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ELECTROCHEMISTRY PROBLEM-SOLVING APPROACHES AND DIFFICULTIES OF SENIOR HIGH SCHOOL STUDENTS

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ABSTRACT

The acquisition of competencies by senior high school (SHS) science students in knowledge-based and computational problem-solving is an important objective of the WAEC chemistry syllabus in support of which this study was designed. Using the think aloud and pen and paper procedure, data were collected from 26 SHS science students as they solved problems based on Faradays laws of electrolysis and related electrochemistry topics. The students' verbalizations were audio-taped as they worked. Analysis of the data showed that most (66%) of the students were analytic in their problem-solving approach while a smaller (19%) proportion was intuitive. A few (15%) of them were however unclassified. On the whole the students performed poorly in various tasks related to Faraday's second law of electrolysis. None of them could state the law in words and in symbols. However a few (15%) of them were able to state Faraday's first law of electrolysis in words and in symbols. The students' performance in computational problems, based on the laws, followed a similar trend. Misconceptions held by some of the students included the belief that protons could be used to balance negative charges in redox reactions and that strong electrolytes (e.g. $AgNO_3$) could only be ionized with the passage of electricity through their aqueous solutions. In sum, the findings indicate that some SHS science students lack the conceptual understanding needed to ensure success in both knowledge and numerical problem-solving in science.
Keywords: Electrochemistry, Problem-solving, Computational, Conceptual, Misconceptions

INTRODUCTION

The West African Examinations Council (WAEC) chemistry syllabus, among other things, is designed to provide students with basic knowledge in chemical concepts and principles through efficient selection of content (WAEC, 2006, p. 131).

The desired knowledge and competencies are not expected to be acquired through expository teaching only but also through the correct application of scientific ideas. While the knowledge base of the chemistry teachers is influential in what the students learn, it is not an indicator of the students' success in problem-solving situations. To a large extent, this depends on the students' own effort, and cognitive strategies.

With respect to the industrial application of chemistry concepts, Faraday's laws of electrolysis (FLE) are of utmost importance. Such applications include metallurgical refining, electroplating and the selective discharge of metal ions (Dillard and Goldberg, 1978; Schwartz et al. 1997). It is therefore necessary for students to receive good grounding in the laws and their applications either in industry or during science lessons.

At the classroom level, solving problems based on Faraday's first law of electrolysis (FFLE) and on Faraday's second law of electrolysis (FSLE) require knowledge and the use of such concepts as the mole, electrolytic cell, electrode, oxidation and reduction among others. It is thus obvious that mere knowledge of the laws does not guarantee success in the solution of electrochemistry problems. This is attested to by research findings reported by Akinmade and Adisa (1984), Anamuah-Mensah and Apafo (1986) and Akpan (1988).

In a study conducted in plateau state, Nigeria, Akinmade and Adisa found that electrolysis and related concepts were among the chemistry topics the surveyed students found difficult to understand. On his part, Akpan (1988) reported that the students he studied in Sokoto State, Nigeria perceived electrolysis as the most difficult topic in the chemistry syllabus. Similar findings were reported in Ghana by Anamuah-Mensah and Apafo (1986). The two researchers found that electrolysis and redox reactions were among the chemistry topics selected Ghanaian students found difficult to learn.

The importance of FLE is exemplified in their close association with such topics as redox equations, electrochemical cells, corrosion, catholic protection etc. in the WAEC syllabus.
With reference to calculations based on FLE students are required to apply the relation *F = Le = 96,500 coulombs and mole ratios to determine the following quantities:

i. Masses of gases, liquids and solids liberated
ii. Volumes of gas liberated
iii. Number of entities or particles liberated
iv. Charges on entities etc. (C.R.D.D. 2003; p.89)

Before being able to perform these listed calculations, students are expected to know how to balance half and overall reactions occurring at the electrodes during electrolysis. This is in addition to other electrochemistry calculations whose novelty can only be limited by the chemistry teachers' ingenuity and innovativeness. Hence apart from possessing a strong background in theoretical concepts underlying FLE students have to possess strong computational skills if they are to be able to cope successfully with various aspects of this topic as it is presented in the chemistry syllabus.

