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AN EVALUATION OF BOTSWANA SENIOR SECONDARY SCHOOL CHEMISTRY SYLLABUS

Isaac Seetso, Adediran Taiwo

Abstract. *The study aimed at evaluating the worth of the recently introduced chemistry syllabus in Botswana. Using a multi-faceted approach, data were collected from Botswana senior secondary school chemistry students, their teachers and pre-service chemistry teachers in the country. It was found that there exists a good link between the new syllabus and Junior Certificate (JC) science syllabus. In addition, it was found that the students viewed the modules on stoichiometry and carbon chemistry among others problematic. The students' views were corroborated, to a large extent, by their teachers'. Deriving from the findings of the study, it was recommended, among other things, that an extra lesson slot per week be allocated to chemistry and that the teaching load of chemistry teachers be reduced.*

Key words: *chemistry syllabus, natural science education, chemistry teachers.*

Isaac Seetso, Adediran Taiwo
University of Botswana, Gaborone, Botswana

Introduction

On the advent of independence in the 1960's, many a nation of Africa revamped their school curricula with a view to satisfying the aspirations of their citizenry. Further modifications to their school curricula were later carried out in the 1980's and 1990's by the different nations of Africa in order to meet the challenges of the 21st century. Botswana, like many other African countries, was not left out in these noble endeavours in that many national commissions on education (e.g.1977 & 1993 commissions) were instituted by the government of Botswana to address the issue of school curricula modifications.

Providing the springboard for this study are the relevant clauses from the report of one of Botswana's national commissions on education (the 1994 Revised National Policy on Education) as they relate to curriculum modification at the senior secondary school level in Botswana educational system. Those clauses gave authority for the localization of senior secondary syllabuses and examinations in order to meet the challenges of the 21st century. Accordingly, one of the clauses (Recommendation 50C) of the 1994 report decrees as follows:

> With respect to the senior secondary examination, the Commission recommends immediate preparation of a comprehensive programme of localization of the COSC [Cambridge Overseas School Certificate] examinations involving the following steps: preparation, re-writing and adaptation of syllabuses, starting with subjects of more local relevance and context (p.27).

As could be expected, chemistry was selected as one of the "subjects of more local relevance and context" to be given the pride of place in the proposed dispensation. This gave birth to the current national Botswana General Certificate of

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Secondary Education (BGCSE) chemistry syllabus which came into being in 1997. The introduction of this new chemistry syllabus underscores the incontrovertible notion that the importance of chemistry to the national economy of a state cannot be over-emphasised (Butts and Smith, 1987). As one of the basic sciences, chemistry does not only provide a very vital link between the school and the world of work but also occupies the centre stage in the industrial development of a nation in areas such as agro-based industry, petro-chemical industry and medico-pharmaceutical industry. The development of the chemistry syllabus was, therefore, hailed as a "watershed in the development of the public education system in Botswana" in the forward to the document by the Permanent Secretary in the Ministry of Education.

To date, the chemistry syllabus has now undergone four full cycles in its implementation since its introduction into the two-year senior secondary school system in January 1999. Four cohorts of students as of December 2003 have, therefore, gone through the entire syllabus. It is, therefore, high time the new BGCSE chemistry syllabus was evaluated. This study was, therefore, undertaken to evaluate the chemistry syllabus through the perspectives of significant stakeholders namely i) pre-service chemistry teachers, ii) practising chemistry teachers and iii) Form V chemistry students. The study, therefore, sought the views of the pre-service chemistry teachers on the nature of the syllabus with regards to its aims, assessment regime etc. while the opinions of the both practising chemistry teachers and their students were sought on the difficulty level of the chemistry syllabus content.

In order to carry out an in-depth study of the purpose of the study, the study was guided by the following research questions:

1) What are the general perceptions of pre-service chemistry teachers at the University of Botswana about:
   i) the development of the syllabus?
   ii) the stated aims of the syllabus?
   iii) the recommended teaching methods?
   iv) the assessment regime of the syllabus? and
   v) the organisation of the syllabus?

2) What are the practising chemistry teachers' opinions about the comparative levels of difficulty of the seven broad areas the syllabus is organized into?

3) What are the perceptions of Form V chemistry students about the relative difficulty levels of the topics covered by the syllabus?

