RELATIONSHIPS AMONG FOUR LEARNER VARIABLES AND THE PERFORMANCE OF SELECTED JAMAICAN 11TH-GRADERS ON SOME STRUCTURED QUESTIONS ON THE MOLE CONCEPT

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This study sought to find out if (a) the performance of 113 Jamaican 11th-graders on a mole concept test was satisfactory or not; (b) there were significant differences in their performance linked to their chemical and mathematical abilities, gender and socioeconomic background (SEB); and, (c) there were significant relationships among the four independent variables and their performance on the test. The participants, comprising 66 boys and 47 girls, were selected from three traditional high schools in Kingston, Jamaica. Nine structured questions that the authors constructed were used to assess their performance. The results revealed that the students' performance was unsatisfactory as their mean score (10.65 or 23.67%) was far below the conventional 50% pass mark; there were significant differences in their performance based on their chemical and mathematical abilities in favour of students with high abilities in both cases; and, there was a positive, statistically significant and 'substantially reliable' correlation (Miller, 1991) between the students' chemical abilities and test performance ($r = .58$, $p < .001$), mathematical abilities and performance ($r = .56$, $p < .001$) all in favour of students with high abilities in each case, while the correlation between their (a) gender and performance ($r = .37$, $p < .01$), and (b) SEB and performance ($r = .27$, $p < .01$) was positive, statistically significant but weak in each case.

INTRODUCTION

The "mole" is the standard method in chemistry for communicating how much of a substance is present in an entity or object. The International Union of Pure and Applied Chemistry (IUPAC) defines the mole as the quantity of substance which contains as many entities as there are atoms in 0.012 kilogram of carbon-12. The union insists that the elementary entities must be specified as these may be atoms, molecules, electrons, ions or particles or groups of particles. The authors of most chemistry textbooks define the "mole" as the International System of Units' (SI) unit for the quantity of a substance. Hewitt (1980) reported that the SI units were examined publicly at the secondary and tertiary levels in 1972, and that the SI units were subsequently introduced into the science curricula in order to standardise units across scientific disciplines internationally. The mole replaced all gram-atom, gram-molecule, gram-equivalent, gram-formula masses, and faraday. A mole can be defined as a certain quantity of a substance that contains 6.02×10^{23} (Avogadro number) of the substance. The mass of a mole of a substance is equal to its formula mass expressed in grams. For example, a mole of sodium hydroxide (NaOH) has a mass of 40g (i.e. its formula mass). One mole of a substance in the gaseous state occupies 22.4 litres ($1dm^3$) at standard temperature and pressure (STP) or $24dm^3$ at room temperature and pressure (RTP).

There are many reasons why many students find the mole concept difficult to understand. First, from our chemistry teaching experiences, we have discovered that students who had difficulty in learning chemistry were those who were unable to think about chemical problems in terms of "moles". The Caribbean Examinations Council's (CXC) examiners' reports on candidates' performance in the secondary education certificate general proficiency examinations (SECGPE) in chemistry (1996-2002) indicated that most of the candidates had not mastered the mole concept because of their lack of understanding of the fact that the ratio by which moles of substances react is the same as the ratio by which their atoms and molecules react. Second, many students lack the problem-solving abilities required for the understanding of the mole concept. The CXC's (1996 - 2002) examiners' reports on the SECGPE in chemistry showed that many candidates' working explanations were mathematically unsound. The reports also underlined the point that the mole, together with chemical equations, is used to show quantitative relationships that exist in reacting systems while at the same time providing information about the reactions at the particulate level. Yet, many of the candidates were ignorant of these facts.