* F = Faraday L = Avogadro's number
e = charge on the electron.

LITERATURE REVIEW

A search of the available literature showed that attempts at determining the strategies students use to solve science problems had been made by Ahiakwo (1991) and Onwu and Asuzu (1987). In a study conducted in Rivers State, Nigeria, Ahiakwo used four instruments to obtain data from 226 students who he later categorized as analytic and non-analytic. Pen and paper tests were used to collect data for this study. Consequently, the thought processes of the students could only be inferred but not directly determined since the instruments used could not measure the verbalizations.

Similarly Onwu and Asuzu used the written protocols of 31 students (while solving an unfamiliar task) to investigate the possible influence of conceptual categorization styles on their inquiry behaviour. As was the case with the approach adopted by Ahiakwo (1991), the exclusive use of written protocols by Onwu and Asuzu (1987) meant that they could only infer the students' thought processes from mute evidence. As was noted by Hodder (1994), written texts are examples of mute evidence which require interpretation. Derrida (1978) contends that meaning does not reside in the text but in the writing and reading of it. As a text is reread in different contexts, it is given new meanings which are often contradictory. Hence only the research subjects know the actual meanings of what they write, but not those who do the interpretation.

It is perhaps to overcome this problem that researchers like Pribyl (1989), Nakleh (1991), and Thorsland and Novak (1974) used think aloud protocols to collect data in their studies. Pribyl was able to detect no significant difference between the information model of the strategies used by both low spatial ability students and high spatial ability students only after he had coded their verbalizations as they worked. Similarly, Nakleh coded the verbal commentaries of the students in her study and used the data to determine the patterns of their mental activity as they titrated.

On their part, Thorsland and Novak asked each of the research subjects (in their study) to solve a problem and at the same time explain what they were doing. The data were used to assess the research subjects' intuitive and analytic modes of thinking.