4) Are there discernible gender differences in the opinions expressed by the students about the difficulty levels of the syllabus?

Methodology of Research

The purpose of the study dictated the adoption of survey design method for data collection purposes since no attempt was made to manipulate the subjects of the study but rather to source information from them through face-to-face interviews and administration of research questionnaires.

The study samples were drawn from three different sources in consonance with the goal of the study. The first set of sample was made up of fifteen post-graduate diploma in education (PGDE) students and twenty-one Year 3 B.Ed (science) students taking related methodology courses in chemistry teaching. The second set of subjects consisted of twelve chemistry teachers in three senior secondary schools in Gaborone, Botswana. The last but not the least set of subjects consisted of one hundred Form V chemistry students from five intact classes from three senior secondary schools in Gaborone. Two instruments [viz i) student questionnaire and ii) teacher questionnaire on Botswana chemistry syllabus] were developed for the study. Both of them were developed after carrying out content analysis of the chemistry content covered by the syllabus. For the student questionnaire, three core topics each were taken from the six broad areas (of matter, chemical reactions, stoichiometry, metals and non-metals, chemistry in the environment and carbon chemistry) of the syllabus. These eighteen items were complemented with two core topics from the remaining seventh broad area of experimental/investigation skills. In its own case, the teacher questionnaire covered the seven broad areas as sub-titled in the syllabus. The respondents to each of the questionnaires were requested to indicate the level of difficulty of each listed topic or area as i) very simple, ii) simple, iii) difficult or iv) very difficult for them or their students as the case may be. Both instruments were face-validated before use.

Data for the study were collected through two different modes. Face-to-face interview technique was used to source data from the pre-service teachers and the two constructed instruments were administered in the selected schools through the assistance of contact persons from the schools. Data analyses for the study employed both qualitative and quantitative statistical techniques in order to resolve the study questions.

Results of Research

In giving their perceptions about the development of the new BGCSE chemistry syllabus, the University of Botswana pre-service teachers noted that curriculum reforms normally adopt different approaches chief among which are i) adaptation, ii) adoption, iii) assimilation and iv) innovation; and opined that the developers of the BGCSE syllabus opted for the 'innovation approach'. They evaluated the syllabus as addressing chemical issues relevant to Botswana situation within the context of chemistry as a distinct and unique discipline. They associated themselves with the wide consultation that gave birth to the document. They, however, expressed a concern that two significant stakeholders namely parents and technical staff of chemistry-related industries were left out in the scheme of things. They expressed the hope that those two missing sources would be taken aboard in the future review of the syllabus.

On the aims of the syllabus, the pre-service chemistry teachers evaluated them as robust, comprehensive and above all achievable given pertinent conducive learning and teaching atmosphere. They opined that the development of positive attitudes towards chemistry and the development of productive and adaptive skills would go a long way in ensuring that its products develop relevant survival skills and abilities to "cope in a changing world". They endorsed in principle the teaching methods recommended by the syllabus. They noted with satisfaction the pertinence and the usefulness of the learner-centred approach and the variety of teaching methods (such as "inquiry, demonstration, practical work, project work, case study, field trips, discussions, computer guided learning etc") recommended for chemistry teaching by the syllabus. This stance corroborates the posture taken by Yandila (2002) in an earlier work. The pre-service chemistry teachers posited that these would go a long way in achieving the ideals of the syllabus. But they wondered whether these recommendations were not too ambitious in the face of i) high teaching loads, ii) over-crowded classes, iii) time table constraints and iv) limited material resources such as computer hard- wares and soft-wares.

They, however, hailed the assessment regime of the syllabus which sought to factor in continuous assessment (CA) into overall certification in the discipline. They believed that CA could thus be used as a motivational instrument to improve the learning of chemistry on the part of their students and could afford them (the teachers) the opportunity to pinpoint areas of student-learning deficiency or gaps in knowledge with a view to offering pertinent remediation and modifying their teaching techniques. They, however, expressed a studied reservation about the attainment of the lofty goal of factoring in CA for the purpose of certification because of the near-insurmountable problem of standardization of CA grades from different sources. It is, however, gratifying to note that this problem (i.e. the inclusion of CA grades in the certification regime) is currently being grappled with by three pilot senior secondary schools in the country.

