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# Curriculum and Instructional Validity of the Scientific Literacy Themes Covered in Zambian High School Biology Curriculum

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The purpose of this study was to establish the nature and extent of scientific literacy (SL) themes coverage in Zambian national high school biology curriculum. The three data sources are biology textbooks, biology syllabi, and grade twelve national biology examination papers for a five-year period (2000–2004). These data sources were analyzed using the framework and procedure developed by Chiappetta, Fillman, and Sethna. The framework has four themes of SL namely: Science as a body of knowledge; Science as a way of investigating; science as a way of knowing; and Interaction between science, technology and society. The results show that the biology textbooks and syllabi content objectives emphasized basic knowledge of science while the biology examination papers, and the syllabi aims and assessment objectives emphasized science as a way of knowing. The interaction between science, technology and society theme was the least represented in the biology course. The results also suggest lack of curriculum and instructional validity in biology examinations with respect to the four themes of SL. The inadequate coverage of interaction of science, technology and society theme in the curriculum materials may be a barrier to a better preparation of scientifically literate citizens. Some recommendations have been made.

**Key Words**: scientific literacy, biology, high school, curriculum, examination

## Introduction

The increased emphasis on preparing scientifically literate citizenry is reflected in national science education reforms (American Association for the Advancement of Science (AAAS), 1989 & 1993); national science education standards (National Council of Research, (NRC), 1996); national educational policies (McEneaney, 2003; Ministry of Education, 1996) and national science curricula (Jenkins, 1990; Holman, 1997; BouJaoude, 2002). For example, the US Science for All Americans reform document (AAAS, 1993) states that the world's economic and environmental destiny is largely dependent on how wisely the public utilizes science and technology. Bybee and Fuchs (2006) also state that through science, the public can learn not only how to make informed decisions about the use of science and technology, but also to assess the applicability and effects of scientific discoveries and technologies on

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society as they emerge. As such, scientific literacy (SL) is one of the main elements in national educational systems worldwide, and the evidence to support this is found in a number of areas which include curricula prescriptions and professional and political discourse (McEneaney, 2003; Roberts, 1983). SL is a broad term and there is no consensus among science educators on its definition. However, SL involves individuals developing sound understanding of scientific facts and scientific inquiry process, and an awareness of the relationships among science, technology, and society (Bauer, 1992; NRC, 1996). Scientifically literate persons are those that have scientific knowledge, scientific inquiry skills, and abilities to make thoughtful decisions about socio-scientific issues (Jenkins, 1990; Laugksch, 2000a). Such individuals appreciate the value of science and technology and understand their limitations (Wilkinson, 1999).

Science education must meet the challenge of improving SL among students who are also future citizens (Roberts, 1983; Maarschalk, 1988). In particular, science teachers have an important role in educating students to become more scientifically literate. Beyond science education reforms and teachers, science teaching materials should promote the development of SL among students by providing a balanced representation of the many aspects of SL. For example, Chiappetta, Fillman, and Sethna (1991a) suggested that in order to effectively achieve SL among students, science curriculum materials should emphasize the following themes of SL: Basic knowledge of science; Investigative skills of science; Science as a way of knowing; and Interaction of science, technology and society. Chiappetta, Fillman, and Sethna (1991a) synthesized these four themes of SL from various research studies (Garcia, 1985; Collette & Chiappetta, 1986; Harms & Yager, 1981), and the National Science Teachers' Association's (NSTA) 1982 position on SL. These four themes of SL have become the main elements in contemporary science education reform documents (AAAS, 1993), national science education standards (NRC, 1996), national education policies (Ministry of Education, 1996), and school science curricula (Holman, 1997; BouJaoude, 2002) worldwide.