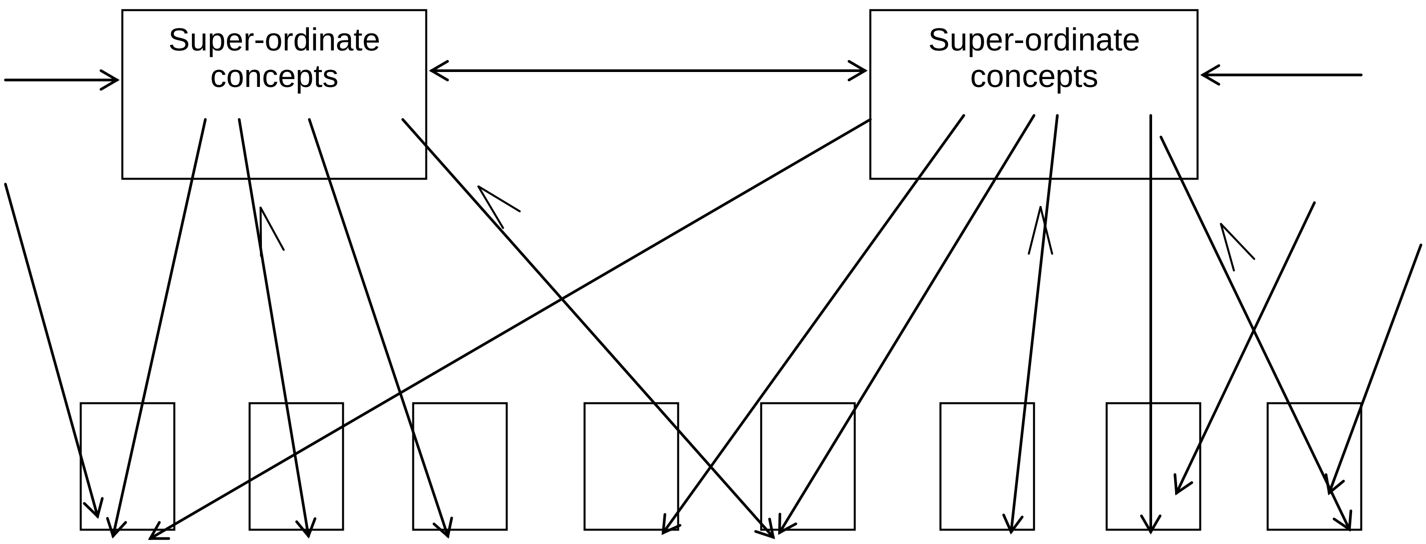
CONCEPTUAL BACKGROUND

The approaches utilized in this study were influenced partly by the results of previous work done by Younger (1995) and also by Selvaratnam and Frazer (1981). Younger noted that think aloud protocols are useful tools for assessing students' thought processes. On the other hand, reports by Selvaratnam and Frazer appear to indicate that the difficulties science students encounter when solving problems are not due to the lack of knowledge. Rather, the difficulties often arise from deficiencies in the way the knowledge is applied. The difficulties students' encounter in problem-solving situations can best be detected when they verbalise their thoughts. For this reason, apart from written texts, think aloud protocols were used to triangulate data for this study using Thorsland and Novak's (1974) model. The approach utilized by the two researchers resulted in the categorization of the students as either Analytic (AN) or intuitive (IN). The analytic students adopted a step-by-step analysis of the problem and were explicit in their approach. The AN approach often involved the use of mathematical equations and symbols.

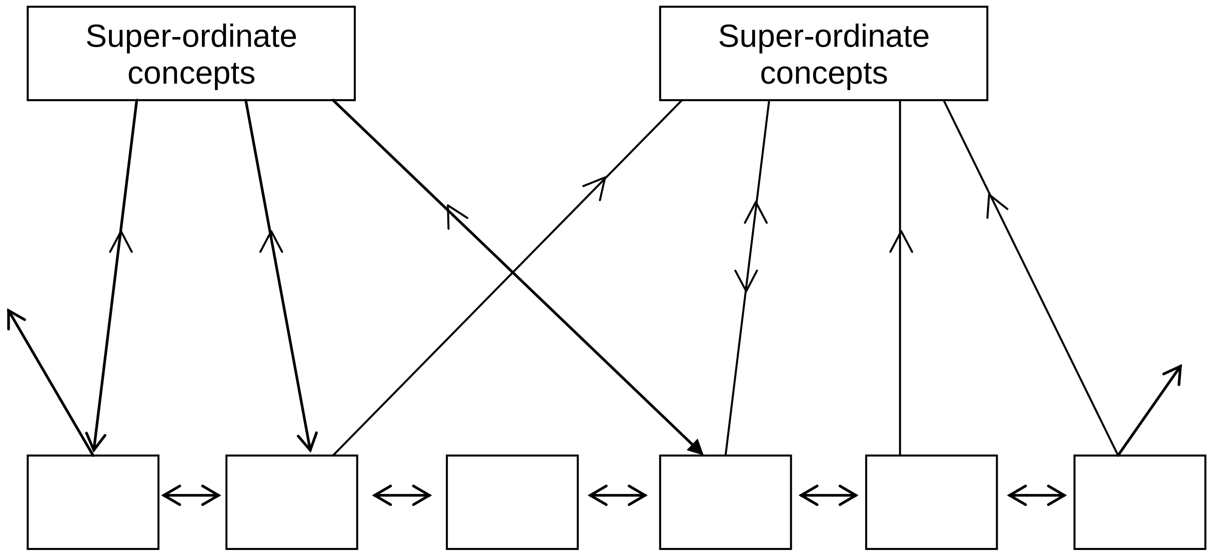
On the other hand, the IN approach was characterised by a somewhat latent or inexplicable knowledge or feel for the subject matter. The IN approach often involved little or no conscious awareness of the steps used in arriving at the answer.