Furthermore, the distinctions among the terms moles, molar mass, and molarity are not obvious to many chemistry students. Other difficulties that Jamaican chemistry students experienced in solving numerical problems on the mole concepts include (a) their inability to deal with calculations involving equations, (b) inability to interpret formulae, and (c) not fully grasping the fact that chemical equations are summaries of chemical reactions and that formulae in equations represent moles of entities (Hewett, 1980). The following reasons—which the CXC's (1996-2002) examiners' reports on 11th-graders' performance on the SECGPE in chemistry advanced as the explanations for the poor understanding of many of the students on the mole concept - support some of Hewett's (1980) reasons, namely:

1. the mole is an abstract concept; this requires a careful building up of prerequisite concepts;
2. the mole needs to be introduced along a concrete/abstract continuum though a sequence of phases as is done with other abstract scientific concepts; and,

3. the successful solutions of numerical problems on the mole concept are dependent on the writing of formulae and the balancing and interpretations of chemical equations.

The findings of numerous studies on learner variables that are associated with differences in high school students' performance in chemistry are inconclusive. Among these variables, which we explored in this study, are the students' gender, chemistry and mathematical abilities and SEB.

Whereas several studies have reported that male high school students significantly outperformed their female peers in all science subjects (Forrest, 1992; Third International Mathematics and Science Study, TIMSS, 1997; Whiteley, 1995), Whiteley (1994) found out that 11th-grade male students in Barbados, Jamaica, and Trinidad and Tobago significantly outperformed their female counterparts in the SECGPE in biology, chemistry and physics. But, Lofters (2002) found no gender differences in Jamaican 11th-graders' performance on the mole concept using multiple-choice items.

Many studies have been conducted on the correlation between students' attitudes to chemistry and their performance in the subject. However, very little has been done to investigate the correlation between students' chemistry ability and their chemistry performance. The CXC's (2000) examiners' report on candidates' performance in the SECGPE in chemistry showed that the Caribbean 11th-grade students performed poorly on questions involving the mole concept particularly those involving calculations. The report noted that the students' chemistry ability did influence their performance on the chemistry examination especially on the mole concept.

The correlation between students' mathematical ability and their chemistry performance has not been widely explored. The authors, therefore, examined the CXC's (1996-2002) examiners' reports on the 11th-graders' performance in the SECGPE in mathematics to investigate this relationship. During this period, the candidates' performance on the algebraic questions was poor. These questions demanded the manipulations of fractions, decimals and percentages and the use of ratio and proportion. These are the mathematical skills required for a good understanding of the mole concept. The authors observed that whenever the candidates' mathematics performance was poor, their chemistry results were correspondingly poor. It could therefore be inferred that the candidates' mathematical ability did indirectly influence their performance in chemistry and, by extension, their performance on the questions involving the numerical problems on the mole concept.

Sociologists such as Slavin (1997) define socioeconomic background (SEB) as the measure of prestige within a society, which is based on an individual's level of income, occupation and years of education. In this study, SEB was determined on whether a student's parent/guardian was a professional (high SEB) or a non-professional (low SEB). Professionals were parents/guardians with high levels of education and high income, while non-professionals were parents/guardians with minimal education and low income. Several studies have demonstrated that students from a high SEB tended to perform significantly better in science than their counterparts from a low SEB (e.g. Fejgin, (1995), among American, Jewish and Asian students; Young & Fraser, (1994), among Australian students). While Clayton-Johnson (1999) recorded a significant SEB difference in Jamaican 11th-graders' biology performance in favour of those from a high SEB, Lofters (2002) found no significant SEB difference in Jamaican 11th-graders' performance on the mole concept using multiple-choice items.

RATIONALE FOR THE STUDY

It is important that high school chemistry students should have a thorough understanding of the mole concept because it acts as a unifying concept linking many aspects of the subject through the syllabus (Gower, Daniels & Llyod, 1977). Yet, as stated earlier, the CXC's (1996-2002) examiners' reports on candidates' performance on the SECGPE in chemistry indicated that many Caribbean 11th-graders performed poorly on questions involving the mole concepts, and we have earlier inferred that their performance was likely to be linked to their chemistry and mathematical abilities. One justification for this study was to find out if there were differences in selected Jamaican 11th-graders' performance on some structured questions on the mole concept based on their chemistry and mathematical abilities because of our belief that the students' understanding of chemistry generally and their mathematical ability in particular were likely to influence their understanding of some of the basic numerical problems on the mole concept.

