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Scientific Literacy Themes Coverage in the Nigerian Senior School Chemistry Curriculum

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ABSTRACT

The current reforms in science education around the world emphasize science for all, with the ultimate goal of achieving scientific literacy. These reform initiatives provide platforms for re-designing coherent science curricula that could serve as resources for scientific literacy, and consequently, contribute to the development of scientifically literate citizens–who will be able to use scientific knowledge in their daily decision-making processes and other socio-scientific issues. This study, therefore, investigated the coverage of scientific literacy themes in the Nigerian senior school chemistry curriculum and examination questions. A framework developed by Chiappetta, Fillman and Sethna (1991) was adopted to analyze aspects of the curriculum and examination questions. The results revealed that the chemistry curriculum placed more emphasis on the knowledge of science and investigative nature of science. The examination questions mostly stressed investigative nature of science and science as a way of thinking. The interaction of science, technology and society was sparingly represented in the curriculum and the theory component of the examination questions, and almost absent in the practical questions. While the chemistry materials may have a prospect to contribute to the preparation of scientifically literate citizens, a re-adjustment to the structure of the chemistry curriculum and examination questions could provide a balance of the scientific literacy themes in chemistry materials.

Keywords: Science education reforms, scientific literacy themes, chemistry curriculum, examination questions

INTRODUCTION

The recent science education reforms as reflected in the national curricula and policies of different nations, place greater emphasis on the need to graduate students who will be able to function effectively in a scientific and technological society. For instance, the science education reforms in the United States of America, stress a science education that will promote scientific literacy among K-12 students (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). In the United Kingdom,

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Holman (1997) reported that, the national curriculum accentuates the promotion of scientific literacy among students.

Similarly, the Nigerian national policy on science education emphasizes the teaching and learning of science processes and principles; which are anticipated to lead to fundamental and applied research in the sciences at all levels of education (Federal Republic of Nigeria, 2013). One common features of these national science education reforms among different countries, is the emphasis on the need for students to understand the interactions among science, technology, and society and be able to use this knowledge in their day-to-day decision-making processes (Mumba & Hunter, 2009).

There is no doubt that scientific literacy (SL) has been referred to as one of the major goals of science education as substantially reflected in several science education reforms and changing education policies taking place in the nations of the world. Scientific literacy is a broad term to define, and also appears controversial (Colagrande, Martorano & Arroio, 2016; Shwartz, Ben-Zvi & Hofstein, 2005). Reform documents describe scientific literacy as the ability to understand media accounts of science, to recognize and appreciate contributions of science, and to be able to use science in decision-making in daily life and socio-scientific issues (AAAS, 1993; NRC, 1996). In Nigeria, the education policy statement conceptualizes the goal of scientific literacy as the knowledge and understanding of the complexity of the physical world, vis-à-vis scientific concepts and processes required for good life and national development (Federal Republic of Nigeria, 2013). While several definitions exist for SL in the literature, science educators have come to agree that scientific literacy advocates for the development of a firm understanding of a range of scientific concepts, processes, awareness of the relationship among science, technology and society, and practices within and across science disciplines (Bauer, 1992; AAAS, 1993; Holman, 2002; Shwartz Ben-Zvi & Hofstein, 2006; Mumba & Hunter, 2009).

In line with these science education reforms and policy statements on education, science curriculum materials should ordinarily be designed or revised to meet the challenges of scientific literacy by providing curriculum materials that have adequate coverage of the scientific literacy themes, which include: (a) the knowledge of science (Theme 1); (b) the investigative nature of science (Theme 2); (c) science as a way of thinking (Theme 3); and (d) the interaction of science, technology and society (Theme 4) (Chiappetta, Sethna, & Fillman, 1993).