Thorsland and Novak's model was based on Ausubel's (1968) conception of the cognitive structures of individuals. According to Ausubel, the cognitive structures of individuals consist of super-ordinate concepts, which subsume subordinate ones. The super-ordinate concepts are more inclusive and are of a higher order while the subordinate concepts are less inclusive, are low level and also highly differentiated.

As shown in Figure 1, during problem-solving, the intuitive students move from one super-ordinate concept to another with rapid reference to the subordinate concepts. There are however less frequent references from the subordinate concepts to the super-ordinate concepts. Such students are able to lift, as it were, solutions to problems from their cognitive structures with little or no written steps. These students are also able to combine two or more steps into a single (more complex) step.



Subordinate concepts
Figure 1: Conceptual organization of intuitive students.
Modified after: Thorsland and Novak(1974).



Subordinate concepts
Figure 2: Conceptual organization of analytic students.
Modified after: Thorsland and Novak(1974).

Figure 2 shows the diagraminatic representation of the problem-solving approaches utilized by analytic students. Such students move mainly within the subordinate concepts and to super-ordinate concepts and then back to the subordinate concepts. These cognitive movements enable the analytic students to expand the super-ordinate concepts. However, little or no interactions occur between the super-ordinate concepts. Analytic students are methodic, often utilizing step-wise problem-solving approaches.

STATEMENT OF THE PROBLEM

Problem-solving is an important aspect of the SHS chemistry course. However research findings (e.g. Anamuah-Mensah and Apafo, 1986; Sheppard, 1997) indicate that an appreciable proportion of SH students encounter various difficulties when asked to solve problems on FLE and related electrochemistry concepts. Locaylocay(2004) also found that college students undergo various conceptual changes as they solve computational problems.

The available literature in the area showed that some related previous studies tended to focus mainly on the categorization of students based on the problem-solving approaches they adopted (e.g. Ahiakwo 1991; Atwater and Alick, 1990). Other researchers (e.g. Akinmade and Adisa, 1984; Akpan, 1988) surveyed students’ perception of topic difficulty in chemistry. In none of the studies was there an attempt to determine the thought processes of the students as they solved problems in electrochemistry. But as Wittrock (1986, p. 297) noted, data on students’ thought processes provide an important link between teaching and student cognition. Hence the need for a study on students’ thought processes as well as the ideas that characterize their problem-solving activities.

PURPOSE OF THE STUDY

This study was designed primarily to determine the sort of ideas students bring to the solution of problems based on FLE and related electrochemistry topics. The second objective of the study was to categorize the students based on the cognitive strategies they utilized in the solution of selected electrochemistry problems. This agrees with Locaylocay(2004) who found that students reacted differently when they encountered challenging chemistry problem-solving situations.

RESEARCH QUESTIONS

The following research questions were explored in the study:

1. Are students who are able to state Faraday's laws of electrolysis in words also able to state them in symbolic form?
2. What meanings do the students attach to the symbols they use in writing Faraday's law of electrolysis?
3. To what extent are the students able to balance redox half equations?
4. To what extent are the students able to work out calculations based on Faraday's laws of electrolysis and related electrochemistry problems?
5. What ideas or misconceptions do the students bring to the solution of problems based on Faraday's laws of electrolysis and related electrochemistry topics?
6. Are there differences among the students with respect to the cognitive strategies they use to solve problems based on Faraday's laws of electrolysis and related electrochemistry topics?

