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An investigation into weaknesses exhibited by senior high school biology students in graph work in the cape coast metropolis of Ghana

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ABSTRACT

The purpose of this study was to examine Biology students' weaknesses as far as graph work is concerned. The target population was SHS 3 students offering biology as an elective science subject in Senior High Schools in the Cape Coast Metropolis during the 2009/2010 academic year. However, the accessible population was elective biology students from six schools in the Cape Coast Metropolis. At each school an intact class was randomly selected and used. In all a sample size of 230 students was used. The study revealed that elective biology students have difficulty with providing headings, an appropriate scale, and labeling the axes of graphs.

Introduction

The development of nations worldwide is dependent mainly upon scientific and technological advancement. Indeed nations are said to be developed on the basis of their achievements in the fields of technology, medicine, agriculture, manufacturing and education. One of the differences that exist between nations labeled developed and those dubbed developing or third world countries, is the scientific inventions and the technological know-how of the citizenry in the usage of the gadgets that the developed nations have. The developed nations did not achieve their status by resting on the oars. Rather, they did so by laying the necessary emphasis on Science Education, which according to Akpan (1992), is the cultivation and disciplining of the mind and other faculties of the individual to make the most of science for improving his/her life, cope with the increasingly technological world, or pursue science professionally, and for dealing with science related social issues. This is to say that developed nations made Science Education a priority for the citizenry and made the necessary inputs that ensured its sustainability.

In the light of this, developing nations that have the vision of becoming developed are also jumping on the bandwagon of educating the citizenry in the sciences. Ghana as a developing nation not wishing to be left out has since independence in 1957 been laying emphasis on the teaching and learning of the sciences. Thus, throughout the educational system, from the basic, to the secondary through to the tertiary level, the teaching and learning of science is a must.

At the secondary level (now known as Senior High School), programmes offered are General Arts, Visual Art, Home Economics, and Science. Science is offered as physics, chemistry and biology. These are offered by general science students. Non-science students as well as science students offer integrated science which comprises of aspects of biology, physics, chemistry, agriculture and computer science (or information communication and technology, ICT). The performance of students in the science subjects is always critically analyzed by stakeholders. This is done to ensure that our students are not just studying the sciences for studying sake, but are doing so to help in achieving the national goals.

The performance of students in the sciences as revealed from SSCE/WASSCE results has come under critical attack in recent years. Several West African researchers have studied the trends in SSCE/WASSCE students' performance. For instance, Akanbi (2006) in his analysis of SSCE Physics results spanning nine years (1999 – 2007) of some schools in the Ogbomoso Metropolis in Nigeria found that "performance in Physics examinations was deteriorating" (p. 26).

Also on Physics, Akanbi (2006) quoted Adebayo and Adams' study as reporting that the performance of the pupils in physics in some selected Secondary Schools in Lagos was quite weak.

The situation is not much different with Chemistry. The performance of chemistry students at the secondary level has been poor and deplorable over the years (Agbadinuno, 1987; Jimoh, 2004; Njoku, 2007). Analysis of students' performance in the sciences at SSCE level as noted by Njoku (2007) revealed that between 1980 and 1991, the annual average pass rate at credit level (grade 1-6) in chemistry was 15.41%, while the absolute failure rate i.e. grade 9) was 61.82%.

Observation has shown that in spite of the various innovations introduced into our science teaching in general and chemistry in particular, the performance of students still remains low. This is buttressed by the poor performance of students in chemistry in the West African Senior School Certificate Examinations [WAEC] (Adejumobi &Ivowi, 1992; Adeyegbe, 1992; Ezeudu, 1995). Friedman (2000) also supported the idea that achievement in science is low and he attributed the reason for this among other things, to the teaching of chemistry by neither teachers with a major nor minor in the subject. Several other reasons have been advanced for the under-achievement in chemistry and other science subjects. Agusiobo

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(1998) posited that the poor capital investment in terms of provision of sciencere sources contributed to student's low level of academic performance.

The performance in Biology has also not seen any significant difference over the years as evidenced by the general comments in the West African Examinations Council (WAEC)

Chief Examiners' reports over the years (WAEC Chief Examiners' reports for July/Aug. and Nov. /Dec., 2000;July/Aug., 2001; July/Aug., 2002; July/Aug., 2004; July, 2005and May/June, 2006; both Biology 1 and 2 papers). Through outall these years, it has always been stated that candidates 'performance was generally unsatisfactory. For instance, after stating that the paper's standard compared favourably with that of previous years, the November/December, 2000 Chief

Examiners' report on Biology 1B stated that candidates' performance was far from satisfactory. Similarly, the July/August, 2001 Biology 1B report indicated that candidates performance was 'pretty low' in spite of the fact that the paper's standard was about the same as previous years.

Indeed the comments on students' performance in the reports for the July/August, 2004 Biology 1B and 2,July/August, 2005 Biology 1B, May/June, 2006 Biology 1 and 2are all in the same vein. It is noteworthy that the comments inthe July/August, 2002 Biology 2, July/August, 2004 Biology 1Band 2, and May/June, 2007 Biology 1 reports all made it clear that candidates' performance remained unchanged; in otherwords the performance was virtually low year after year without any marked positive deviation (with the exception of the reports on the November/December, 2000 Biology 2 which stated thus "candidates in the well-endowed schools in the urban areas performed quite better than those in the rural areas" (p.132), and that for the July/August, 2001 that clearly acknowledged an improvement in candidates' performance); according to the Chief Examiners' reports for 11 different papers for six consecutive years.

Over the years students' poor performance at the SHS in the science subjects has been of much concern to parents, school authorities, as well as other stakeholders such as teachers and educationists. This has been attributed to many factors.

The latest Chief Examiners' report at the time of theresearch was that for the May/June, 2006 West African SeniorSecondary Certificate Examination (WASSCE) Biology 1 and 2.