Another justification for this study was that the authors were unable to access any study that had been undertaken in Jamaica or elsewhere on the relationship among students' gender, chemical and mathematical abilities, and SEB, and their performance on structured/numerical questions on the mole concept, although Lofters (2002), using a multiple-choice test, investigated the relationships among Jamaican 11th-graders' gender, attitudes to chemistry, school location, and SEB and their performance on the mole concept. We believed that the use of structured items would (a) eliminate the chances of the students correctly guessing any of the answers to the questions, which was possible if we had used multiple-choice items, (b) give a true indication of the students' level of understanding of the mole concept as they were required to show all their working in solving the problems, and (c) indirectly test their "deep" understanding of the English language and general knowledge of chemistry.

PURPOSE OF THE STUDY

This study, therefore, sought to find out whether,

(a) the level of performance of selected Jamaican 11th-graders on a test based on some structured questions on the mole concept was satisfactory or not;

(b) there were significant differences in their performance linked to their gender, chemistry and mathematical abilities, and SEB; and

(c) there was a significant correlation between each of the four independent variables and their performance on the mole concept test.

METHODOLOGY

Research Design

As this study aimed at determining if there were significant relationships among students' four variables listed above (the independent variables) and their performance on the mole concept test (the dependent variable), an *ex post facto* research design was utilised (Wiersma, 1995).

Sample

The main study sample consisted of 113 grade 11 students (66 boys, 47 girls) from three conveniently-sampled high schools – one all-boys'(n = 52), one all-girls'(n = 39) and one co-educational high school (n = 22) - in Kingston, Jamaica. Three other high schools in Kingston that had initially consented to participate in this study declined at the eleventh hour. Many other schools that could have participated in the study refused to do so because the chemistry teachers of the prospective participants who were in their final year of their five-year secondary education claimed that they could not spare the time needed to complete the mole concept test administered in this study.

Table 2 shows the detailed composition of the study's sample based on the four independent variables. Although the students were of mixed intellectual abilities, they were among the primary school students who excelled in the common entrance examinations (CEE) that was used to select them into the traditional high schools in 1998. Up till 1998, in Jamaica, primary school students who excelled in the CEE were usually admitted into the traditional high schools while the students who did not do well were admitted into the upgraded high schools. The traditional high schools are the "grammar-school-like" post-primary institutions where the curriculum focuses mainly on academic subjects although some vocational/technical subjects are also offered. These schools traditionally enjoy the services of the most qualified and experienced teachers. On the other hand, the curriculum emphases in the newly upgraded high schools are essentially technical/vocational and the teachers who teach there are usually less qualified and have less teaching experience than their counterparts who teach in the traditional high schools. In short, this study's participants were among the cream of the Jamaican 11th-graders' cohort who were admitted into the prestigious traditional high schools. All the participants had been taught aspects of the mole concept tested in this study.

INSTRUMENTATION AND PROCEDURE

The Mole Concept Performance Test (MCPT), that the authors developed, was used to assess the students' understanding of the mole. It consisted of nine numerical problems based on the concept which was in Section A (Principle of Chemistry) of the CXC's (1998) chemistry syllabus. The questions covered all the nine specific objectives stated on the concept in the syllabus. The areas covered in the MCPT included molar mass and Avogadro's law, the applications of the mole concept to equations, algorithmic calculations involving the mole and molar volume, the applications of volumetric analysis to the mole, and calculations on electrolysis involving the mole. The authors developed a test table of specifications showing the number(s) of specific questions that were used to assess each of the nine specific objectives on the concept. Copies of the questions and the table of specifications were given to the chemistry teachers of the sampled students, an expert in test construction, and two M.Ed. students who were chemistry teachers in traditional high schools. They were requested to comment on (a) the clarity of the language used in writing the questions, (b) the questions' face and content validity, and (c) the accuracy of the specimen model answers to the question and weighting of the points scored in the marking scheme. The validators confirmed the face and content validity of the questions, and minor modifications were made to some of the questions and marking scheme based on their suggestions.