METHODOLOGY

Sample

The research subjects consisted of 26 senior high school 3(SHS3) students from four well-established schools in the central region of Ghana. The students were randomly selected with the help of their teachers. Out of an expected sample of 40 students, only 26 of them reported at the data collection centres. The distribution of the research subjects was as follows:

School A (Cape Coast)	5 students
School B " "	8 students
School C " '	7 students
School D (Winneba)	6 students
Total	**26 students**

INSTRUMENTATION

A three-part instrument incorporating a pen and paper activity and interviews was used in the study. The items in the pen and paper activity are in the appendix.

The interview involved unstructured items designed to determine the mental processes that underpin the problem-solving approaches utilized by the research subjects.

DATA COLLECTION PROCEDURE

Data collection sessions were arranged separately with each student in the selected schools. On each occasion, the student was supplied with sheets of paper and the optional use of a calculator. The student was then given the questions to read though silently for about three minutes before being asked to respond to the items by writing down their answers. They were also to verbalise their thoughts as they solved the problems.

The students' responses were audio-taped for analysis. As the students described what they were doing, the researcher intermittently asked questions. He also wrote down certain aspects of the students' verbalizations for later clarifications. For example when students S8 (in school B) balanced a chloride ion with a proton, the researcher noted it and asked why. While asking questions that caused the students to clarify some statements they made, the researcher did not give any verbal or facial cues. He used expressions such as "What else?", "Go on.", "Is that all?" "How did you arrive at that solution?" etc.

After each session, the sheets of paper were collected from the student and stored with the audio cassette for later data extraction and analysis.

RESULTS

Simple statistical techniques were used to analyse the data to answer the research questions. The first research question dealt with whether students who are able to state FLE in words will also be able to state them in symbolic form.

The results showed that only 4 (15%) of the students could state the first law correctly in words and in symbols while 9(35%) of them got both the symbolic and statement forms of the law wrong.

On the other hand, 22(85%) of the students got both the statement and symbolic forms of the second law wrong. Half of the students admitted that they had no idea of FSLE. The results have been summarized in Table 1.

Table 1: Performance of Students with Respect to the Statement and Symbolic Forms of Faraday's Laws of Electrolysis.

Faraday's Laws of Electrolysis	Statements and symbolic forms correct	Statement correct but symbolic form wrong	Statement wrong but symbolic form correct	Both statement and symbolic forms wrong
First Law	4 (15%)	8 (31%)	5 (19%)	9 (35%)
Second Law	0 (0%)	4 (15%)	0 (%)	22 (85%)
Average	2 (7.5%)	6 (23%)	3 (9.5%)	16 (60%)

Wrong symbolic forms of the first law written by some students are as follows:

1. $M \propto T$
2. $Q = It$
3. $I \propto M$
4. $Q = Z\,It$
5. $Q = IM$

The second research question explored the meanings the students attached to the symbols they used in writing FLE. The results are as follows:
T = quantity of electricity
Z = equivalent of electrolysis
Q = quantity of heat in joules
Z = I Faraday
Q = quantity of heat in coulombs
M = number of moles
Some of the students appeared to have been confused by the practice of some science textbook writers to present both "heat" and "electric charge" by the letter Q.

The third research question focused on the extent to which the students balanced redox half equations correctly. It was found that about one third (27%) of the students could not balance any of the four redox half equations. An equal proportion (27%) of the students could only balance one of the four equations. Only 3(12%) could balance all the four redox equations correctly. The results have been summarized in tables 2 and 3.

Table 2: Number of Students who Correctly Balanced Each of the Redox Half Equations.

Redox equation	Number and proportion of students correctly balancing each equation
A. $Cu^{2+}_{(aq)} \longrightarrow Cu(s)$	16(62%)
B. $H_2O \longrightarrow H^+_{(aq)} + O_{2(g)}$	3(12%)
C. $Cl^-_{(aq)} \longrightarrow Cl_{2(g)}$	8(31%)
D. $Au(s) \longrightarrow Au^{3+}_{(aq)}$	15(58%)

Table 3: Summarized Data on the Students' Performance in the Equation Balancing Activity.