In the context of this research, there are previous studies that have analyzed science textbooks, curricula and examination questions for scientific literacy coverage, and reported imbalance in the representation of the scientific literacy themes, with emphases on the knowledge of science, and less attention on the other themes (BouJaoude, 2002; Chiappetta, Sethna, & Fillman, 1991; Lelliot, 2014; Lumpe & Beck, 1996; Mumba & Hunter, 2009; Ramnarain & Padayachee, 2015). Even though, Lelliot (2014) adopted Roberts' (2007, 2011) notions of vision I and vision II scientific literacy to analyze curricula statements and their approach to the concept of scientific literacy, the curricula documents were reported to have the dominance of the products and processes of science. In the analysis of South African life sciences and biology textbooks, Ramnarain and Padayachee (2015) recently reported that the textbooks did not reflect the aspirations of the current science education reforms that advocated for a more balanced coverage of the nature of science as a critical component of scientific literacy.

It is evident in the literature that studies in other countries on this important goal of science education, have only been channeled to examine science textbooks, with comparatively few studies on chemistry curriculum and examination questions (Cansiz & Turker, 2011; Erdogan & Koseoglu, 2012). Chemistry plays a very critical role in understanding the physical environment that is filled with chemical products (Gilbert &

Treagust, 2009). It is this understanding that helps people participate meaningfully in public debates and to make decisions about their everyday lives and environment (Irez & Çakir, 2006; Celik, 2014). Despite the critical role chemistry plays in promoting scientific literacy, there was no other research available to the researchers on scientific literacy themes coverage in any of the Nigerian senior school science curricula to the best of our knowledge, as at the time of this study.

The benefits of this research will not be limited to Nigeria only, but could be of international relevance to other developing countries that have revised their science curricula documents to align with the reforms advocacy, so as to confirm the possibilities of such documents to provide the needed scientifically literate citizens. For a country like Nigeria, that seeks to promote the study of science among its teeming population of young people; produce adequate number of scientists; and scientifically literate citizens capable enough to inspire and support national development, scientific literacy ought to be adequately reflected in our science curricula as a deliberate pursuit of the realization of these aspirations.

It is against these backdrops that we sought to investigate scientific literacy themes coverage in the Nigerian senior school chemistry curriculum and its potential to contribute to the preparation of scientifically literate citizens. Since chemistry curriculum encompasses examination questions, the chemistry questions of Senior School Certificate Examination conducted by the West African Examinations Council were included in our analysis. Within this scope, the study was guided by a research question on: What is the extent of coverage of the scientific literacy themes in the Nigerian senior school chemistry curriculum?

Scientific Literacy and the Nigerian Senior School Chemistry Curriculum

In Nigeria, the science curricula projects (African Primary Science Programme, Nigerian Integrated Science Project, *etc.*) which have been phased out, were well-intentioned and initially developed to promote scientific literacy among learners. However, these science curricula were not adequately implemented. Teachers taught science from textbooks adopted from developed countries and students ended up learning science contents, without sufficient understanding of its relevance to their day-to-day living and decision-making processes (Abimbola, 2009). In the wake of the 21st century, when the advocacy for science education reform initiatives became stronger, science curricula were revised to better position the curricula to inform and produce scientifically literate citizens.

The current chemistry curriculum was adapted and revised from the 1985 editions developed by Comparative Education Study and Adaptation Centre (CESAC). The curriculum was written and published in 2007 by university lecturers and senior school chemistry teachers in conjunction with the Nigerian Educational Research and Development Council (NERDC), and adopted by the Federal Ministry of Education for use in schools in 2009. In the curriculum document, the objectives of this curriculum were said to have been derived from the national policy statements on education, which are: “to prepare students with the basic knowledge in chemical concepts and principles through efficient selection of contents and sequencing; to acquire the ability to apply scientific knowledge to everyday life in matters of personal and societal needs, among others” (NERDC, 2009, p. 4).