Several science textbooks have been analyzed to establish the representation of the four themes of SL mentioned above (Garcia, 1985; Fillman, 1989; Baarah, 1991; Chiappetta et al., 1991b,c; Chiappetta et al., 1993; Lumpe & Beck, 1996; Wilkinson, 1999; Laugksch, 2000b; BouJaoude, 2002; Mumba, Chabalengula & Hunter, 2006). In general, these studies report that the basic knowledge of science aspect of SL is the most emphasized theme followed by science as a way of investigating theme, less on science as a way of knowing, and even less on the interaction of science, technology, and society theme. However, none of these studies have provided an explanation for the unequal representation of the four themes of SL in science textbooks. In addition, none of these studies have holistically investigated the coverage of SL themes in school science curriculum by analyzing textbooks, syllabi, laboratory manuals and past examination papers that are used in a science course. Yet, in many countries in Africa (Seetso & Taiwo, 2005; Mumba, Chabalengula & Hunter, 2006) and Asia (Wei & Thomas, 2005), science courses are taught and learned through the national science curriculum materials which comprise national science textbooks, syllabi, laboratory manuals, and past science examination papers. The national science textbooks, syllabi and laboratory manuals provide the instructional support beyond the teachers. The national science examinations are used to assess students' learning at the end of their high school education. If SL is an implied goal of science teaching in Zambian schools, then the national science curriculum materials should have a balanced coverage of the four SL themes mentioned above. In addition, there should be a congruent between curriculum and instructional validity with regard to SL themes. Bybee and Ben-Zvi (1998) also assert that the ideal science curriculum development initiatives are those that express the balance of SL themes. This is the reason why this holistic analysis of Zambian high school science curriculum materials for representation of the themes of SL was conducted.

The purpose of this study, therefore, was to investigate the nature and extent of SL themes coverage in the Zambian national high school biology course. In particular, we were interested in establishing the nature and extent of the SL themes representation across and within the Zambia national high school biology course materials. The research question was: What is the nature and extent of the SL themes coverage across and within the Zambia national high school biology curriculum materials?

### *Zambian High School Biology Education*

High school education starts in grade ten and ends in grade twelve. Biology is a compulsory subject and all students are required to take it for three years in high schools. The prescribed biology textbooks and syllabus are the main curriculum materials for biology teaching and learning in high schools. Each biology teacher is given three prescribed textbooks (Biology 10, 11, and 12) and one copy of the national biology syllabus as a guide for scope and depth of the content to be taught in each grade. Each student is given a copy of the biology textbook and returns it after each grade. There are five periods of biology lessons per week for a class and each period is forty-five minutes long. Biology lessons have theory and laboratory experiment sessions. There are three school terms per year: January to April, May to August, and September to December, and each term is thirteen weeks long. By the end of their grade twelve, students will have received more than 140 hours of biology education At the end of their grade twelve, students take national examinations, equivalent to the Ordinary-Level standard in the British system for certification, admission to universities and colleges and employment. In the biology course, there are three examination papers - Paper 1 with forty multiple choice questions, paper 2 with eight structured and theory questions and paper 3 with two laboratory experiments. Examinations are prepared by experienced high school biology teachers and biology lecturers from a local national university in conjunction with the Examination Council of Zambia. Examiners use the prescribed national biology textbooks and syllabus as guides for preparing examinations.

## Methodology

### *Data Sources and Descriptions*

The data sources were: three biology textbooks (Biology 10, Biology 11, and Biology 12); two national biology syllabi (Biology 5090, and Biology High School Syllabus [BHSS]); and fifteen grade twelve national biology examination papers for a five-year period (2000-2004). These data sources were chosen because they constitute the national biology curriculum materials used in Zambian high schools.

### *Biology Textbooks*

The three biology textbooks 10, 11, and 12 are used by teachers and students in grades 10, 11, and 12 respectively. They are named after the grade in which they are used. These textbooks were written by Zambian biology educators. The full references of these textbooks are found in the reference list. Table 1 below shows topics and number of pages in each biology textbook. Table 1 show that Biology 10 textbook has 130 pages, and covers fourteen topics, Biology 11 has 169 pages and has ten topics, and Biology 12 has 110 pages, and 8 topics. The presentation of information in these textbooks starts by biological facts, followed by hands-on and/or minds-on activities and ending with review questions or exercises.