In December, 2002, after obtaining permission from the principals of the selected schools, one of the authors administered the MCPT to the students on specific dates agreed on with their chemistry teachers under examination conditions. The test lasted 60 minutes. The maximum score was 45. As it was not possible to do a pilot study using a test-retest technique to determine the test's reliability, a random sample of the answer scripts of five of the students were photocopied and given to a grade 11 chemistry teacher with a BSc in chemistry to mark using the marking scheme that one of the authors prepared. The overall inter-rater reliability coefficient obtained between the marking of one of the authors and the independent marker was 0.89. This indicates that the two markers were highly consistent in the grading of the students' scripts.

Figure 1 shows the subconcepts of the mole concept tested in this study and the numbers of the structured questions used to assess the students' understanding of the various subconcepts. Appendix A displays the structured questions, while Appendix B exhibits some of the specimen answers and marking scheme used.

Subconcepts tested	Question numbers
Perform calculations involving molar volume	3, 4, 6, 7
Apply the mole concept to equations (ionic and molecular)	5
Write balanced equations including state symbols to represent chemical reactions	5, 7
Perform calculations involving the mole	1, 2, 5, 6, 7
Use the results from volumetric analysis to calculate the (a) mole ratio in which the reactants combine, and (b) concentration and mass concentration of reactants	8

Figure 1: Question numbers and the subconcepts tested on the mole concept test

RESULTS AND DISCUSSION

Table 1
Frequency Distribution, Mean and Standard Deviation of Students on the Mole Concept Test

Score	Frequency	%	Mean	SD
0	6	5.31		
1 - 22	100	88.50	10.65	6.61
23 -29	7	6.19		

Maximum score = 45

The first purpose of this study was to find out if the students' performance on the mole concept test was satisfactory or not. Based on the data in Table 1, we considered the students' performance as unsatisfactory for the following reasons: their mean score 10.65 amounted to only 23.67% of the maximum score; 88.50% of them scored less than 22.50 (or the conventional 50% pass mark) of the maximum score; only about 6% of them scored between 50% and 64% of the maximum score. This finding was expected as it confirmed CXC's (1996-2002) examiners' reports on Caribbean 11th-graders' performance on the SECGPE in chemistry indicating that many students performed poorly on the mole concept questions particularly on questions involving calculations. The finding also receives an indirect support from the findings of Soyibo (1989), and Lofters (2002) that some Nigerian and Jamaican 11th-graders they tested respectively performed poorly on the mole concept.

The second purpose of this study was to determine if there were significant differences in the students' performance on the mole concept test linked to their gender, chemistry and mathematical abilities, and SEB. Table 2 shows the means and standard deviations of the students on the test based on the four variables.

Table 2
Means and Standard Deviations of Students on the Mole Concept Test Based on Four Independent Variables

Variables	n	Mean	SD
Chemistry ability			
High	3	21.33	4.73
Average	40	14.95	6.24
Low	70	7.74	4.97
Mathematical ability			
High	49	14.86	6.36
Average	41	8.19	4.63
Low	23	5.39	4.88
Gender			
Male	66	8.61	5.01
Female	47	13.53	7.52
SEB			
High	54	13.19	7.55
Low	59	9.34	4.67

Table 2 indicates that (a) the means of students with high chemistry and mathematical abilities are higher than those of their peers with average and low abilities respectively; (b) the mean of females is much higher than that of males, and (c) the mean of students from a high SEB is higher than that of those from a low SEB. In all cases, the standard deviations are relatively high suggesting that there were relatively wide variations in the scores of the high and low scorers on the test.