Students' Performance	Number and Proportion of students at Each Performance Level
Able to balance all 4 equations correctly	3 (12%)
Able to balance only 3 equations correctly	4 (15%)
Able to balance only 2 equations correctly	5 (19%)
Able to balance only 1 equation correctly	7 (27%)
Unable to balance any equation	7 (27%)

From Table 2 it can be inferred that in increasing order, the level of difficulty experienced by the students in balancing the redox half equations is as follows:

A ⟶ D ⟶ C ⟶ B.

The fourth research question concerned the extent to which the students were able to work out calculations based on FLE and associated electrochemistry topics. The data showed that on the average, 5 (19%) of the students worked out correct solutions to both parts of the three calculations while 4 (15%) worked out correct solutions to only one part of each of the three calculations. On the other hand, on the average, 17 (66%) of the students got all the calculations wrong. The summary of the results is in Table 4.

Table 4: The Overall Performance of the Students in the Calculations.

	Correct Solution To Both Parts	Correct Solution to Only 1 Part	Both Parts Wrong
Question 1 (Based on the 1st law	4 (15%)	7 (27%)	15 (58%)
Question 2 (Based 2nd law)	2 (8%)	3 (12%)	21 (80%)
Question 3 (Aspect of quantitative electrolysis)	9 (34%)	2 (8%)	15 (58%)
Average	5 (18%)	4 (15%)	17 (66%)

From the data in Table 4 it can be inferred that the students found calculations based on Faraday's second law more difficult to work out compared to the other calculations.

The fifth research question dealt with the wrong ideas or misconceptions the students brought to the solution of problems based on FLE and associated electrochemistry topics. Following is a summary of the major misconceptions and wrong ideas exhibited by some of the students:

1. Balancing only the atoms in the redox equations but not the charges.
   e.g. $2H_2O \longrightarrow 4H^+ + O_2$

2. Using protons to balance negative charges. Two students from School B used protons to balance the chloride ion (Cl^-). This probably meant that this problem may be peculiar to students in school B only.

3. Belief that strong electrolytes (e.g. $AgNO_3$) ionize only when electricity flows through the electrolytic solution.

4. Examples of wrong statements (i) "silver nitrate will separate giving silver electrons and nitrate electrons". Other students in the same school (School C) made mention of "aluminium electrons".

   (ii) "1 mole of silver metal is deposited to produce 1 mole of electrons"
   (iii) "Reduction occurs when copper metal gains electrons to become copper ion. When it gains the electrons, the charge will be + 2".

   (iv) "One Faraday equals one electron".

5. Wrong charges on some species
   (i) The charge on an electron was given as -2.
   (ii) The charge on silver ion was variously given as + 2 and + 3.

The sixth research question focused on differences among the students with respect to the strategies they used to solve problems based on FLE and associated electrochemistry topics. The results showed that while 17(66%) and 5(19%) of the students respectively used analytic and intuitive approaches 4(15%) of them were unclassified. The distribution of the students based on their problem-solving strategies is shown in Table 5.

Table 5
Distribution of the Students Based on Their Problem-Solving Approaches

Classification				
School	Analytic (AN)	Intuitive (IN)	Unclassified (UN)	Total
A	3	1	1	5
B	5	2	1	8
C	4	2	1	7
D	5	0	1	6
Total	17(66%)	5(19%)	4(15%)	26

From Table 5 it is obvious that the majority of the students adopted the analytic approach in working out the calculations in the electrochemistry problems.

DISCUSSION

It was found that 60% of the students could neither state FLE nor write them in symbols. It is thus not likely that such students are going to be able to solve problems based on the two laws. This in confirmed by results in Table 4. On the average 66% of the students got both parts of the three computational problems wrong.