This report also states explicitly that "candidates' performancewas not encouraging, below average and does not differ fromthe previous year's" (p.59, 69).From data collected for the Programme Reform andAlignment for increasing Competencies of Teachers and forImproving Comprehension and Application in Learning Scienceand Mathematics (PRACTICAL) project plan, the percentage ofstudents who had passing grades in Biology which qualify themto enter tertiary institutions, that is, students having grades A toD were 31.7%, 19.2%, 27.6%, 39.0%, 39.4% and 40.9%respectively for the years 1999, 2000, 2001, 2002, 2003, 2004and 2005. This indicates that over a period of seven consecutiveyears less than 50% of candidates had passing grades in Biologythat could qualify them for further studies. Those who had grades A to C ranged between 9.7% and 30.9% during the sameperiod.

Statement of the Problem

With the passing of the years, many students who sit the SSSCE in the sciences, specifically, Biology, do not perform as expected. This is a constant source of worry to parents, teachers, educationists and those who have the advancement of science education in Ghana at heart. However, year after year Chief Examiners' reports in Biology hammer on recurring weaknesses, even going to the extent of labeling some as 'perennial' problems. Some of the weaknesses listed in the WAEC Chief Examiners' reports studied for 11 papers are as follows:

1. Inability to plot, describe or explain graphs drawn (Nov./Dec.,2000, Biology 2; Jul./Aug., 2001, Biology 2; Jul./Aug., 2004,Biology 2)
2. Poor diagrams – proportion, labeling, captioning, positioning of organelles (Nov./Dec., 2000, Biology 1B & 2; Jul./Aug.,2001, Biology 1B; Jul./Aug., 2002, Biology 2; Jul./Aug., 2004, Biology 2).

As indicated by the papers listed alongside the weaknesses above, the difficulties are evident in both the theory and practical papers for both the regular July/August and the private November/December candidates' papers. Thus, for both papers, the same weaknesses are reported on by the chief examiners.

Noteworthy is this general comment in the July/August, 2004 Biology 1B Chief Examiners' report: "The candidates' performance was average. There has not been any improvement because the weaknesses that we point out, year in year out don't seem to have been addressed by the schools" (p.189). Evidently the recurrence of the exhibition of the weaknesses has a direct bearing on the performance of the candidates. Since year after year the same weaknesses are demonstrated, then of course the performance will continue to be 'poor', 'below average', 'unsatisfactory' and 'not encouraging', as reported by the Chief Examiners. This conveys the idea that the problem has persisted down through the years, with no significant improvement noted.

Thus, the fact that nobody seems to be addressing the documented weaknesses of elective biology students in graph work is an issue that needs to be addressed. In the light of this, an investigation into some specific weaknesses exhibited by SHS 3 elective biology students in graph work will thus be most appropriate.

Hypotheses

The study was based on the following hypotheses:

1. There is no significant difference in the achievement of male and female students on graph work.
2. There is no significant difference in performance of the male and female students in the coeducational schools on graph work.

Research Questions

The following research questions were answered by the study:

1. What specific weaknesses are exhibited by SHS 3 students on graph work?
2. What reasons account for students' weaknesses on graphing?

Research Design

A descriptive survey was employed as the design for this study. Data was gathered during the senior high school second term in school, with the intention of describing the nature of SHS biology students' difficulties with graphing as well as investigating the probability of there being differences or not in students' performance on graphing between single-sex female, single-sex male and coeducational schools within the Cape Coast metropolis of the Central Region of Ghana.

Population

The target population was all SHS 3 students offering elective biology in the Cape Coast Metropolis during the 2009/2010 academic year. However the accessible population was elective biology students from seven schools in the Cape

Coast Metropolis. The accessible population consisted of 939 students.

Sample and Sampling Procedure

There are seven public senior high schools in the Cape Coast metropolis which offer elective biology. Two of the schools were single-sex female (SSF) and were selected conveniently. Three were single-sex male (SSM) schools, and using computer generated numbers, two were randomly selected to participate in the study. The remaining two were coeducational (CE) schools. As such these were also conveniently selected to be part of the study. All the four single-sex (SS) schools are Category A schools (according to GES classification) whereas the two coeducational schools are both Category B schools. These categories are assigned depending on the available facilities (GES, 2009), and not according to academic performance.

At each school an intact class was randomly selected (using computer generated numbers, obtained from Microsoft EXCEL) and used since each of the six schools had more than one science class. (Both CE schools had three science classes each, while one SSF school had five, one SSM had four, with the remaining two SS schools (one SSF one SSM) each had three science classes).

Of the two intact classes selected from the two SSF schools one had 35 students and the other consisted of 32 students. However, of the classes selected from the SSM schools one was made up of 40 students and the other of 41. The classes selected from the CE schools were made up of 46 (that is 29 females, 17 males) and 36 students (14 females, 22 males). In all a sample size of 230 students was used. In all the schools the intact classes can be said to be equivalent in terms of numbers, since the differences in the number on roll were just plus/ or minus five. Overall, the sample was made up of 110 females and 120 males.

For the focus group interviews, in each school, students who were identified as having exhibited the documented weaknesses on the achievement test were singled out and organized for the interviews. (In four of the schools, all the students in the classes selected were involved in the focus group interviews).

Instruments

Two instruments were used to collect data for the study.
They were:
[1] a Biology Achievement Test (BAT)
[2] an Interview Schedule (IS)

The BAT consisted of selected past WASSCE items on graph. The items on the achievement test consisted of one question (with sub-divisions) on graph work. The question required the plotting of two graphs on the same graph sheet, interpretation of graph obtained and explanation of the results. In all 14 points were required tobe plotted on the graph sheet provided. In addition, students though not told, were required to provide all the rubrics of a biological graph – an appropriate title/heading, joining lines neatly ruled, appropriate scale for the graph, correct choosing of the axes (showing students' knowledge of the dependent and independent variables), correct labeling of axes (including correct units) and an appropriate key.