In selecting the contents, three major issues – globalization; information and communication technology and entrepreneurship, that shape the development of nations worldwide, dictated the organization of the contents around four themes of: (i) the chemical world; (ii) chemistry and environment; (iii) chemistry and industry; and (iv) chemistry and life. Table 1 presents the summary of the Nigerian senior school chemistry curriculum, which includes the topics to be taught and the thematic approaches used in the revised curriculum (Oloruntegbe & Agbayewa, 2013).

Table 1. *Summary of the Nigerian Senior School (SS) 1-3 Chemistry Curriculum*

Theme/Year	SS1	SS2	SS3
Chemistry and Industry	Chemistry and Industries	Periodic table, Chemical reactions, Mass-volume Relationship	Quantitative and qualitative analysis
The Chemical World	Introduction to chemistry, Particulate nature of matter, Symbols, formulae and equations, Chemical combination, Gas laws	Acid-base reactions, Water, Air, Hydrogen, Oxygen, Halogens, Nitrogen, Sulphur	Petroleum, Metal and their compound iron Ethical, legal and social issues
Chemistry and Environment	Standard separation techniques for mixtures, Acid, bases and salt, Water	Oxidation-reduction (redox) Reaction, Ionic theory, Electrolysis	Fats and oil, Soap and detergent, Giants molecules
The Chemistry of Life	Carbon and its Compounds	Hydrocarbons, Alkanols	

Source. Adapted from Oloruntegbe and Agbayewa (2013).

Note. SS 1 – 3 represents senior school level of education in Nigeria, which is equivalent to Grade 10 – 12 in countries that use grade system.

In planning the new chemistry curriculum, a spiral approach to sequencing a science course was adopted. The spiral approach allows concepts/topics to be taught in greater depths as the course progresses, in such a way that a particular concept can run throughout the three years of senior school education (see Table 1).

The West African Senior School Certificate Examination (WASSCE) conducted by the West African Examinations Council (WAEC), is one of the foremost summative assessments to mark the end of senior secondary education in Nigeria. The WASSCE is a qualitative and reliable examination in West Africa that has a strong influence on learning, teaching, and assessment (Ojerinde, 2011).

Chemistry is one of the elective and non-vocational subjects students are examined in. The results from these examinations could influence students' progression to the next stage of education. The structure of the examination questions is designed by the Examination Boards of the member countries (Nigeria, Liberia, Ghana, Sierra Leone and Gambia), though, not limited to the objectives and contents of the national curriculum and syllabi operational in each of those countries.

For chemistry, there are three papers – Paper 1, Paper 2 and Paper 3. Candidates are usually required to take either Papers 1 and 2 or Papers 2 and 3 only. Paper 1 is a two-hour practical test, while paper 3 also test practical knowledge, but is an alternative to paper 1. The candidates are required to answer all the three questions. Two of the questions are on quantitative and qualitative analyses, while the third question test candidates' familiarity with the practical activities suggested in their teaching syllabuses (West African Examinations Council [WAEC], 2005).

Paper 2 is a three-hour theory paper that covers the entire syllabus and carries a total of 150 marks, i.e., 75% of the total marks of the external examination. The paper has two parts; Part A and Part B. Part A contains fifty multiple choice questions drawn from Section A of the syllabus, where candidates are required to answer all the questions within 60 minutes for 50 marks. In this study, only the essay (theory) and practical questions were analyzed for the coverage of the scientific literacy themes.

CONCEPTUAL FRAMEWORK FOR THE STUDY

This study is hinged on a framework/procedure developed by Chiappetta *et al.* (1991, 1993) to analyze chemistry curriculum. The framework was developed from reviews of literature on scientific literacy and has been extensively used by researchers to analyze science textbooks and curricula documents (Abd-El-Khalick, 2002; BouJaoude, 2002; Chiappetta & Fillman, 2007, Ramnarain & Padayachee, 2015). This framework is considered to have addressed the dimensions of scientific literacy within four themes of:

1. *The knowledge of science:* In this category, the intent of the texts should be to present, discuss, or ask the student to recall information, facts, concepts, principles, laws, theories, hypotheses, and models. The texts in this category require students to recall facts or information. This theme reflects the transmission of scientific knowledge where the student receives information.