An important finding of this study is that the students found it extremely difficult to solve problems based on FSLE. Only 2(8%) of the students were able to do that. This seems to be supported by Holderness and Lambert (1982) who noted that the second law was the most difficult to understand. An examination of some chemistry books (e.g. Ameyibor and Wiredu 1999; Holderness and Lambert, 1982; Robinson, 1982; Bajah and Godman, 1984) showed that while their statements of the first law were identical, the authors gave vastly different statements of the second law. It is thus likely that the students consulted different chemistry books for information on electrolysis and were thus confused by the different statements and interpretations of the second law. This was perhaps the reason why all the students got both the statement and symbolic forms of FSLE wrong.

One other possible contributory factor to the students' poor performance might be due to the inadequate treatment of the electrochemistry aspect of the chemistry syllabus. It is perhaps the reason why an appreciable proportion of the students wrote the symbolic forms of FLE wrongly and also interpreted them wrongly.

It was also found that the students held a lot of misconceptions about FLE and other electrochemistry topics. For example, some of them used protons to balance chloride ions. This shows that such students did not know that protons can only be used to balance nuclear reactions but not chemical reactions.

Some of the students also believed that $AgNO_3$ ionized only when electricity was passed through the solution. This is a very serious anomaly and indicates weaknesses in the students' conceptual structures on electrolytes. Also revealing is the explanation some students gave as they worked. Student S3 in school B for example said that:
"The Au has 3 positive ions, so you add 3 electrons where it be neutralized to Au, that is gold.

He then wrote:

$$Au \longrightarrow Au^{3+} + 3e^{-}$$

It is clear that the redox half equation above is balanced. However the thought process behind it is faulty. This agrees with Berg and Brouwer (1991) who noted that the fact that students are successful on knowledge-based questions or numerical problem-solving does not mean that they have integrated the desired scientific conceptions into their cognitive structures (p.12).

Of serious concern is the writing of wrong charges on an electron (-2) and on silver ion (+2 and +3) by some of the students. Such students are likely to fail in working out solutions to computational problems based on such species. One other significant finding is the notion of electrons being associated with particular metals or species/e.g aluminium electrons and silver electrons. Such students are probably not aware that unlike cations and anions, electrons are all alike.

In writing the symbolic form of FFLE, some of the students referred to Q as the quantity of heat in joules while others said that Q was the quantity of heat in coulombs. It appears that such students were confused by the simultaneous use of Q as "quantity of heat" and as "quantity of electricity" in some science books. Examples of such books are the Ghana Association of Science Teachers (GAST) chemistry book by Ameyibor and Wiredu (1999; p.143 & 455) and GAST physics book by Abbey and Essiah (1999; p. 145 & 255).

CATEGORIZATION OF THE STUDENTS

Based on the findings of this study 17(66%) and 5(19%) of the students were classified as analytic (AN) and intuitive (IN) problem-solvers respectively. However, 4(15%) of the students were unclassified (UN). These are the students who made little or no attempt to solve the problems.

The results showed that the AN students usually started with a redox equation with interpretations that were not always accurate. For example S6 in school B interpreted

$$Cu^{2+}(aq) + 2e \longrightarrow \underset{64}{Cu(s)} \text{ thus}$$

"64g of copper deposits 1 mole".

Because the AN students moved mostly within the subordinate concepts with occasional reference to the super-ordinate ones (see figure 2), their problem-solving steps were comparatively detailed.

A possible explanation for 66% of the students adopting AN approaches is that they were influenced by the systematic approaches used by their teachers who themselves had been influenced by the analytic marking schemes developed by WAEC.

Unlike the AN students, the IN students in the study did not adopt elaborate problem-solving steps. This is because in their case (as figure 1 shows) the solution incubation phase involved extensive interactions within the super-ordinate concepts with occasional reference to the subordinate ones. The IN students used minimal steps and explanations but wrote equations and formulae, which with the right substitutions, yielded the solution to the problem.

Typical computational problem-solving approaches used by the AN and IN students in the study can be found in the appendix.