The BAT was used to assess the students' competence with regard to graph work.

The interview schedule (IS) was based on students' responses to the achievement test. It was used to further explore the reasons why students made the mistakes they did on the test. It consisted of a part for students and a part for teachers. The part for students sought students ideas on why they made the mistakes noted on the various competencies on the graph work. For instance, students were asked to confirm whether they had been taught how to plot, describe and interpret graphs in biology. They were then asked to give details of what they had been taught with regards to graphing in biology. The teachers' part also consisted of questions directed at pinpointing teachers' views on why their students made the mistakes identified. To begin with teachers were asked whether they had taught their students graph work as required by the biology syllabus. Subsequent questions required the teachers to elaborate on their answer to the first question. For example

(i) Kindly enumerate the rubrics of graphs that your students are aware of.
(ii) Do they know the importance of each of these rubrics?
(iii) A number of your students did not provide headings for the graphs plotted. Can you explain why?

Validity of the Instruments

The face validity of the achievement test was determined by giving copies of the test to experts in biology education in the Department of Science and Mathematics Education of the University of Cape Coast for their perusal and comments. A biology teacher in one of the schools was also given a copy for comments on any ambiguities, confusing terminologies or statements. Comments and inputs from the experts were used to fine-tune the test into the final one used for the actual study. The content validity was ascertained by using the biology syllabus as a form of table of specification to check whether the questions covered all aspects of both graph work in biology as stipulated.

The construct validity was assumed since the questions were all culled from past WAEC SSSCE biology papers. (All WAEC examination questions are supposed to have gone through various test of validity as a team of experts in assessment are employed to check all that.)

For the interview schedule, only the face validity was considered. This was done by giving copies to experts of biology education in the Department of Science and Mathematics Education of the University of Cape Coast. They read through and gave their comments. After making the required changes, the schedule was used for the study.

Reliability of the Instruments

The instruments were administered as a pilot test to a school in the Cape Coast Metropolis which was not used for the actual study. A marking scheme was developed for scoring the items dichotomously, with the exception of the graph description and interpretation which were scored subjectively.

The inter-rater reliability of the scores on the free-response part of the graph work was determined. (This part was scored subjectively, that was why another scorer was also asked to score using the same marking scheme and the inter-rater reliability determined.) The inter-rater reliability coefficient was found to be 0.93.

Kuder-Richardson (KR) 20 was used to determine the reliability of the other items which were scored objectively. The KR 20 value for the other part of the graphing was found to be $r = 0.81$.

Data analysis

Both quantitative and qualitative analyses were employed inthis study. Quantitative analysis was used to analyze the resultsfrom the achievement test in the form of inferential anddescriptive statistics such as frequencies, percentages, means, T-testand ANOVA. The qualitative analysis was used for datafrom the interviews where the responses were pure descriptions.

A marking scheme was prepared for scoring the BAT items.

The scoring, in the most part was done in the form of a checklist, where a mark was given for the required competency indicated and '0' was for absence/incorrect competency demonstrated.

To answer research question one, descriptive statistics (such as means, percentages, and frequencies) were used. Percentages were used in pinpointing the specific areas on the graph work where students exhibited weaknesses. The frequencies and percentagees of students who failed to exhibit the competencies required were then compared, and the areas where students failed most (i.e. where more than 20% of students had it wrong)were considered to be the most difficult ones and were therefore labeled as the specific weaknesses of the students.

The descriptive statistics were most appropriate since ithelped pinpoint students' specific weaknesses with graph work.Responses from the interview were analysed thematically andused to explain students' answers on the test.

To help answer research question two, a pure description ofboth the teachers and students' responses were giventhematically. This was most appropriate since the interviewresponses were used for this.

The independent sample t-test was used at 5%significant level to test whether male and female studentsperformed differently on the graph. However, One-wayAnalysis of Variance (ANOVA) test was also used to testwhether there were significant differences in performance ofstudents in the different school types.

Box plots were used to explore the distribution of scores inthe three school types. They were also used to further explore the differences in the distribution of scores between the males and females in the coeducational schools. This was done in order to find out whether the differences in performance between the male and female students were due to other factors other than mere gender differences. Thus the box plot displays for the male and female students in the whole sample were compared with that of the male and female students in theco educational schools. The differences noted were then explained.

Results and discussion

Differences in Performance on the BAT by Gender

The first null hypothesis sought to test whether differences exist in the achievement of males and females on the graphwork. To test this, students' scores on the various competencies on the test were analysed using independent samples t-test.

Differences in Performance on the Graph Work by Gender

Hypothesis 1 was tested using independent sample t-test. Table 1 presents the independent samples t-test analysis of students' scores on the graph work by gender. The test was conducted to compare the graph work scores for males and females. (The total score for the graph work was 28). The results revealed that there was a significant difference between the scores of females (M = 5.16, SD = 1.86) and males (M =4.22, SD = 1.75, p = .001). (The research hypothesis 1 tested at the .05 significance level is 'there is no significant difference in the achievement of male and female students on the graphing and drawing tests'.)

The t-test analysis indicated that female students performed significantly better on the graph work than the male students. The magnitude of the difference in the means was moderate (et as quared = .064) indicating that there is a moderate associationbetween gender and performance on graph work (Cohen, 1988).

Table 1: Comparison of the Mean Scores of Male and Female Students on the Graph work

Gender	Mean	SD	df	t-value	p-value	η^2
Male	4.22	1.86	228	3.95	.001	.064
Female	5.16	1.16				

To further compare the distribution of scores on the graph work by the males and females, a box plot was employed. Figure 1 is a box plot of the distribution of scores on the graph work for the male and female students. From the output, the distribution of scores on graph work for males and females is quitedissimilar.

While the male students had the least score in the distribution, they scored the same high score as the females. Thus there was some overlapping of scores from score 4 to score 7.