The organization of the syllabus around seven broad areas logically sub-divided into topics

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with each topic having "general objectives which give rise to specific objectives" were highly rated and commended by the pre-service teachers. But while endorsing the logicality of the sequencing of the broad areas in general, they opined that having "carbon chemistry" as the last broad area left much to be desired as this is a completely new branch of chemistry to the students due to the lack of its (carbon chemistry) coverage at the Junior Certificate (JC) level.

In addressing Research Question 2, the following results (see Table 1 below) were obtained on analysing the responses of the twelve chemistry teachers who were asked to rate each of the seven broad areas covered by the syllabus on a four-point scale of very simple (VS), simple (S), difficult (D) and very difficult (VD) from the point of view of their students.

Table 1. Frequency table of chemistry teachers' opinions about the levels of difficulty of the seven broad areas of BGCSE chemistry syllabus.

	Broad Content Areas	VS	S	* % S	D	VD	** % D
1	Experimental/investigation skills	0	4	33	6	2	**67**
2	Matter	6	6	**100**	0	0	0
3	Chemical reactions	0	4	33	8	0	67
4	Stoichiometry	0	0	0	2	10	**100**
5	Metals and non-metals	4	4	**67**	4	0	33
6	Chemistry in the environment	0	10	**83**	2	0	17
7	Carbon chemistry	2	2	33	4	4	**67**

*%S = % Simplicity
**%D = % Difficulty

As could be seen from the table above, the content areas of "matter", "metals and non-metals" and "chemistry in the environment" do not constitute difficult areas for the chemistry majors as gleaned from their teachers' responses of how they perceive the levels of difficulty experienced by their students in their coverage of the syllabus. For example, the content area of matter is rated by all the teachers as constituting either a very simple or a simple area. The reason for this one hundred percent agreement on this content area is not far-fetched. "Matter", as an area of study to the students, is not a completely new area as they would have come across the rudiments of matter in their primary and JC science. In fact, the JC science syllabus which they have been privileged to go through before enrolling at the senior secondary school level covers topics such as i) understanding matter, ii) states of matter, iii) changes in states of matter, iv) atoms, elements, mixtures, molecules and compounds" etc.

The same story is true of the content area of "metals and non-metals" as a 10-period coverage is devoted to the treatment of metals and non-metals in Year 3 of JC science syllabus (Module 2, Unit 2.6). No wonder then, the two content areas are not perceived by the chemistry teachers as constituting difficult areas for their students. The third content area of "chemistry in the environment" which was classified by 83% of the chemistry teachers as "simple" for the chemistry majors is probably so because of the nature of the topics covered under this broad content area. It is instructive to note that the area covers topics like water, air, recycling, sources of energies, pollution etc. The chemistry majors in Botswana senior secondary schools are no strangers to these topics as evidenced by their JC science backgrounds; and hence it is logical for their teachers not to have much difficulty in explaining the "nitty gritties" of this aspect of chemistry to them.

However, four of the seven broad content areas of the syllabus were perceived by the teachers as difficult for their students. These are i) experimental/investigation skills, ii) chemical reactions, iii) carbon chemistry (with each of them attracting 67% difficulty rating from the teachers and iv) stoichiometry (with 100% difficulty rating).

Prophet and Vlaardingerbroek (2003) ascribe the difficulty in understanding the concepts and principles involved in those areas to the level of cognitive development of the students. And perhaps, another reason for those four areas being perceived as difficult areas is that the chemistry students are being exposed for the first time to these aspects of science to a great extent with little or no time to dissect, digest and internalise the concepts involved. Even though at JC level, the students would have been exposed to some hands-on activities in their integrated science and would have had a 'go' at some rudiments of chemical reactions, at this level (i.e. Senior Secondary School level), the expectation is that they would be able to apply basic science process skills to problem solving through scientific (empirical) investigations and to demonstrate familiarity with the fundamentals of chemical reactions such as acid-base reactions, oxidation-reduction reactions etc which are far cries from what they were exposed to at the JC level. Their exposure to chemistry at this level is further compounded by their introduction to the quantitative aspects of chemistry in the realm of stoichiometry.