Table 3

Factorial Analysis of Variance in Students' Mole Concept Test Performance By Chemistry and Mathematical Abilities, Gender and Socioeconomic Background (SEB)

Source of variation	SS	df	MS	F
Chemistry ability	645.21	6	322.605	12.846**
Mathematical ability	377.033	2	188.516	7.507*
Gender	9.172	1	9.172	0.365
SEB	39.810	1	39.810	1.585
Explained	2012.729	6	335.455	13.358
Residual	1833.221	73	25.113	
Total	3845.95	79	48.683	

*p < .01 **p < .001

To find out if the differences in their means were statistically significant linked to the four variables, a four-way analysis of variance was computed. The results (Table 3) show that there are significant differences in their means based on their chemical abilities ($F(2) = 12.846$, $p < .001$), and mathematical abilities ($F(2) = 7.507$, $p < .01$). A look at Table 2 indicates that the significant differences are in favour of students with high chemical and mathematical abilities respectively. Table 3 also suggests that the differences in the students' means linked to their gender ($F(1) = 0.365$, $p > .05$) and SEB($F(1) = 1.585$, $p > .05$) are not statistically significant. This implies that the gender and SEB differences in their mean scores shown in Table 2 could only have occurred by chance.

Based on the authors' teaching experience of the mole concept to high school students in the Caribbean and Nigeria, the findings that students with high chemical and mathematical abilities performed significantly better than their counterparts with average and low abilities were expected. Additionally, the CXC's (1996-2002) examiners' reports on candidates' performance on the SECGPE in mathematics showed that many of them performed poorly in the subject because of their lack of understanding of such concepts as the changing of the subject of a formula and ratio. Yet, these are the basic concepts needed for solving many of the mole concept's numerical calculations tested in this study. In sum, students with high chemical and mathematical abilities in this study had a better mastery of the chemical and mathematical skills and concepts that were required for the solutions of the numerical problems explored in this study.

The authors expected the finding that there was no statistically significant gender difference in the students' performance. This was because Lofters (2002) found no significant gender differences in the performance of Jamaican 11th-graders on the mole concept using multiple-choice test items. But, the finding in respect of the lack of gender differences in the students' performance in this study, indirectly conflicts with that of Whiteley (1994) who reported that Jamaican female O-level and A-level chemistry students significantly outperformed their male counterparts in the 1992-1993 examinations on the subject. This study's finding also indirectly contradicts the findings of many previous studies (e.g., Forrest, 1992; Khale & Lakes, 1983; Levin, Sabir & Libman, 1991) that had recorded significant gender differences in high school students' science performance in favour of the male students. On the other hand, the finding receives indirect support from the findings of few previous studies which documented a lack of gender difference in high school students' science performance (Greenfield, 1996; McCulloch & Soyibo, 2003; Ugwu & Soyibo, 2004).

That there were no significant SEB differences in the students' performance in this study is not surprising to us as the finding is consistent with Lofters' (2002) finding that there were no SEB differences in the mole concept test performance of some Jamaican 11th-graders who he assessed using multiple-choice items. However, this study's finding is inconsistent with the findings of several international studies (e.g., Fejgin, 1995; Fidler, 1989; Tamir, 1989; Young & Fraser, 1994) which had recorded statistically significant SEB differences in high school students' science performance in favour of students from a high SEB. The finding also conflicts with the findings of few local studies which had documented significant SEB differences in the science performance of Jamaican high school students in favour of those from a high SEB (e.g., Clayton-Johnson, 1999; Beaumont-Walters & Soyibo, 2001). A likely, rational explanation for this study's finding came from Thorpe and Soyibo (1999) who observed that, in Jamaica, there had been instances where parents/guardians with "poor" educational background and low income (low SEB) did toil diligently to invest in their children's/ward's education so that the children/ward could achieve academic excellence like the children of the highly educated and financially well-to-do parents/guardians (high SEB). Such a situation was likely to be true in this study.