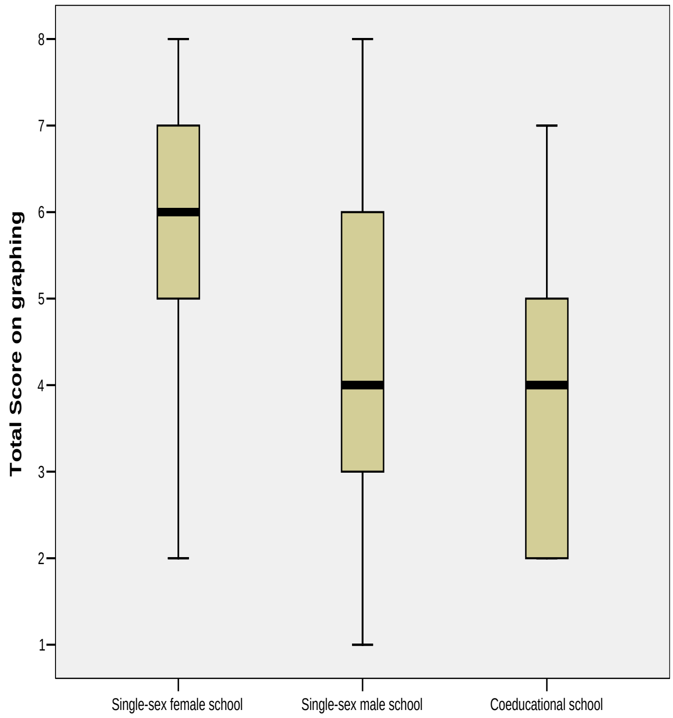

Fig.1: Distribution of scores on Graph work for the Three School Types

School Type and Performance on the Graphing

The first null hypothesis sought to test, if any, differences exist between the three school types (that is, single-sex female (SSF), single-sex male (SSM) and co-educational (CE) schools) with regards to students' performance on the graph work. Students' scores on the various competencies on the graph work by their school types were analysed using a one-way Analysis of Variance (ANOVA).

There was a statistically significant difference at the alpha=.05 level between the mean scores on graph work for the three school types [F (2, 227) = 33.21, p = .001]. However, despite reaching statistical significance, the actual difference in mean scores between the groups was quite small. The effect size, calculated using eta squared, was .023. This is small, according Cohen (1988).

Gabriel posthoc test was run to find out where the differences exist. The pair wise comparisons using Gabriel posthoc test indicated that the mean score for SSF (M = 5.90, SD = 1.634) was significantly different from both SSM (M = 4.51, SD = 1.85) and CE (M = 3.71, SD = 1.40). SSM also differed significantly from CE. This shows that students in single-sex female schools performed better than their counterparts in both the single-sex male and coeducational schools on the graph work. Also, students in single-sex male schools did better on the graph work than students in the mixed schools. Therefore, the null hypothesis is rejected.

Table 2: Performance on Graphing by School Type

School Type	Mean	SD	F	p
SSF	5.90	1.61		
SSM	4.51	1.85	33.21	.001
CE	3.71	1.40		

To further explore the variability of the scores on the graph work by the three school types, box plots of the distribution of the scores was made. This is presented on Figure. The display shows that while there was some overlapping of scores between the single-sex female schools and the single-sex male schools, there was no overlapping with the coeducational schools.

However, the distribution of scores obtained by the single-sex male schools had some overlapping with the scores of theco educational schools. The overlapping ranged between scores 3 and 5. Also both the single-sex male schools and theco educational schools had the same median value of 4.

The boxplot display also indicates that the single-sex male schools had the least score on the graph work. Yet they had the same high score as the single-sex female schools. Single-sex female school Single-sex male school Coeducational school.

From the analyses above, the hypothesis two that no significant differences exist between the school types with regards to performance on the graph work is rejected because statistically significant differences were found in the performance of the students from the various school types.

Overall, single-sex female schools outperformed the single-sex male and coeducational schools. Also the single-sex male schools outperformed the coeducational schools.

From the literature reviewed, these two findings both confirm and contradict other research findings. The finding that single-sex females outperformed both single-sex male and coeducational school on the graph work is similar to what Jimenez and Lockheed (1998) found in a study. They found that girls in single-sex female schools have been found to do better in biology than girls in coeducational schools (Jimenez, 1998).

Yet Harker (2000) found no difference in single-sex school girls' biology achievement when compared with those in coeducation. Also, a number of studies conducted in Britain in the 1970s and 1980s indicated something similar. Ormerod (1975), Spender and Sarah (1980), and Deem (1984) all found that girls tended to have higher academic achievement levels in single-sex classes and/or schools. However, Goldstein *et al* (1993) found no significant advantage in the educational achievement of girls in single-sex schools, once intake differences among schools were taken into consideration.

That both single-sex female and single-sex male schools had a performance edge over the coeducational schools confirmed what Malacova (2007) found in a study. He found that both boys and girls in more selective single-sex schools had a performance advantage. Thus, the single-sex schools out-performing the coeducational schools may be due to the fact that the single sex schools are selective in terms of the caliber of students they admit to their science programs.

Performance of the Male and Female students in the Coeducational Schools on the Graph Work

Hypothesis 2 sought to find if differences in the performance of the male and female students in the coeducational schools on the graph work existed. To test this, their scores on the graph work were analysed using independent samples t-test. The results of the test are presented in Table 3.

The independent-samples t-test was conducted to compare the graph work scores for males and females in the coeducational schools. There was no significant difference in scores for males (M = 3.62, SD = 1.36) and females (M = 3.83, SD = 1.47, p = .001). The magnitude of the differences in the means was small (eta squared = .01). Therefore the null hypothesis 4 which states that there is no significant difference in performance of the male and female students in the coeducational schools on graph work is accepted.

To further explore the distribution of scores for the males and females from the coeducational schools boxplots were employed. The display is presented as Figure 5.