Analysis of the responses of the one hundred Form V chemistry students who responded to the student questionnaire for the resolution of research question 3 yielded the following result.

Table 2. Frequency table of chemistry students' opinions about the levels of difficulty of BGCSE chemistry syllabus.

No	Topics	VS	S	D	VD
1	Handling experimental observations	4	45	40	11
2	Applying basic process skills to problem solving	4	20	**67**	**9**
3	The nature of matter	**34**	**53**	12	0
4	The structure of atom	**53**	**33**	11	3
5	The period table	**20**	**60**	18	2
6	Chemical reactions	5	41	42	12
7	Oxidation/reduction reactions	10	31	41	18
8	Electrolysis	9	28	44	19
9	The mole concept	5	30	47	18
10	Chemical calculations	5	23	**54**	**18**
11	Quantitative analysis	5	24	**59**	**12**
12	Chemical properties of metals	**30**	**52**	12	6
13	Common alloys	20	45	30	4
14	Forms of carbon	14	45	33	8
15	Air pollution	**20**	**61**	17	2
16	Conservation of natural resources	**25**	**48**	24	3
17	Fossil fuels	**12**	**64**	19	5
18	Organic compounds	6	23	**51**	**20**
19	Synthetic polymers	0	13	**69**	**18**
20	Natural macromolecules	2	8	**72**	**18**

A cursory look at the frequency table above shows that there appears to be a strong convergence between the opinions of the students and those of their teachers about the relative difficulty levels of the different segments of the chemistry syllabus. The students are relatively at home with topics like i) the nature of matter (87%), ii) the structure of atom (86%) and iii) the periodic table (80%); all of which are within the broad content area titled "matter" in the syllabus. Parallels could also be drawn between the views of the students and their teachers in the broad content areas of i) metal and non-metals [see items 13 (65%) and 14 (59%) above] and ii) chemistry in the environment [see items 15 (81%), 16 (73%) & 17 (78%)]. Deriving from the frequencies above, over 84% of the students are of the opinion that the "matter" section of the syllabus is

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either "very simple or simple". Similar views were expressed by the students for the content areas of "metals/non-metals and chemistry in the environment" by over 68% and 76% of the students respectively. One of the commonalities among these three areas is the fact that their fundamentals are covered by the JC science syllabus and as such they are not completely new to the students. Another reason why the students feel they are at home with these content areas is probably due to their non-quantitative nature.

But the same thing cannot be said of item 9 (the mole concept) with 65% difficulty level, item 10 (chemical calculations) with 72% difficulty level and item 11 (quantitative analysis) with 72% difficulty level. In fine, over 60% of the students classified these topics as either "difficult" or "very difficult". These topics belong to the stoichiometry section which was viewed by all the chemistry teachers surveyed as a difficult content area for their students. One need not be discouraged though by this, as research findings (Johnston, 1973) have shown that secondary students generally have difficulty with chemical calculations. In like manner, Herron (1990) finds that any concept like the mole concept which involves a ratio is extremely difficult for many a secondary school student. What is needed on the part of the student is hard work and perseverance.

The students also expressed a feeling of discomfiture with experimental investigation skills (items 1 and 2) and chemical reactions (items 18, 19 and 20) as could be gleaned from the table above. This trend is in perfect conformity with the opinions volunteered by their teachers on these content areas. It is instructive to note that overall over 82% of the students opined that carbon chemistry area [items 18 (71%), 19 (87%) and 20 (90%)] is either a difficult or very difficult area. The reason for this is probably not far-fetched as the students are encountering this aspect of chemistry for the first time since their exposure to science as a discipline from their primary schools.

To resolve research question 4, the students' responses which were analysed along gender dimension resulted in the outcomes contained in Tables 3 and 4 below:

Table 3. Frequency table of female chemistry students' opinion about the levels of difficulty of BGCSE chemistry syllabus (N = 40).