The third purpose of this study was to find out if there were significant correlations among the students' (i) chemical ability, (ii) mathematical ability, (iii) gender, and (iv) SEB, and their performance on the mole concept test. To categorise the students into three ability groups, their final grades in their schools' chemistry and mathematics examinations were used. Students who scored 65% and above were classified as having a high ability; students with scores of 45% - 64% were classified as having an average ability;

while students with scores below 45% were classified as having a low ability. Table 4 shows the levels of the students' performance on the test based on their chemical and mathematical abilities.

Table 4
Levels of Students' Performance on the Mole Concept Test Based on Their Chemistry and Mathematical Abilities

Variables	n	Mean	SD
Chemistry ability			
High	3	21.33	4.73
Average	40	14.95	6.24
Low	70	7.74	4.97
Mathematical ability			
High	49	14.86	6.36
Average	41	8.20	4.63
Low	23	5.39	4.88

As the authors expected, Table 4 indicates that students with high chemical and mathematical abilities, score higher than their average and low ability counterparts respectively. Nonetheless, the means of the high ability students in both cases are less than the 22.50 or the conventional 50% pass mark.

Table 5
Point-biserial Correlation Coefficients Relating Students' Mole Concept Performance to their Chemical and Mathematical Abilities, Gender and Socioeconomic Background

	Chemical Ability	Mathematical ability	Gender	SEB
Mole concept test score	.58**	.56**	.37**	.27*

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

Point-biserial correlation test was used in this study. This was because the four independent variables belong to nominal or categorical variable and two of them (gender, and SEB) show genuine dichotomies, while their chemical and mathematical abilities had three categories (Guilford & Fruchter, 1978: 308). Point bi-serial correlation coefficients (Table 5) relating the students' chemical and mathematical abilities to their mole concept test scores revealed that there was a positive, statistically significant correlation between the students' (a) chemical ability and their mole concept test score (= 0.58, $p < .001$), (b) mathematical ability and their mole concept test score ($r = 0.56$, $p < .001$), (c) gender and their mole concept test score ($r = 0.37$, $p < .01$), and, (d) SEB and their performance on the mole concept ($r = .27$, $p < .01$). The first two reliability coefficients are considered as 'substantial reliability', while the last two coefficients are regarded as 'slight reliability' (Miller, 1991). The findings in respect of chemical and mathematical abilities are consistent with the data in Table 3 discussed earlier, while those regarding gender and SEB significant correlations with the students' performance are inconsistent with the data in Table 3.

Although the authors do not regard the four independent variables explored in this study as the actual causes of the significant differences recorded in the students' performance on mole concept test, as the research design did not allow for the rigorous control and manipulation of the variables, the calculations of the effect sizes of the four variables (Table 6) lent further support to the data in Tables 3 and 5. The effect sizes were calculated by dividing the differences between the means by the pooled standard deviations.

Table 6
Effects Sizes of Independent Variables on Student Mole Concept Test Performance

Variable	Mean	Pooled SD	Effect Size
Chemistry ability			
High	21.33	5.31	1.88
Average	14.95		
Low	7.74		
Mathematical ability			
High	14.86	5.29	1.53
Average	8.19		
Low	5.39		
Gender			
Male	8.61	6.27	0.78
Female	13.53		
Socioeconomic Background			
High	13.19	6.11	0.63
Low	9.34		

Noteworthy are the relatively high effect sizes of all the four variables in Table 6. The table data suggest that the students' chemical abilities accounted for the highest difference recorded in their test performance, followed by their mathematical abilities, gender, and SEB. Indeed, evident from Table 6 is the fact that while the possible influence of the students' chemical abilities on their performance is slightly higher than that of their mathematical abilities' influence, the impact of the former is about thrice and two and half times higher than the impacts of their SEB and gender respectively on their performance. Again, while the findings in respect of the possible impact of their chemical and mathematical abilities on their performance confirm the data in Table 3, those in respect of gender and SEB conflict with the data in Table 3.