RECOMMENDATIONS

The findings of this study indicate that the research subjects held ideas about FLE and related electrochemistry topics that conflict with accepted scientific views. It is possible that their counterparts in other schools might be experiencing similar problems. It is suggested that chemistry teachers mediate the learning difficulties of their students by adopting approaches that ensure deep conceptual understanding of various chemistry topics. The same goes for teachers in the other science content areas.

Since some of the students confused the different meanings attached to the letter Q in their physics and chemistry text books, steps should be taken to reverse the cognitive damage. It is suggested that physics and chemistry teachers stress the difference between "heat" as an energy term and "charge" as an electrical phenomenon-although both terms are usually represented by Q in science books.

On its part, GAST has to review the use of Q as the symbol for both "heat" and "charge" in its physics and chemistry books in the country. The fact that some of the research subjects adopted intuitive problem-solving approaches indicate that they are likely to lose marks if their calculations are scored using analytic marking schemes. WAEC should therefore adopt flexible marking schemes to cater for students who might adopt intuitive approaches in their calculations.

CONCLUSION

This study has shown, in part that the performance of science students in knowledge-based and computational problems is multidimensional. One of the critical factors is the type of ideas they hold about various science concepts and topics.

Although students may provide solutions to various problems, the underlying ideas may be faulty. This is amply shown by the findings of this study. Science teachers, as facilitators of learning, can intervene (Danjuma and Akpan, 2000), by designing lessons that challenge the students to rethink their ideas and also cause them to reveal their misconceptions for redress as early as possible.

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APPENDIX A

PART A

1 (a) State Faraday's first law of electrolysis (FFLE) in (i) words (ii) symbolic form
(b) What do the symbols stand for?

2 (a) State Faraday's second law of electrolysis (FSLE) in
(i) Words (ii) symbolic form.
(b) What do the symbols stand for?

Part B

Balance each of the following redox half equations.

(i) $Cu^{2+} \longrightarrow Cu$

(ii) $Au \longrightarrow Au^{3+}$

(iii) $Cl^- \longrightarrow Cl_2$

(iv) $H_2O \longrightarrow H^+ + O_2$

Part C

1. 9650 Coulombs of electricity was passed through a solution of $AgNO_3$. Calculate the
(i) Number of moles silver metal deposited
(ii) Mass of silver metal deposited

[Ag = 108, 1 Faraday's = a6500C]

2. An electrolytic solution containing a soluble salt of a divalent metal M was connected in series to a second electrolytic solution containing a soluble salt of a univalent metal T. If passage of electricity deposits 2.4g of M, calculate

    (i) The mass of T deposited
    (ii) The number of moles of T deposited [M = 24.0g: T = 18.0g]

3. How many moles of electrons will be required to deposit?
    (i) 3.2g of copper from $CuSO_4$ solution
    (ii) 2.7g of aluminium from $AICl_3$ solution [Al = 27.0g; Cu = 64.0g; 1Faraday = 96,500C]

APPENDIX B
SPECIMEN PROBLEM-SOLVING APPROACH OF AN ANALYTICAL STUDENT

$AgNO_3 \longrightarrow Ag^+ + NO_3^-$

Mole ratio

1 Faraday will deposit 1 mole of Ag

since 1 Faraday = 96,500C
Using 9650C will release Xg
But 1 mole of Ag = 108g
:. 96500C = 108g
9650C = Xg

:. $X = \frac{9650X108}{96500} = 10.8g$

No of moles = $\frac{mass}{molarmass} = \frac{10.8g}{108g} = 0.10mole$

APPENDIX C
SPECIMEN PROBLEM-SOLVING APPROACH OF AN INTUITIVE STUDENT

$AgNO_3$ = 108 + 18 + 16 X 3 = 184

Moles of Ag = Mass of Ag

IF ≡ 1 mole of Ag ≡ 96,500C

Moles of Ag = $\frac{9650\ X108}{96500X108} = 0.10mole$