No	Topics	VS	S	D	VD
1	Handling experimental observations	1	21	13	5
2	Applying basic process skills to problem solving	2	10	**25**	**3**
3	The nature of matter	**14**	**22**	14	0
4	The structure of atom	**18**	**14**	7	1
5	The period table	**9**	**23**	6	2
6	Chemical reactions	2	20	14	4
7	Oxidation/reduction reactions	3	11	**21**	**5**
8	Electrolysis	2	8	**23**	**7**
9	The mole concept	3	11	**21**	**5**
10	Chemical calculations	2	8	**26**	**4**
11	Quantitative analysis	0	8	**23**	**9**
12	Chemical properties of metals	**10**	**24**	3	3
13	Common alloys	**5**	**21**	13	1
14	Forms of carbon	0	20	18	2
15	Air pollution	**5**	**31**	4	0
16	Conservation of natural resources	**11**	**23**	6	0
17	Fossil fuels	**4**	**24**	12	0
18	Organic compounds	0	8	**21**	**11**
19	Synthetic polymers	0	4	**18**	**18**
20	Natural macromolecules	0	4	**21**	**15**

Table 4. Frequency table of male chemistry students' opinions about the levels of difficulty of BGCSE chemistry syllabus (N = 60).

No	Topics	VS	S	D	VD
1	Handling experimental observations	3	24	27	6
2	Applying basic process skills to problem solving	2	10	**42**	**6**
3	The nature of matter	**20**	**31**	9	0
4	The structure of atom	**35**	**19**	4	2
5	The period table	**11**	**37**	12	0
6	Chemical reactions	3	21	**28**	**8**
7	Oxidation/reduction reactions	7	20	**20**	**13**
8	Electrolysis	7	20	**21**	**12**
9	The mole concept	2	19	**26**	**13**
10	Chemical calculations	3	15	**28**	**14**
11	Quantitative analysis	5	16	**36**	**3**
12	Chemical properties of metals	**20**	**28**	9	3
13	Common alloys	**15**	**24**	17	3
14	Forms of carbon	**14**	**25**	15	6
15	Air pollution	**15**	**30**	13	2
16	Conservation of natural resources	**14**	**25**	18	3
17	Fossil fuels	**8**	**40**	7	5
18	Organic compounds	6	15	**30**	**9**
19	Synthetic polymers	0	9	**51**	**0**
20	Natural macromolecules	2	4	**51**	**3**

A close study of Tables 3 and 4 above reveals that they show similar trends as depicted in Table 2 also. The import of this is that the same content areas constitute difficult areas for both the female and male students. The chi square analyses carried out to find out whether there are gender differences in the opinions expressed by the students about the difficult areas of i) experimental/investigation skills, ii) chemical reactions, iii) stoichiometry and iv) carbon chemistry yielded non-significant results contained in Tables 5a to 5d below.

Table 5a: A 2 x 2 contingency chi square table for the determination of gender differences in the area of experimental/investigation skills.

Gender	Difficulty levels		Totals
	S	D	
Boys	20 (33.3)	40 (66.7)	60
Girls	17 (42.5)	23 (57.5)	40
Totals	37	63	100

Chi square value: 2. 07

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Table 5b: A 2 x 2 contingency chi square table for the determination of gender differences in the area of chemical reactions.

Gender	Difficulty levels		Totals
	S	D	
Boys	26 (43.3)	34 (56.7)	60
Girls	14 (35)	26 (65)	40
Totals	40	60	100

Chi square value: 0.742

Table 5c: A 2 x 2 contingency chi square table for the determination of gender differences in the area of stoichiometry.

Gender	Difficulty levels		Totals
	S	D	
Boys	20 (33.3)	40 (66.7)	60
Girls	11 (27)	29 (73)	40
Totals	31	69	100

Chi square value: 1. 50

Table 5d: A 2 x 2 contingency chi square table for the determination of gender differences in the area of carbon chemistry.

Gender	Difficulty levels		Totals
	S	D	
Boys	12 (20)	48 (80)	60
Girls	5 (12)	35 (88)	40
Totals	17	83	100

Chi square value: 2. 23

Specifically, the chi square values of 2.07, 0.742, 1.50 and 2.23 obtained for the four areas were found to be non-significant at 0.05 level of significance. These results are in consonance with the generally non-significant correlations between students' perceptions about science and their gender (Neathery, n. d.) In effect, there are no discernible gender differences in the opinions expressed by the students about the difficulty levels of the new chemistry syllabus.