CONCLUSIONS AND EDUCATIONAL IMPLICATIONS

The authors found the students' overall performance on the test to be unsatisfactory because only about 6% of them scored above 50% of the test's maximum score of 45. This implies that most of them had not mastered the basic principles underlying the mole concept. Hence, Jamaican grade 11 chemistry teachers need to employ effective teaching strategies that would enable their students to explicitly understand the fundamental principles that underpin the mole concept because such an understanding is likely to enable the students to do well on the numerical problems on the concept. Eleventh-graders' chemistry teachers elsewhere whose students exhibit a low understanding of the numerical problems on the mole concept, like the participants in this study, need to consider and implement this recommendation for their students' benefit.

Evident from this study was that it was the few students with high chemical and mathematical abilities who significantly outperformed their counterparts with average and low abilities. Consequently, for Jamaican 11th-graders to perform well on the numerical problems on the mole concept, their teachers need to utlilise a variety of student-friendly instructional strategies to teach them the relevant (a) chemical concepts (e.g., writing of formulae, balancing and interpretations of chemical equations), and mathematical concepts (e.g. simple proportions, and change of the subject in a formula) which are required for solving the numerical problems on the mole concept. Indeed, 11th-grade chemistry teachers should not leave the teaching of the basic mathematical concepts their students need to be able to competently solve the numerical problems on the mole concept to the mathematics teachers alone as many chemistry teachers tend to do. This caveat-cum-suggestion is based on the authors' high school chemistry teaching experience.

The findings that there were no significant gender and SEB differences in the students' performance suggest that Jamaican 11th-graders are likely to perform well on numerical problems on the mole concept regardless of the differences in their gender and SEB. Nevertheless, we suggest that Jamaican 11th-grade chemistry teachers (and their counterparts elsewhere) should endeavour to employ instructional strategies that are gender-and-SEB-fair in the teaching of the mole concept and other related chemistry concepts to enhance their students' understandings of these concepts as well as their cognitive performance on them.

The "substantial" and "weak" correlations recorded in this study suggest that there were other variables which could have accounted for the significant differences in the students' performance which were not identified and explored. Such variables - which should be investigated in future studies on this topic - include the differences in students' English language abilities, learning styles, teachers' teaching qualifications and experience and teaching styles. Moreover, there were other intervening variables besides these ones which could have significantly influenced the students' performance that could not be controlled in this study. Again, note that the independent variables were not assumed to be the real causes of the significant differences documented in the students' performance. Nevertheless, evidence abound that there were significant correlations among the four variables and the students' mole concept test performance. But relationship does not imply causality. Among other limitations of the study were the small sample size and the fact that it was not representative of Jamaican traditional high school chemistry students.

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APPENDIX A

Structured Questions on the Mole Concept for 11-th Graders

1. Given that the relative atomic mass of sodium is 23.00, calculate:
   (a) the mass of 8 mol Na;
   (b) the number of moles in 75.80g of the element;
   (c) the mass of 1.2 x 10^{25} atoms of Na; and
   (d) the total number of individual atoms in 45.3g of the element.
2. Calculate the number of moles of potassium chloride formula units present in 2.26g of potassium chloride.
3. What volume is occupied by 10g of carbon dioxide at r. t. p.?
4. How many hydrogen molecules are present in 6.50dm^3 of hydrogen at s. t. p.?
5. How many molecules of carbon dioxide are liberated at s. t. p. when 10g of calcium carbonate are heated? (Ca = 40, C = 12, O = 16; 1 mole of a gas occupies 22.4dm^3 at s. t. p.).
6. How many moles of oxygen are liberated at s. t. p. when 56.25g of potassium chlorate are heated? $2KClO_3 = 2KCl_{2\,+} 3O_2$ (K = 39, Cl = 35.5, O = 16).
7. 10g of copper metal were reacted with hydrochloric acid at r. t. p. until all the metal reacted with the acid. The gas given off was collected. Calculate the volume of the gas collected.
8. If 25.00cm^3 of a dilute solution of calcium hydroxide (lime water) required 20.00cm^3 of 0.015mol dm^3 hydrochloric acid for neutralization. Calculate the concentration of lime water in (i) mol dm^3, and (ii) g dm^3.
9. 3.50A of current was passed through copper (II) sulphate solution using an inert electrolyte for 1.50hours. Calculate (a) the mass of copper deposited, and (b) the volume of oxygen liberated.