2. *The investigative nature of science:* In this category, the intent of the text should stimulate thinking and doing by asking the student to 'find out'. It reflects the active aspect of inquiry and learning, which involves the student in the methods and processes of science, such as observing, measuring, classifying, inferring, recording data, making calculations, experimenting. In this category, the texts would require students to answer a question through the use of charts, tables, and graphs; require students to make a calculation; require students to reason out an answer; or engage students in a thought experiment or activity.

3. *Science as a way of thinking:* In this category, the intent of the texts should illustrate how certain scientists, went about discoveries. This aspect of the nature of science represents thinking, reasoning and reflection, where the student is told about how the scientific enterprise operates. Texts in this category: describe how scientists experiment; show the historical development of an idea; emphasize the empirical nature and objectivity of science; illustrate the use of assumptions; show how science proceeds by inductive and deductive reasoning; give cause and effect relationships; and discuss evidence and proof.

4. *Interaction of Science, Technology, and Society:* In this category, the intent of the texts should illustrate the effects or impacts of science on society. This theme of scientific literacy relates to the application of science and how technology helps or hinders humankind. Texts in this category describe the usefulness of science and technology to society; recognize the negative effects of science and technology on society; discuss social issues related to science or technology; and bring out careers and jobs in scientific and technological fields.

BouJaoude (2002) made three adaptations to the framework that led to the expansion of Theme 4, to include "personal use of science to make everyday decisions, solve everyday problem and improve one's life and the impact of ethical and moral concerns on these activities' (p. 145). BouJaoude (2002) further argued that, the current discussions on the conceptions of the philosophy of science makes 'science as a way of knowing' to be more inclusive, rather than, science, being conceived, 'as a way of thinking'. An expanded detail of each of the themes of scientific literacy that aligns with subsequent discussions of the conceptions of scientific literacy is presented in the texts above. This framework developed by Chiappetta *et al.* (1991) and the modified version advanced by BouJaoude (2002) was employed to analyze the scientific literacy themes coverage in the Nigerian senior school chemistry curriculum.

RESEARCH METHODS

A mixed-method research design that employed content analysis was used to analyze the senior school chemistry curriculum and examinations questions. A valid and reliable procedure developed by Chiappetta *et al.* (1991, 1993) was used to analyze the documents. A typical example on electrolysis shows of the three components of the curriculum and the units analyzed or examined for scientific literacy coverage in Table 2.

Table 2. *An Example of the three Components of the Curriculum and the Units Analyzed*

Topic	Performance Objectives	Students' Activities	Evaluation Guide
Electrolysis	Students should be able to: (i) explain the quantitative aspects of electrolysis	Set-up an electrolytic cell	Define electrolysis
	(ii) illustrate the electrolysis of acidified water, Copper(II) sulphate and brine	Explain the electrolysis of acidified water, Copper(II) sulphate and brine	Set-up the electrolytic and electrochemical cells
	(iii) construct the electrolytic and electrochemical cells	Describe the principle of Hoffman's voltammeter in the electrolysis of acidified water	Carryout the electrolysis of acidified water
	Explain the uses of electrolysis in extraction of metal and purification	State the uses of electrolysis	State the uses of electrolysis

Source. Adapted from the Nigerian Senior School (SS) 1-3 Chemistry Curriculum (NERDC, 2009)

The data sources for this study were 585 units of the performance objectives, students' activities and the evaluation guides of the chemistry curriculum and 398 questions drawn from the senior school certificate examinations conducted by the West African Senior School Certificate Examinations (WASSCE) for a period of 5 years from 2010 – 2014. In each year, there were four questions with many parts for students to answer. For ease of analysis, each of the many parts of a question was taken as a unit or single question to be analyzed. In coding the units for analysis, a deductive approach was used to analyze the texts according to the framework of Chiappetta *et al.* (1991). Examples of units that agree with the categories of each of the scientific literacy themes are presented alongside the quantitative data in the research findings section.