Table 3: Comparison of the Mean Scores of Male and Female Students from Coeducational Schools on the Graph work

Gender	Mean	SD	df	p-value	t-value	η^2
Male	3.62	1.36	80			
Female	3.83	1.47	80	.001	.674	.01

From Figure 2, the distribution of scores for the female students overlaps that of the male students. Also the two groups had the same median mark of ‘4’. Comparing these results with that for the male and female scores for the three school types, it appears that the differences in achievement found may not be due to inherent gender differences. The differences may be due to the quality of students in the single-sex female schools used for the study.

Indeed the single-sex female schools used for the study are ranked among the best in the country as a whole. Also they are known to perform highly in the SSSCE/WASSCE. Thus the performance advantage that the female students in the whole sample had over the male students may solely be due to the high scores obtained by the students from the single-sex female schools.

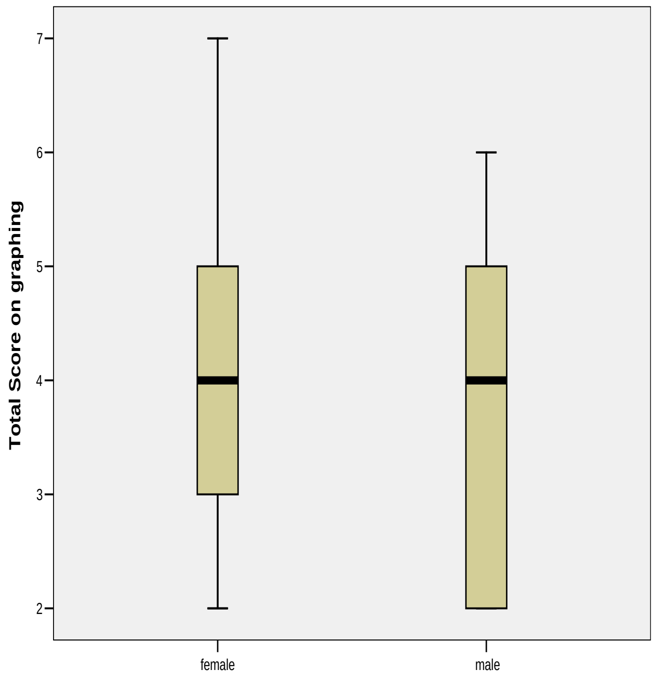

Figure 2: Distribution of Scores on the Graph work by the Male and Female Students from the Coeducational Schools

Specific Weaknesses Exhibited by Students on Graph Work

The first research question sought to find out the specific weaknesses exhibited by SHS 3 students on biological drawings and graph work. Table 4 presents the frequencies and percentages of students who did not exhibit the necessary competencies required on the graph work.

Table 4: Frequencies and Percentages of students having the Competencies on the Graphing wrong (N=230)

Competency	Frequency	Percentage (%)
Wrong/missing heading for graph	154	67.0
Lines joining points not ruled	57	24.8
Scale (Inappropriate/not provided)	139	60.4
Wrongly chosen axes	8	3.5
Wrong labeling of axes	174	75.7
No key provided	121	52.6

Table 4 shows that with graphing majority (over 60%) of students had difficulties with the heading, scale, labeling of axes, and provision of a clear key. The most difficulty was withthe labeling of axes (75%) even though almost all students (96.5%) were able to choose the correct axes. Neatly ruling lines to join points plotted was not a problem for about three-quarters of the students compared to what are listed above, yet one-quarter of the students still had this problem.

These findings confirm Cain's (2006) assertion that students have difficulty choosing the variables to plot, indicating on the graph what they have plotted (i.e. provision of an appropriate key), and labeling the correct units.

Also, it was found that students had the most difficulty with description and explanation of the graphs drawn (that is graph interpretation). When asked to describe the graph obtained after plotting it, 97.8% of students described the shape of the graph, instead of mentioning the changes in the conditions/phenomena the graph was based on. Students therefore demonstrated a lack of one of the skills needed to interpret graphs in biology which

Brasell (1990) refers to as understanding the meaning of the shape of the graph when describing how one variable relates to another. If students understood the meaning of the shape of the graph they would not have just described the 'rise and fall' of the graphs plotted. They would rather have described the fluctuations in blood glucose level of the two people involved (one with a normal pancreas and the other with a defective pancreas) with time as represented by the graphs plotted.

These responses should have rather highlighted the following:

Glucose level was always higher in person with defective pancreas. It was originally 100 mg/ 100 ml of blood in normal person and returned to the same value 2 hours after taking the glucose drink. It was 250 mg/ 100 ml of blood in person with defective pancreas and returned to the same value 4 hours after the glucose drink. The level rose by 70 mg /100 ml of blood in one hour after taking the drink for the normal person and rose by 230 mg in person with defective pancreas within the same time frame – that is 10% and 92% respectively.

Thus for this question, out of a total of 4 marks, only 2.2% of the 230 students could score a mark. This indicates that students find it very difficult explaining results obtained from plotted graphs.

However, the following are examples of students' wrong answers:

For the graph of one with a normal pancreas, the graph was constant between 6:00 am and 7:00 am after which it rosesharply between 7:00 am and 8:00 am and declined sharply between 8:00 am and 9:00 am. The graph rose gradually between 9:00 am and 10:00 am and remained constant till noon(Student, School F2).

This student from school F2 (a single-sex female school) just stated what was given in the data for plotting the graph. This could have been written without plotting the graph at all. Itseems this student saw the graphs plotted simply as two linesrising and falling with time. She did not see the graph as representing a phenomenon even though it was stated in thequestion. Thus she interpreted the graph as if it was a picture(or as if it were some other kind of graphic display) (Bell, Brekke& Swan, 1987).

Students' responses from Schools C2 (a coeducational school) and M1 (a single-sex male school) shows similar responses on description of the graph. This shows that students from all the three school types had similar difficulties with description of the graph.