APPENDIX B

Solutions to Some of the Structured Questions on the Mole Concept Test

1 (a) Mass = Number of moles x R. A. M (1 mark)
Mass = 8 mol x 23gmol^{-1}
= 184g (1 mark)

(b) Number of moles = Mass/R.A. M (1 mark)

Number of moles = 75.8g/23g
= 3.29 moles (1 mark)

(c) 6.023×10^{23} particles = 1 mole of particles (1 mark)
1.2×10^{25} atoms = x moles of atoms
x = $1.2 \times 10^{25} / 6.023 \times 10^{23}$
= 20 moles (1 mark)

mass = number of moles x R. A. M
= 20 x 23
= 460g (1 mark)

(d) Number of moles = 45.3g/23g
= 1.97 moles (1 mark)

Number of atoms = number of moles x 6.023×10^{23} atoms (1 mark)
= $1.97 \times 6.023 \times 10^{23}$ atoms
= 1.19×10^{24} atoms (1 mark)

5. $CaCO_3$ (s) = CaO (s) + CO_2 (g) (1 mark)

Number of moles = 10g/100g
= 0.10 moles (1 mark)

Mole ratio is 1:1

0.10 mole of $CaCO_3$ (s) produces 0.10 mole of CO_2 (g) (1 mark)

1 mole of the gas has 6 x 10 x 10^{23} molecules of CO_2

Therefore, 0.10 mole of CO_2 has 6 x 10^{23} x 0.10 moles

= 6 x 10^{22} molecules of CO_2 (1 mark)

8. $Ca(OH)_2$ (aq) + 2HCl (aq) = $CaCl_2$ (aq) + $2H_2O$(l) (1 mark)
Number of moles of HCl used = 20cm^3 x 0.015 mol dm^{-3}/1000
= 3 x 10^{-4} moles of HCl used

(1 mark)

(i) Mole ratio is 1: 2

The number of moles of $Ca(OH)_2$ = 3 x 10^{-4} /2
= 1.5 x 10^{-4} (1 mark)

25 cm^3 of $Ca(OH)_2$ contain 1.5 x 10^{-4} moles of lime water
Therefore, 1000 cm^3 contain 1.5 x 10^{-4} x 1000/25
= 0.006 moles
Concentration in mol/dm^3 = 0.006 mol/dm^3 (1 mark)

(ii) Mass concentration = molar concentration x R.M.M
= 0.006 x 74
= 0.44 g/dm^3 (1 mark)

9. Q = It
Q = 3.5 x 1.5 x 60 x 60
= 18,900C (1 mark)

(i) At the anode At the cathode

$4OH^- = 2H_2 + O_2 + 4e^-$ $Cu_2{}^+ + 2e^- = Cu$ (s) (2 marks)

1 mole of Cu was deposited by 2 x 96, 500C of current (1 mark)

Number of moles of Cu
deposited = 18,900/2 x 96,500
= 0.098 moles of Cu (1 mark)

Mass of Cu deposited = 0.098 x 63.5 g
= 6.22g (1mark)

(ii) Volume of oxygen liberated
1 mole of O_2 was liberated by 4 x 96,500C (1 mark)

Number of moles of O_2
liberated = 18,900/4 x 96,500 moles
= 0.049 moles (1 mark)

Volume of oxygen liberated = 0.049 x 24dm^3
= 1.18 dm^3 (1 mark)