To ensure reliability of the study, a random selection of 10% of the curriculum units and chemistry (theory and practical) questions were analyzed. From the curriculum document and examination questions, specific texts were identified and selected for analysis by using a random-number generator (www.random.org). The selected texts were independently analyzed by one of the researchers and a Professor of science education who understands the goal of scientific literacy, its representations in curricula contents and examination questions.

The values of Kappa's measure of agreement were calculated based on the classification of the peer-raters, for each of the performance objectives, students' activities, evaluation guides, chemistry theory and practical questions. The Kappa-values for the performance objectives, students' activities, evaluation guides, chemistry theory and practical questions were .68, .74, .82, .86 and .67 respectively. The substantial Kappa-values ($\kappa > .65$) for the units analyzed indicated a good measure of agreement between the two raters, which consequently, guaranteed a good reliability for the study.

RESEARCH FINDINGS

The objectives of the chemistry curriculum make clear reference to all the four themes of scientific literacy framework provided by Chiappetta *et al*. (1991). The objectives of the curriculum are to:

> *facilitate a smooth transition in the use of scientific concepts and techniques acquired in the new Basic Science and Technology curriculum with chemistry* [Themes 1 & 2]*; provide students with basic knowledge in chemical concepts and principles through efficient selection of content; enable students to appreciate the scientific method which involves experimentation, accurate observation, recording, deduction and interpretation of scientific data; enable students to develop laboratory skills, including an awareness of hazards in the laboratory and the safety measures required to prevent them; create an awareness of the inter-relationship between chemistry and other disciplines* [Themes 2 & 3]*; show chemistry and its link with the industry, the environment and everyday life, in terms of benefits and hazards* [Theme 4].

These excerpts from the objectives of the chemistry curriculum overtly justify the intentions the developers of the curriculum to provide contents capable of producing scientifically literate citizens' outline in the framework for analysis.

Table 3 indicates that all the four themes were represented in varying degrees in the performance objectives of the curriculum. However, there were inconsistencies in the representation of the themes in the objectives from SS1 to SS3. The basic knowledge of science received the most emphasis (45.1%), followed by science as a way of thinking (26.2%), then the investigative nature of science (22.4%) and the interaction of science, technology and society (6.3%).

Table 3. *Representations of the Scientific Literacy Themes in the Performance Objectives of the Curriculum*

Performance objectives	Scientific literacy themes									
	The basic knowledge of science		The investigative nature of science		Science as a way of thinking		Interaction of science, technology and society		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Senior School 1	24	38.1	19	30.2	14	22.2	6	9.5	63	26.6
Senior School 2	49	45.5	22	20.4	35	32.4	2	1.9	108	45.6
Senior School 3	34	51.5	12	18.2	13	19.7	7	10.6	66	27.8
Total	**107**	**45.1**	**53**	**22.4**	**62**	**26.2**	**15**	**6.3**	**237**	**100**

Table 4 contains scientific literacy themes coverage in students' activities in the curriculum for the three senior school years. On average, investigative nature of science (53.8%) is the most represented theme in students' activities, followed by the basic knowledge of science (27.8%), science as a way of thinking (14.8%) and the interaction of science, technology and society (3.6%).

The emphasis on Theme 2 reflects active inquiry and learning, where students are actively involved in the scientific processes. For example, the intent of the excerpts on students' activities below engages students in well-thought experiments:

> *Prepare standard solutions, carry out acid-base titrations using given indications and record titre values correctly to 2 decimal places. Carry out experiments on the removal of hardness of water by boiling and the addition of washing soda. Observe the experiment on the laboratory preparation of chlorine, and record your*

observations. Demonstrate the bleaching action of chlorine [Theme 2] (Senior Secondary Education Curriculum, Chemistry for SS 1 – 3, Chemistry and Environment, Pp. 16, 17 & 21).