The graph of the person with the normal pancreas was constant from 6 am to 7 am, and then rose quite sharply at 8 am. It fell quite sharply at 9 am and rose gently at 10 am. It remained constant from 10 am to 12 noon. The graph of the person with the defective pancreas was constant from 6 am to 7am, rose very sharply from 7 am to 8 am, and then fell gently at 9 am. The graph then fell quite sharply from 9 am to 10 am, then from 10 am to 11 am (still fell quite sharply), and then remained constant from 11 am to 12 noon (Student, School C2).

From the graph of a person with normal pancreas, the graph was horizontal initially and rose sharply to its peak. The graph then declined sharply and rose gently again and became horizontal. From the graph of a person with defective pancreas, the graph was horizontal initially and rose sharply to its peak. It declined gently, then sharply and became horizontal. A person with normal pancreas had a blood glucose level of 100 mg/100 ml blood from 6:00 am to 7 am. Immediately, the person took the drink containing 100 g of glucose, the person's blood glucose level rose to 170 mg/100 ml blood. After 2 hours, the person's blood glucose level returned to 100 mg/100 ml blood. A person with defective pancreas had a blood glucose level of250 mg/100 ml blood from 6 – 7 am. After consuming the solution containing 100 g of glucose, the person's blood glucose level rose to 480 mg/100 ml blood. After 3 hours, the person's blood glucose level returned to 250 mg/100 ml blood.For the person with a normal pancreas, the graph neither fell nor rose from 6 am to 7 am. It rose sharply from 7 am to 8 am then it fell sharply till 9 am from which time it leveled out till 12 noon. For the person with a defective pancreas, the graph neither fell nor rose from 6 am to 7 am. It rose steeply from 7 am to 8 am then it fell gently till 9 am from which time it fell more steeply till 11am. It then leveled out till 12 noon (Student, School M1).

However, this student from School M1did better than the other two students from schools C2 and F2. This is because in addition to describing the graph as a line rising and falling with time, this student made mention of changes in the blood glucose. However, the student saw the graph plotted as only a line rising and falling.

Another question tested students' skills in extracting essential information from a given graph, and explaining trends shown in the graph in terms of content knowledge. The following are examples of students 'responses to the question which required them to explain the results obtained from plotting the graph as far as they could for the person with the defective pancreas.

The person with the defective pancreas had his blood glucose level increasing vastly after taking a solution with glucose. It then decreased gradually to normal. This was because the defective pancreas could not convert glucose easily to glycogen and so it does that in a slow process. The slow process of converting glucose to glycogen accounts for the steep nature of the graph as it ascends and descends (Student, School F1).

The responses from this student from School F1shows that her knowledge of the functions of the pancreas is inadequate. This is because a defective pancreas cannot convert glucose to glycogen for storage, not even slowly as she assumed. This response is similar to that of a student from School C1:

The person with the defective pancreas had a fairly constant but higher glucose level than the one with the normal pancreas before the glucose solution was taken and the glucose level shot up very high from its constant value because the insulin in the defective pancreas is unable to effectively control glucose levels as a normal pancreas would. The glucose level therefore was very high for some time before hitting 250 mg/100 ml blood again which is still abnormal due to the ineffective work of the insulin (Student, School C1).

This student also failed to highlight what the defective pancreas was not doing as well as explain why the person's blood glucose level went back to the original level after some time. Obviously, he could not predict changes in the trends when a variable (i.e. the glucose level) was manipulated. In addition, he was unable to link the graph with the variables or with phenomena in the real world (Brasell, 1990).

Also, the following examples from Schools M2 and C2must also be noted:

The blood glucose level of the person with the defective pancreas increased by nearly 100% after he had taken the 100 g glucose solution. This was quite abnormal due to the fact that the pancreas which was defective could not immediately regulate the blood sugar level within a reasonable range. After a while though, the level reduces to 450 and then after an hour, to360. This is because the defective pancreas gradually and slowly stabilizes the sugar content in the blood (Student, School M2).

For the person with the defective pancreas, measurements of his blood glucose level around 6 am were around 250 mg/100ml which due to its initial value remained constant for the next minute. After this period, the level increased to the highest level 480 mg/100 ml due to the presence of the defective pancreas which cannot help in controlling the blood sugar level. After this level, which was around 8 am, the body became weak and was eventually approaching death, so around 9 am to 12 noon, the body became restless till 12 noon when death was encountered (Student, School C2).

These examples from the two students from schools M2 andC2, portray students' lack understanding and application in answering the question. The student from school M2 had the misconception that a defective pancreas though unable to function immediately when more glucose was introduced could do so after some time. This was used to explain why the blood glucose went back to the level it was before the consumption of the glucose solution. The answer from the other student from School C2 is quite interesting. After attributing the high rise in blood glucose level in the person to the defective pancreas, he went further to state that the body of the person with the defective pancreas became weak and was about to die. It became agitated till it died at noon. This is apparently his own interpretation of what he thinks happens to someone with a defective pancreas eventually, but he stated it as a fact.

The correct response should have captured the following:

Defective pancreas was not producing any insulin so the glucose in the blood could not be converted into glycogen by the liver. The blood sugar level fell later after they had taking the glucose because some were excreted by the kidney and some metabolized by the body.

This answer was for 2marks. For this question, only 2% of students were able to obtain half of the total score (1 mark). The rest of the students failed to score any mark on this question.

Sub-question (d) asked students to explain why the glucose level of their blood rose immediately after the glucose solution was taken in. This question tested students' application of knowledge to explain the phenomenon. Some of the students' responses were as follows:

The results show that if there is less insulin in the system (blood) there will be more glucose in the system. The person with the defective pancreas produces less insulin and this accounts for the high level of glucose in his blood (Student, School F1).

It appears this student had no idea that glucose does not undergo digestion but is absorbed directly into the bloodstream from the stomach. The student seems to be equating the defective pancreas' not producing the needed insulin with regulation of blood sugar level. He did not even consider the case of the normal pancreas as the blood glucose level of that person also rose immediately after taken in the glucose solution. Clearly, he failed to apply the appropriate knowledge in his explanation.