Table 1. Profile of biology textbooks.

| Textbook | Topics | No of pag-es |
|---|---|---|
| Biology 10 | Organisms and life processes, animal and plant cells, cells and water, nutrients, enzymes, dentition in mammals, nutrition in animals, soil, photosynthesis, saprophytic nutrition, respiration, gaseous exchange, nutrient cycles, food chains and food webs. | 130 |
| Biology 11 | Plants and animals, transport and storage in plants, circulatory system in humans, excretion, homeostasis, growth and development, tropic responses, endocrine system, sense organs, and diseases. | 169 |
| Biology 12 | Skeleton and locomotion, sexual reproduction in flowering plants, sexual reproduction in mammals, asexual reproduction, vegetative reproduction, genetics, population, and ecology. | 110 |

It is also worth to note that none of the three prescribed textbooks covered the nature of science as a separate chapter or topic.

### *Biology Syllabi*

The two biology syllabi are coded Biology 5090, and Biology High School Syllabus Grades 10-12 (BHSS). The full references of these syllabi are found in the reference list. These two syllabi were analyzed because the old syllabus (Biology 5090) was still being used in some schools at the time this study was conducted. Therefore, either syllabus was still being used in schools. Table 2 below shows the profiles of the biology syllabi.

The Biology 5090 syllabus was written and published by the University of Cambridge in England in 1980s. The first two pages are about the introduction, aims, assessment objectives, and the weighting of the assessment objectives. Pages three to ten consist of four major sections, topics under each section, and the objectives under each topic. The Biology High School Syllabus (BHSS) was published in 2002 by the Ministry of Education in Zambia. The first eight pages cover the introduction, aims, assessment objectives, and the weighting of the assessment objectives. The rest of the pages consist of thirteen major units, topics under each unit, the objectives under each topic, and notes which refer teachers and students to some other topics, or indicates where emphasis should be stressed.

In both syllabi, the objectives are clearly stated in terms of whether students should state, identify, examine, investigate, or conduct an experiment. The syllabi are also elaborate on the type of materials to be used – such as using fresh specimens or using diagrams. In some cases the objectives also indicate the type of instruments (such as the hand lens) to be used.

### *Biology Examination Papers*

Three national final biology examination papers 1, 2, and 3 are taken by all students at the end of their grade twelve each year. The grade twelve biology examination papers that were written between 2000-2004 were analyzed for SL themes coverage. In total, fifteen biology examination papers were analyzed in this study.

Table 2. Profile of biology syllabi.

| **Syllabus** | **Sections/Units** | **No. of pages** | **No. of content objective statements** |
|---|---|---|---|
| Biology 5090 | Section I – Organization and maintenance of the individual, Section II – Diversity of organisms, Section III – Relationships of organisms with one another and with the environment, and Section IV-Developments of organisms and continuity of life. | 10 | 166 |
| Biology High School sylla-bus (BHSS) | Unit 1 - Living organisms, Unit 2 – Nutrition, Unit 3 – Transport, Unit 4 – Respiration, Unit 5 – Ex-cretion, Unit 6 – Homeostasis, Unit 7 – Growth and development, Unit 8 – Responses, Unit 9 – Locomotion, Unit 10 – Reproduction, Unit 11 – Health, Unit 12 – Genetics, and Unit 13 – Ecology. | 41 | 251 |

Paper 1 consists of forty multiple choice questions, each with four possible answers A-D. Students are required to choose only one best answer. Students are required to complete this paper in fifty minutes. Some questions in this paper are accompanied by diagrams, charts, or graphs to aid students. Typically, paper 1 is printed on 14 pages. Paper 2 is a theory paper in which students are required to write short answers or essays. This paper consists of ten questions, but has two sections, A and B. Both sections have five questions each. Students are required to answer all the five questions in section A. However, in section B students are given leeway and only asked to answer any three questions of their choice. Unlike in Paper 1, each question in paper 2 has sub-questions, though the number of these sub-questions is not always the same for all major questions. Paper 3 is a practical examination, which requires students to conduct an experiment, make observations, describe an experimental procedure, write short description about a provided specimen, or respond to the questions. There are two questions, and students are required to answer both of them in seventy-five minutes. The two questions also have sub-questions.

*Framework for Analyzing Biology Curriculum Materials*

The content analysis of the biology curriculum materials was carried out using a valid and reliable framework procedure developed by Chiappetta, Filman, and Sethna (1991a). The procedure provides a list of units of analysis that should be used for analyzing SL themes, and a description of the SL themes to be considered when analyzing a science curriculum material. The units of analysis include complete paragraphs, questions, figures with captions, tables with captions, marginal comments, and complete steps in a laboratory. The four themes of SL outlined in the framework are: Basic knowledge of science (Theme I); Investigative skills of science (Theme II); Science as a way of knowing (Theme III); and interaction of science, technology and society (Theme IV).