Table 4. *Representations of the Scientific Literacy Themes in the Students' Activities of the Chemistry Curriculum*

Students' Activities	Scientific literacy themes: The basic knowledge of science		The investigative nature of science		Science as a way of thinking		Interaction of science, technology and society		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Senior School 1	14	20.4	24	45.3	12	22.6	3	5.7	53	41.4
Senior School 2	22	27.5	45	56.2	12	15.0	1	1.2	80	47/3
Senior School 3	11	30.6	22	61.1	1	2.8	2	5.6	36	21.3
Total	**47**	**27.8**	**91**	**53.8**	**25**	**14.8**	**6**	**3.6**	**169**	**100**

Table 5 presents the frequency and percentage distribution of the scientific literacy themes coverage in the evaluation guides/questions of the curriculum. From the Table, basic knowledge of science is the most emphasized with 54.7%, while investigative nature of science and science as a way of thinking were marginally at 19.6% and 20.7% respectively. Lesser focus was on science as a way of thinking and investigative nature of science, which would have engaged students in cognitively demanding tasks or activities that requires reasoning out the answers. The interaction of science, technology and society is the least emphasized in the evaluation questions.

It is noted earlier that the design of the chemistry curriculum adopted a thematic approach where the different topics were grouped around the four themes of *chemistry and industry, the chemical world, chemistry and environment* and *the chemistry of life*. Examples of evaluation guides or questions drawn from *chemistry of life* expected to be covered at the third year of senior secondary school is given as:

> *Name substances that contain fats and oils. List the physical and chemical properties of fats and oils. Define saponification… State the uses of fats and oils* [Theme 1] (Senior Secondary Education Curriculum, Chemistry for SS 1 – 3, Chemistry of Life, p. 36).

The intent of these questions is to ask students to recall knowledge about fats and oils, state or list the properties of fats and oils and their uses.

Table 5. *Representations of the Scientific Literacy Themes in the Evaluation Questions of the Curriculum*

Evaluation questions	Scientific literacy themes: The basic knowledge of science		The investigative nature of science		Science as a way of thinking		Interaction of science, technology and society		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Senior School 1	30	60.0	10	20.0	7	14.0	3	6.0	50	27.9
Senior School 2	46	52.9	19	21.8	21	24.1	1	1.1	87	48.6
Senior School 3	22	52.4	6	14.3	9	21.4	5	11.9	42	23.5
Total	**98**	**54.7**	**35**	**19.6**	**37**	**20.7**	**9**	**5.0**	**179**	**100**

Table 6 demonstrates that scientific literacy themes were also represented in the chemistry examination questions. The chemistry paper 2 (theory) placed more emphasis on investigative nature of science (38.1%), while knowledge of science and science as a way of thinking (25.0%) were the next emphasized, followed by interaction of science, technology and society (11.9%).

It is evident in Table 6 that; investigative nature of science was the most emphasized in each of the examination years from 2010 – 2014. Even though, the questions were not such that actively engage students in well-thought experiments or activities, the questions classified under Theme 2 reflects the processes of science and the active aspect of inquiry and learning. For example, the question below reflects the representation of some of the scientific literacy themes:

> *i. Define each of the following terms. I. biotechnology; II biogas ii. State two applications of biotechnology. b (i). Describe briefly the production of ethanol from sugarcane juice. (ii). State the by-products of the process in b (ii). b (iii). Mention two uses of the by-products. (iv). Ethanol can be produced from both sugarcane and petroleum. Explain briefly why the ethanol from sugarcane is renewable, but that from petroleum is non-renewable* [Theme 1, 2 and 4] (WASSCE Chemistry Paper 2, 2012).