The glucose level of their blood rose immediately after the glucose solution was taken because glucose is an end product of digestion, hence absorbed in the stomach and thus escapes the pancreas. But after a while when the blood sugar rises, insulin is secreted and it begins to work on the glucose in the blood. Thus the blood level rose immediately as it was absorbed by the blood stream just a few minutes (immediately) it (the glucose) was taken in (Student, School C2).

This student from School C2 was on the right path, but failed to distinguish between a defective and normal pancreas as to why the glucose went to its initial level in each of the cases.

Otherwise, his answer was a good one. However, the following responses from Schools M2 and F2 show students have the notion that glucose undergoes digestion.

The glucose level of their blood rose immediately after the glucose solution was taken because it increased the level of glucose drastically. Insulin had not yet been produced to regulate the sugar content (Student, School M2).

The glucose level of their blood rose immediately after the glucose solution was taken in because the pancreas needed some time to be able to secrete enough insulin to nullify the effect of increased glucose intake (Student, School F2).

For these students it appears they have forgotten that glucose does not undergo digestion but is absorbed directly into the blood stream. Both of them concentrated on the defective pancreas not secreting the required insulin to regulate the sugar level. They even ignored the case of the normal pancreas which was in working condition and could therefore secrete the required insulin for the sugar level regulation. The correct response which earned 2 marks was:

Glucose is a monosaccharide and as such does not require digestion first before absorption. It is absorbed in the stomach where it reaches immediately after drinking.

Thus for this question, only 20% of the students who took part in the BAT scored the total of 2 marks; 35.7% scored 1 mark with the remaining 44.3% not scoring any mark on the question.

It can therefore be concluded that the most difficult part of graphing for students seems to be providing descriptions of the phenomena represented on graphs and applying concepts learned to explain those phenomena.

However, when asked to recall directly the concepts during the interviews without reference to the graphs, students were generally able to produce correct answers which they could not give on the test. The weaknesses of students were therefore that of applying what had been learnt.

In summary, the specific weaknesses of students on graphing therefore were:

1. difficulty with providing an appropriate heading,
2. failure to choose an appropriate scale,
3. incorrect labeling of axes,
4. inability to provide a clear key,
5. failure to use neatly ruled lines to join points plotted,
6. problem with giving accurate description of graph drawn,
7. inability to explain phenomenon represented by graph (where concepts learned need to be applied), and
8. difficulty in making deductions from data given.

These findings are consistent with what is in the literature. Comparing these findings with the Chief Examiners' reports, it could be seen that though the reports frequently label students inability to describe graphs plotted (WAEC, 2000), inability to derive practical value from data provided for the graphs (WAEC, 2000; 2004) and not giving proper headings to graphs drawn (WAEC, 2004) as the specific weaknesses exhibited by candidates on graphing, weaknesses of students on graphing go beyond these as enumerated above. Furthermore, the weaknesses are not solely limited to non-exhibition of integrated skills needed for graph work in biology, but include inability to exhibit basic skills needed to make graphs in biology as well.

Table 11 presents the frequencies and percentages of the students who could not exhibit the desired competencies on the drawing. It can be seen from the Table that with making biological drawings, students had the most difficulty in providing an appropriate heading for the drawing, avoiding any form of shading, drawing accurate features of specimen given and making ruled guidelines with no arrowheads. This is because on these competencies the percentages of students who failed are all above 25%.

Students Views on why they made Mistakes on the Graph Work

Provision of Heading for Graph

According to 11 of the students, they could not provide an appropriate heading for the graph because the information provided on the BAT was not explicit enough. They could therefore not deduce the heading from the given information.

However, the majority of the students interviewed (25 in number) said they could have provided an appropriate heading but for forgetfulness. This may mean that they rather gave attention to aspects of the graph that they found more difficult thereby forgetting those that they could have scored marks for easily.

Choosing of an Appropriate Scale

While 11 students said they could not provide an appropriate scale for the graph because they were not familiar with plotting two graphs on the same axes using the same scale, 22 said they had the scale in mind but only forgot to indicate it on the graph. The remaining three students did not give any reason for their failure to provide an appropriate scale for the graph. This means that the examples worked in class did not include plotting more than one graph on the same axes, although this is in the syllabus. Also almost all the past questions on graph require more than one graph plotted on the same axes. It is therefore very surprising that students gave this as a reason.

Labeling of the Axes

With the exception of eight students who said they forgot to label the axes, all the other students interviewed said they labeled the axes but had no knowledge of the need to include the units. Thus instead of labeling the abscissa 'Blood Glucose Level (mg/100 ml of blood)' they simply wrote 'Blood Glucose Level'. It was obvious that these students could have scored the mark for the competency had they not been ignorant of the fact that label includes the units.

Provision of a Clear Key

All the interviewees but two said they knew they had to provide a key for the graphs plotted, but that they forgot to do so. The other two interviewees said they used labels for the graphs and thought that could suffice as the key since they thought the labels would differentiate between the two graphs.

Description of Graph

One student said he was not able to describe the graph he plotted because they were not taught into details as to how to go about. When asked to elaborate on his statement, he said what he was taught was what he used in giving the description he gave. But since he had it wrong, then he believed he was not taught what was needed to answer the question, what he called the details. Seventeen of the students interviewed said they did not know what was required for doing this. Eighteen of the interviewees said they had the idea that describing the shape of the graph was enough.

Explanation of the Results from the Graph

Seventeen of the students said they did not get the underlying concepts they needed to apply in giving the needed explanations when asked why they could not give the appropriate explanation of the results from the graph. One of them summed it up succinctly in the following words:

We had been taught assimilation of glucose but we could not apply it on the test because we did not really know how to do it.