Conclusions and recommendations

Deriving from the findings of this study, it could be inferred that:

a) The BGCSE chemistry syllabus is a well thought-out document with concern for the milieu within which its content is being offered. It places the learner at the centre stage of learning activities with accent on hands-on experience and concern for the world of work. Above all, its development strategy is commendable. More work, however, need to be done in the realm of its proposed assessment regime which advocates the factoring in of continuous assessment (CA) grades into certification in light of the difficulty associated with the standardization of CA grades.

b) There appears to be convergence of opinions between the students and their chemistry teachers. Both identified content areas (such as matter) whose fundamentals are normally covered at the Junior Certificate [JC] level as not being problematic. They, however, opined that the content area dealing with the quantitative aspects of chemistry (such as the Mole concept) are difficult for the students. Carbon chemistry was another content area pinpointed as a difficult area, perhaps due to the lack of pertinent foundation in this area at the JC level.
c) There appears to be no gender differences between the perceptions of the students about the relative difficulty levels of the different segments of the BGCSE chemistry syllabus.

Based on the findings of the study, the following recommendations are made to address some of the identified shortcomings of the syllabus:

a) That at least an extra lesson slot per week be allocated to chemistry in the general school timetable. This is with a view to providing more contact time for chemistry teachers to adequately address the identified problem areas.
b) That the teaching loads of chemistry teachers be reduced to allow them more time to concentrate on the difficult aspects of chemistry in their lesson preparations and thereby offer their students better quality attention.
c) That chemistry teachers should devote some attention in their lessons to some aspects of mathematics, such as proportions and ratios that are germane to the understanding of quantitative aspects of chemistry such as the Mole concept.
d) That in the short run, carbon chemistry be introduced to the students earlier in the course possibly before the content area of 'chemistry in the environment' to allow more time on the part of the students for the internalisation of this new aspect of chemistry.
e) That in the long run, the rudiments of carbon chemistry be introduced into the JC science syllabus to provide some foundation for this important aspect of chemistry before the students get embroiled in greater details in it at the senior secondary school level.

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Резюме

ОЦЕНКА ПРОГРАММЫ ПО ХИМИИ ДЛЯ СРЕДНЕЙ ШКОЛЫ В БОТСВАНЕ

Исаак Сеетсо, Адедиран Тайво

В статье дается оценивание новой программы по химии для старшей средней школы в Республике Ботсвана. На появлении независимости в 1960-ых, много стран Африки обновляли их школьные учебные планы в целях удовлетворения стремлений их населения. Дальнейшие модификации к их школьным учебным планам были позже выполнены в 1980-ых и 1990-ых различными странами Африки, чтобы встретить вызовы 21-ого столетия. Новые программы по химии подготовлены четыре года назад. В принципе трудно судить о их эффективности. С другой стороны, для Ботсваны, как активно развивающейся страны, любые перемены в сфере системы образования очень актуальны и полезны. И наконец, оценивание новой программы по химии очень важная проблема для Ботсваны.

Данные для исследования были собраны двумя различными способами. Была использована техника интервью для исходных данных и опрос. Данные анализируются используя качественные и количественные статистические методы.

Установлено, что существует конвергенция мнений между учащимися и их преподавателями /учителями/ химии. Также установлено, что нет никаких гендерных различий между восприятием учащимися трудности различных уровней новой программы по химии /BGCSE/. Рекомендуется, чтобы учителя обратили больше внимания на различные вопросы химии, особенно на те, которые вызывает определенные трудности для учащихся. Для этого необходимо уменьшить педагогические нагрузки учителям химии, чтобы они могли сконцентрироваться на эти трудные аспекты химии и таким образом предоставить учащимся более качественное образование.

Ключевые слова: программы по химии, естественнонаучное образование, учителя химии.

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Isaac Seetso	He holds an M.Ed degree in science education from the University of Botswana in Southern Africa. He is a secondary school chemistry teacher. E-mail: taiwoaa@mopipi.ub.bw
Adediran Taiwo	He is a full Professor of Science Education, a position he has held since October 1985. He was appointed the Foundation Professor of Science Education in October 1990 by the University of Botswana in its Department of Mathematics and Science Education. University of Botswana, Private Bag 0022, Gaborone, Botswana Phone: +267 355 2162 E-mail: taiwoaa@mopipi.ub.bw