The intent of this question does not only require students to recall information about biotechnology and biogas, but also to explain scientific processes, in this case, the process(es) of producing ethanol from sugarcane. Part of the questions would also require students to state the applications of biotechnology (domestic and industrial applications), some of which could be consumables, while others are non-consumables, but useful to mankind.

Table 6. *Frequency and Percentage Distributions of Scientific Literacy Themes in the SSCE Chemistry Questions*

Years	Scientific literacy themes									
	The basic knowledge of science		The investigative nature of science		Science as a way of thinking		Interaction of science, technology and society		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
2010	17	27.4	27	43.5	11	17.7	7	11.3	62	18.9
2011	16	19.8	31	38.3	25	30.9	9	11.1	81	24.7
2012	17	26.6	24	37.5	15	23.4	8	12.5	64	19.5
2013	13	21.7	23	38.3	19	31.7	5	8.3	60	18.3
2014	19	31.1	20	32.8	12	19.7	10	16.4	61	18.6
Total	**82**	**25.0**	**125**	**38.1**	**82**	**25.0**	**39**	**11.9**	**328**	**100**

The results in Table 7 presents the scientific literacy themes coverage in the practical chemistry questions (paper 1) from 2010 – 2014. From the Table, it is expected that more questions are classified under Theme 2, with investigative nature of science (54.3%) as the most emphasized, followed by science as a way of thinking (28.6%), then basic knowledge of science (12.9%). The interaction of science, technology and society (4.3%) was the least emphasized in the chemistry practical questions.

In some of the examination years (2010, 2012 and 2014), interactions of science, technology and society did not appear in the practical questions. While basic knowledge of science did not feature in the 2010 practical questions, comparatively fewer questions require the knowledge of science to solve in the other years, except for year 2012 with more questions. The SL Theme 3 was represented in each of the years, but the questions were fewer compare to practical questions on Theme 2.

Table 7. *Representations of the Scientific Literacy Themes in the SSCE Chemistry Practical Questions*

Years	Scientific literacy themes									
	The basic knowledge of science		The investigative nature of science		Science as a way of thinking		Interaction of science, technology and society		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
2010	0	0	10	67.7	5	33.3	0	0	15	21.4
2011	1	7.7	7	53.8	3	23.1	2	15.4	13	18.6
2012	5	31.2	7	43.8	4	25.0	0	0	16	22.9
2013	2	15.4	6	46.2	4	30.8	1	7.7	13	18.6
2014	1	7.7	8	61.5	4	30,8	0	0	13	18.6
Total	**9**	**12.9**	**38**	**54.3**	**20**	**28.6**	**3**	**4.3**	**70**	**100**

For example, the following question provides an evidence for theme 2:
***C** contains two cations and two anions. Perform the following exercises on **C**. Record your observation and identify any gas(es) evolved. State the conclusion you draw from the result of each test (Table 8). (a). Dissolve all of **C** in about 10 cm^3 of distilled water. Stir the resulting solution thoroughly*.

Table 8. *Practical Chemistry Questions (see the attached text)*

No.	Test	Observation	Inference
i.	To about 2 cm^3 of the solution, add few drops of $AgNO_3$ followed by $HNO_{3(aq)}$. To the mixture add excess $NH_{3\ (aq)}$.		
ii.	To another 2 cm^3 portion of the solution, add dilute HCl, followed by $BaCl_2$ solution.		
iii.	To another 2 cm^3 portion of the solution, add NaOH $_{(aq)}$ dropwise, and then in excess. Warm the mixture.		
iv.	To another 2 cm^3 portion of the solution, add $NH_{3\ (aq)}$ dropwise, and then in excess.		

[Theme 2] (WASSCE Chemistry Paper 1, Practical Question 2, 2014).

This question requires students to carry out an experiment, report observations, draw inferences, and to ultimately suggest a chemical formula for **C** at the last stage of the experiment in the column for inference, which students will have to reason out on the basis of the inferences.