This may mean that application of what they were taught on the topic to real life situations was lacking. This buttresses what the Chief Examiners have been reporting. Making deductions is a difficult exercise for candidates (WAEC, 2003). Since this problem is persistent, and not limited to only graph work inbiology, some drastic measures need to be put in place to arrestit.

Teachers Views on Why Students made Mistakes on the Graph Work

Next teachers' views on why students made the mistakes were considered. They were also presented in themes as it was done for the students' views.

Provision of Heading for Graph

According to two of the teachers the students who could not provide heading for the graph were lazy and not serious with things that they considered to be trivial. Another said she could not fathom why the students failed to provide the heading. She believed it must have been forgetfulness on the part of the students since they had been taught all the rubrics of graph work, provision of an appropriate heading inclusive. And if it was because they forgot to provide the heading, she said it might have been because the students took the test as an examination; thus examination uptightness could be blamed for the omission.

Obviously, this teacher was in agreement with the students, who implied the same thing. (That is, it was due to examination tension). The remaining three teachers could not give any reason for the students' failure on this competency. They simply shrugged their shoulders and said they could not tell why.

Choosing of an Appropriate Scale

'For some of these it appears students need to be reminded of such in the examination hall', so said one of the teachers interviewed. This he said because he believed if you have taught students all they need to know on a topic, such as graph work, taken them through all the necessary rubrics, then they should be able to score when it comes on an examination. Thus if they could not score, then perhaps they should be reminded of what to write even in the examination room. The others made no comment other than just shrugging.

Labeling of the Axes

Two of the teachers said the students were just lazy. Otherwise they should have been able to label the axes. They had been taught that unless a variable has no unit when labeling the axes units are necessary, so why will they label without the units when it was clearly indicated in the question. Another teacher thought may be the students found the rubrics to be too many and thus tended to forget some of them. That teacher was in agreement with eight of the students who ascribed their in ability to label the axes to forgetfulness. The remaining three teachers just shrugged, saying they could not come up with any reasons why the students will label the axes wrongly.

Provision of a Clear Key

All the six teachers agreed with the students that those who did not provide a key for the graph must have forgotten to do so. They argued that since they had taught them that the nature of the graphs in biology required a key to enable whoever is going to mark their work distinguish between the two or more graphs that they will be required to plot. They had had classroom exercises where for the students' inability to describe the graph plotted, the teachers felt the students failed to do so because they had not solved the same question in class for them to rote learn and reproduce. This means that the students could not apply what they had been taught to solve questions other than those that they had solved in class. Here it is clear that both students and teachers are in agreement on the fact that application of what is taught to practical situations is lacking on the part of the students.

The teachers blamed the students' inability to link concepts learned to the phenomenon presented on the graph as the reason for their being unable to explain the results from the graph. All this is in accordance with what Lowrie and Diezmann (2007) have reported. According to them interpreting graphics is complex for students. Also students restrict themselves to reading data and processing specific aspects of the material and encounter problems when they have to go beyond the basic/elementary level and interpret the information represented.

In the light of this it is clear that the students lack the integrated skills required to do graph work in biology. In other words students' ability to change the information seen into meaningful information, that is, their graphic cognition (Kali, 2005) is faulty. However, if it was only on this particular test that they omitted to provide them, then it could be ascribed to just an oversight.

Description of Graph

Five of the teachers said that the students could not describe the graphs because they had not solved the same question in class for them to rote learn and reproduce the answer on the test that is why they could not do it. They said that short of that they could not think of any reason for the students' inability to give the description required, since they had solved similar questions in class, where they had been taught how to describe graphs plotted.

This means that the students could not apply what they had been taught to solve questions other than those that they had solved in class. Here it is clear that both students and teachers are in agreement on the fact that application of what is taught to practical situations is lacking on the part of the students.

Explanation of the Results from the Graph

All the six teachers blamed the students' inability to link concepts learned to the phenomenon presented on the graph as the reason for their being unable to explain the results from the graph. All this is in accordance with what Lowrie and Diezmann (2007) have reported. According to them interpreting graphics is complex for students. Also students restrict themselves to reading data and processing specific aspects of the material and encounter problems when they have to go beyond the basic/elementary level and interpret the information represented. In the light of this it is clear that the students lack the integrated skills required to do graph work in biology. Inother words students' ability to change the information seen into meaningful information, that is, their graphic cognition (Kali,2005) is faulty.

Since an inadequate mastery of graphing skills is a major hurdle in understanding [some] scientific concepts (Jackson *etal.*, 1993; Mokros& Tinker, 1987), these students need to be helped to acquire the skills they lack with regards to graph work.

Also, when this problem is addressed not only will their performance on graph work improve, their understanding of some scientific concepts related to graph work, in subjects such as physics and chemistry as well as biology will also perk up.

Conclusions

It was the objective of this study to examine specific weaknesses exhibited by SHS 3 elective Biology students on graphing in the light of what WAEC Chief Examiners have been reporting. Also, the study investigated the probability of there being differences or not in students' performance on graphing between single-sex female, single-sex male and coeducational schools in the Cape Coast Metropolis.

From the literature reviewed for the study it emerged that when it comes to graph work students have problems with data plotting, because they do not understand the fundamentals of graphing. They also have difficulty choosing the variables to plot, indicating on the graph what they have plotted, and labeling the correct units. Furthermore, according to the literature, interpreting graphs is complex for students because they restrict themselves to reading data and processing specific aspects of the material and thus encounter problems when they have to go beyond that elementary level and interpret the information represented. Indeed the findings from the study were in support of those from the literature review.

Recommendations for Policy and Practice

Based on the findings from the study, it is recommended that

1. Biology teachers should try as much as possible to use the Chief Examiners' reports in their teaching so that weaknesses pointed out by the examiners will be taken care of. This will help students avoid repeating them in their write-ups.
2. Biology teachers and their students should go the extra mile in ensuring that the rubrics of graphing are at students' fingertips. Teachers can do this by giving students lots of exercises on graphing and drawing, making sure that such exercises are marked and discussed in class with students

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