coefficient calculated on the scores that one of the authors and an independent marker gave on ten randomly selected scripts of the students' answers on the GAT was .99. This implies that the two markers were very consistent in their use of the prepared marking scheme in grading the students' answer scripts.

Table 1. Main contents of the items on the genetics achievement test

Question number	Main content tested
1	Mitosis and meiosis
1	Gametogenesis
2	DNA and RNA
3	Chi-square
2 & 4	Gene and chromosome mutations
4 & 5	Genetic variation

Procedures

On request, the principals of the participating schools permitted us to administer the instruments to students in their schools. On the days the instruments were administered, the biology teachers and one of the authors supervised the students for 90 minutes under examination conditions. To group the students into cognitive abilities in biology, we used their final mock biology examination scores obtained from their teachers as follows: high cognitive ability - 70% and above; average cognitive ability - 50% - 69%; and low cognitive ability - below 50%.

RESULTS AND DISCUSSION

The first purpose of this study was to find out if the level of performance of some Jamaican 12th-grade CAPE biology students on the genetics achievement test (GAT) was satisfactory or not. In this study, students who scored 70% and above were considered to have attained a 'satisfactory' or "acceptable standard". The students' mean 22.81 (45.62%) is regarded as "unsatisfactory" because it is far below 60% which the CXC considers as the minimum pass mark in the CAPE in biology; and we regard 70% as the minimum "satisfactory" pass mark.

Table 2. Frequency distribution, mean and standard deviation on the genetics achievement test

Score	Frequency	Percentage	Mean	SD
2	2	0.56	22.81	10.19
3-24	179	50.14		
25-29	72	20.17		
30-35	54	15.13		
36-	48	13.44		
4346	2	0.56		
Total	357	100.00		

n = 357 Maximum score = 50

Table 3. Means and standard deviations on the genetics achievement test based on the five independent variables

Variables	*n*	Mean	SD
Gender			
Male	102	20.18	10.44
Female	255	23.86	9.91
Self-Esteem			
High	31	28.29	9.96
Average	282	22.70	9.99
Low	44	19.64	10.23
Cognitive abilities			
High	23	34.91	5.37
Average	155	27.27	9.11
Low	179	17.39	8.14
School-type			
All-boys	52	14.15	7.45
All-girls	109	21.89	11.31
Coeducational	196	25.61	8.70
Socioeconomic background			
High	227	22.02	10.01
Low	130	24.18	10.38

Evident from Table 2 is that (a) 102 (29%) of the students scored 60% and above, while only 50 (14%) of them scored 70% and above. The students' poor performance (a) is consistent with CXC's (1999-2003) CAPE biology examiners' reports which showed that since 1999 many candidates did not perform well on the questions set on genetics; and (b) receives an indirect support from some previous researchers (Walker, Mertens & Hendrix, 1979; Woolley, 1979) who reported that many post-secondary school students performed poorly on genetics tests because they perceived genetics to be a difficult concept to understand.

The second purpose of the study was to find out if there were significant differences in the students' performance based on their gender, self-esteem, cognitive abilities in biology, school-type, and SEB. Exhibited in Table 3 are the means and standard deviations of the students based on the five variables.

Table 3 shows that (a) the mean of the females is slightly higher than that of the males; (b) the mean of students with a high self-esteem is appreciably higher than that of their counterparts with an average and a low self-esteem; (c) the mean of students with a high cognitive ability in biology is much higher than that of their peers with average and low cognitive abilities; (d) the mean of students in the coeducational schools is higher than the means of students in the all-girls' and all-boys' schools; and (e) the mean of students from a high SEB is slightly lower than that of students from a low SEB. The standard deviations are fairly high in all cases implying that there were relatively wide variations in the GAT scores of the high and low scorers based on the variables.

To determine if there were statistically significant differences in the students' GAT means, linked to the five independent variables, a five-way factorial analysis of variance (ANOVA) was computed.

Implicit in Table 4 are that there are statistically significant differences in the students' performance on the GAT associated with their self-esteem, cognitive abilities in biology and school-type, whereas there are no significant gender and SEB differences in the their performance. The data in Table 3 suggest that the differences are in favour of students (a) with a high self-esteem, (b) with high cognitive abilities in biology, and (c) students in the coeducational schools. Hence, the numerical differences in the students' means in Table 3 based on gender and SEB were likely to have occurred by chance. The Scheffe *post-hoc* tests on the main effects of self-esteem, cognitive abilities in biology and school-type were applied. The Scheffe tests confirmed that the conceptual knowledge of genetics of students (a) with a high self-esteem was significantly better than that of students with an average and a low self-esteem respectively: [F (2) = 6.859, $p < .001$]; (b) with a high cognitive ability in biology was significantly better than that of students with average and low cognitive abilities respectively: [F (2) = 82.296, $p = .001$]; (c) in the coeducational schools was statistically significantly better than that of students in the all-girls', and all-boys' schools respectively: [F (2), 31.157, $p < .001$].

We anticipated the first finding that students who exhibited a high self-esteem would statistically significantly outperform those with average and low self-esteem on the GAT. This was because, as stated earlier, whereas it had been shown in several studies that students with a high self-esteem performed significantly better in science than their classmates with a low self-esteem (Brookover *et al*., 1965; Ugwu & Soyibo, 2004), Soyibo and Pinnock (2005) reported no significant self-esteem differences in high school students' performance in biology. But, we could not find any studies in which the association between students' self-esteem and their performance in genetics had been investigated.