DISCUSSION AND CONCLUSION

The aim of this study was to examine the scientific literacy themes coverage in the Nigerian senior school chemistry curriculum and chemistry examination questions for a period of 5 years. The results of this study revealed that the knowledge of science was the most covered theme, followed by investigative nature of science, then science as a way of thinking and the interaction of science, technology and the society. This finding is consistent with the reports of previous studies on science curricula (BouJaoude, 2002, Cansiz & Turker, 2011, Erdogan & Koseoglu, 2012; Mumba & Hunter, 2006; Ramnarain & Padayachee, 2015). The study of BouJaoude (2002), analyzed Lebanese science curriculum for scientific literacy themes (Chiappetta *et al.*, 1991), and reported the emphases on scientific literacy themes 1, 2 4, and the neglect of science as a way of thinking (Theme 3). In the same vein, Erdogan and Koseoglu, (2012) concluded that the representation of the scientific literacy themes was not proportionate, and the understanding of the nature of science was inadequate. These findings confirm the observation that the chemistry curriculum focuses more on the accumulation of facts, concepts, generalizations, laws and theories than the other themes of the scientific literacy.

From this result, a realization that the curriculum is a vital component of science education and the significant role it plays in chemistry instruction raises a serious concern on why the *basic knowledge of science* (Theme 1) is emphasized more than necessary in the chemistry curriculum. This finding suggests that the curriculum developers did not develop the chemistry contents in line with the objectives the curriculum had intended to achieve. An implication of this finding is that teachers who implement this curriculum may as well limit their emphases in classroom instructions to mainly the delivery of chemistry concepts, facts and a little of scientific processes.

The chemistry examination questions analyzed revealed that the WASSCE chemistry paper 2 (theory) had a fairly adequate coverage of Themes 1, 2 and 3, except Theme 4 that was lesser, about 11.9%. It is adjudged fair in comparison with the coverage of the chemistry curriculum. This result could be attributed to the nature of the WAEC chemistry questions, which may not be necessarily limited to the national curriculum of any of the 5 member countries, but are questions drawn to reflect the objectives of the chemistry syllabi of the countries that clearly seek to promote scientific literacy. The chemistry paper 1 (practical questions), placed more emphasis on the investigative nature of science, then, science as a way of thinking. This finding is expected as laboratory-based examinations should be inquiry-based and should seek to assess students' understanding of the processes of science. These results are fairly similar to the findings of Mumba and Hunter (2009), where all the themes had an excellent representation of the four themes of scientific literacy in both chemistry theory and practical questions. These results indicated that the chemistry questions have the potential to promote active aspect of inquiry, and develop students' thinking processes, but may not be sufficient enough to prepare scientifically literate populace. The implication of a curriculum that does not adequately covers the scientific literacy themes is reflected in the examination questions. Therefore, it could really be difficult for teachers to understand, explicitly teach and assess students in chemistry from the perspective of current paradigms of science that underpin students to effectively function as scientifically literate citizens after school.

The findings of this study has shown that, the chemistry curriculum and examination questions did not provide adequate coverage of the scientific literacy themes. Though, the four themes were represented in the curriculum documents, but not in equal representations. For a country whose education policy statements conceptualize scientific literacy goals as the understanding of scientific concepts and processes required for good life and national development, an adequate coverage of the scientific literacy themes in terms of knowledge and depth of engagement that is explicit-reflective, should be reflected in chemistry curriculum for students' learning experience.

RECOMMENDATIONS

Based on the outcomes of this study, it is recommended that, curriculum developers should re-structure the chemistry curriculum to provide the scientific literacy themes in all the units of the curriculum in equal proportions. This could involve a deliberate effort to present chemistry curriculum objectives and contents that reflect the core concepts, theories and models put forward by science to explain the natural world; the methods employed by scientists to gain new knowledge and how scientific and technological enterprise relates to societal issues and problems. Once this is achieved, test developers are likely to adjust subsequent examination questions to reflect the scientific literacy themes that aligns with the goals of the examinations.

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