Table 4 results - showing that there are significant cognitive abilities' differences in the students' performance on GAT - are not surprising. This was because, Walker, Mertens and Hendrix (1979) reported a positive correlation between students' reasoning ability and problem-solving ability in genetics. In addition, Esiobu and Soyibo (1995), showed that Nigerian10th-graders with high cognitive ability in biology significantly outperformed their peers with average and low abilities in ecology and genetics tests.

The finding that students in the coeducational schools performed significantly better than those in the all-girls' and all-boys' schools was expected (Soyibo & Ishola, 1986 in respect of Nigerian 11th-graders' performance in genetics). However, this study's finding conflicts with several previous studies' findings indicating that girls' schools performed better in many school subjects including science than boys' and mixed schools (Forrest, 1992; Blair-Walters & Soyibo, 2004), and few research findings that boys in all-boys' schools significantly outscored students in all-girls' and mixed schools in biology (e.g., Soyibo & Pinnock, 2005).

We did not expect the absence of statistically significant gender differences in the students' performance on the GAT recorded in this study. This was because Woolley (1979) reported significant gender differences in British "A"-level students' performance on the genetics component of his study in favour of the males. Nonetheless, this study's finding receives some indirect support from Soyibo and Ishola's (1986) and Esiobu and Soyibo's (1995) findings that there were no significant gender differences in selected Nigerian 11th and 10th-graders' performance in genetics respectively.

We anticipated the data in Table 4 showing that there is no significant SEB difference in the students' performance on the GAT. This was because, whereas Clayton-Johnson and Soyibo (2004) reported the existence of statistically significant SEB differences in the biology performance of selected Jamaican 11th-graders in favour of students from a high SEB, Soyibo and Pinnock (2005) reported the absence of significant SEB differences in the biology performance of some Jamaican 11th-graders.

The third purpose of this study was to find out if any significant relationships existed among the five independent variables and the students' performance on the GAT.

Table 4. Five-way factorial analysis of variance in the genetics achievement test scores of students

Source of variation	SS	df	MS	*F*
Gender	16.495	1	16.495	.263
Self-esteem	1222.330	2	611.165	9.744*
Cognitive abilities	7729.688	2	3864.844	61.619*
School-type	1833.486	2	916.743	14.616*
Socioeconomic background	182.676	1	182.676	2.912
Model	15102.578	8	1887.822	30.098
Residual	21837.086	348	62.722	
Total	36929.664	356	103.735	

* $p < .001$

Table 5. Point-biserial correlation coefficients linking students' genetics achievement test scores to five variables

	Gender	Self-esteem	Abilities	School-type	SEB
GAT scores	.16**	.22***	.56***	.20***	.10*

* $p < .05$ **$p < .01$ ***$p < .001$

Point-biserial correlation test was used because the five independent variables are nominal or categorical variables and two of them (gender and SEB) show genuine dichotomies, while the remaining three had three categories (Guilford & Fruchter, 1978, p. 308). In Table 5 are the results.

Table 5 indicates that there is a positive, statistically significant but weak relationship between the students' (a) gender, (b) self-esteem, (c) school-type, and (d) SEB and their performance on the GAT, whilst the relationship between their cognitive abilities in biology and their performance on the GAT is considered as "substantial reliability" (Miller, 1991). The findings regarding self-esteem, cognitive abilities and school-type confirm the data in Table 4, while the findings in respect of gender and SEB are inconsistent with the results in Table 4. Moreover, the weak relationships and the "substantial reliability" suggest that there were other factors apart from the students' self-esteem, cognitive abilities and school-type which could have accounted for the significant variations in the students' performance on the GAT that were not explored in this study.

CONCLUSIONS AND IMPLICATIONS

We considered the overall performance of the students (mean = 22.81 or 45.62%) as unsatisfactory because it is much less than the official 60% pass mark of the CXC in the CAPE in biology. Implicit in this study's finding is that the majority of the students lacked a sound conceptual knowledge of genetics and that their performance and that of their counterparts on genetics questions in internal and external examinations is likely to be poor.

Students with a high self-esteem and a high cognitive ability in biology performed significantly better than their counterparts with (a) an average self-esteem, and (b) a low self-esteem, and (c) an average cognitive ability, and (d) a low cognitive ability respectively. But a close look at Table 2 indicates that the mean (28.29 or 56.58%) of students with a high self-esteem (n = 31 or 8%) and the mean (34.91 or 69.82%) of students with a high cognitive ability (n = 23 or 6%) are less than the 70% which we consider as the minimum "satisfactory" grade in this study. Hence, Jamaican 12th-grade CAPE teachers need to (a) improve their students' basic mathematical knowledge that they need in the solutions of genetics numerical problems; and (b) use a variety of activity-oriented instructional strategies to improve their students' knowledge of and performance in genetics, regardless of the differences in their self-esteem and cognitive abilities in biology. This is because, based on our teaching experience, many A-level biology teachers tend to use the lecture method to teach the subconcepts of genetics and many of the teachers and their students have a poor knowledge of mathematics.

We did not obtain any empirical data to explain why the students in the coeducational schools significantly outperformed their counterparts in the all-girls' and all-boys' schools. To assist Jamaican male and female 12th-graders in single-sex schools to perform as well as their peers in mixed schools, their biology teachers need to motivate them to learn the subject meaningfully by varying their instructional strategies. Other variables that could have contributed to the significant differences in the students' GAT performance - which should be identified and investigated in future studies on the topic - include: the differences in the students' learning styles and cognitive abilities in mathematics, subject preference, their teachers' teaching experience, mathematical background and teaching styles.

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