> 1) *The Basic Knowledge of Science*. Check this category if the intent of the text is to present, discuss, or ask the student to recall information, facts, concepts, principles, laws, theories, models etc. This category reflects the transmission of scientific knowledge where the student receives information.
>
> 2) *The Investigative Nature of Science*. Check this category if the intent of the text is to 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 etc. This type of instruction can include paper-and-pencil as well as hands-on activities.
>
> 3) *Science as a way of Knowing*. Check this category if the intent in the text is to illustrate how science in general or certain scientists in particular went about finding out. This aspect represents thinking, reasoning, and reflection where the student is told how the specific enterprise operates.
>
> 4) *Interaction of Science, Technology, and Society*. Check this category if the intent of the text is to illustrate the effects or impacts of science on society. This aspect of SL pertains to the application of science and how technology helps or hinders humankind. It involves social issues and careers. Nevertheless, the student receives this information and generally does not have to find out (Chiappetta, Fillman, & Sethna, 1991a, pp. 943-944).

The selection of the units of analysis from the biology textbooks, syllabi, and examinations was guided by the framework procedure described above. In the textbooks, the units that were analyzed included complete paragraphs, review questions, figures with captions, tables with captions, charts with captions, marginal comments, and complete steps in a laboratory activity. However, instead of using a 5% random sample of pages from each textbook as Chiappetta, Fillman, & Sethna (1991a) proposed, we analyzed all pages in each textbook in this study. This was because the three biology textbooks used were relatively brief (pages ranged from 110-169 pages) compared to the five life science textbooks (whose pages ranged from 493-570) analyzed used by Chiappetta, Fillman, & Sethna (1991a). In the syllabi, the introduction, aims, assessment and content objectives, and notes to teachers were selected as units of analysis. In the examination papers, instructions, diagrams, figures, questions, and sub-questions were selected as units of analysis.

### *Analysis Procedure*

Two science educators independently analyzed the biology textbooks, syllabi, and examination papers using the same procedure, which involved matching the elements of the four SL themes with the text, pictures, tables, questions, figures, marginal comments, and laboratory activities. The data sheet analysis produced by Chiapetta, Fillman, & Sethna (1991a) was used for the content analysis. Each curriculum material was read and each unit of analysis was identified and placed into one of the four themes of SL. Then, the percentages of the four themes of SL were obtained for each biology curriculum material.

After the two science educators independently analyzed the biology curriculum materials, they came together to discuss their coding. In cases where there was mismatch between them, they resolved the difference by either adopting one category, or redoing the analysis together. The raters then computed the percentage of agreement and interrater coefficients. The interrater agreement coefficients were calculated using Cohen's Kappa (Cohen, 1960). Cohen's Kappa (k) is a coefficient of interrater agreement that takes into consideration agreement by chance.

## Results

### *Interrater Agreement*

The interrater agreements between the two raters in the biology curriculum materials are shown in Table 3 below.

Table 3. Interrater agreement values for each biology curriculum material.

| **Biology curriculum material** | | **Percent agreement** | **Kappa value** |
|---|---|---|---|
| Textbooks | Biology 11 | 92.5 | 0.92 |
| | Biology 10 | 87.8 | 0.86 |
| | Biology 12 | 85.8 | 0.83 |
| Syllabi | Biology 5090 | 89.2 | 0.88 |
| | BHSS | 91.8 | 0.91 |
| Examinations | Paper 1 | 89.2 | 0.88 |
| | Paper 2 | 85.4 | 0.85 |
| | Paper 3 | 90.0 | 0.80 |

The percentage of agreement on the analysis of the biology curriculum materials for SL themes coverage ranged from 85.4 % to 92.5% with a corresponding kappa coefficients range of 0.80 to 0.92. The percentage agreement of more than 75% and kappa values above 0.5 are considered to indicate good level of interrater agreement (Chiapetta, Fillman & Sethna, 1991a). Therefore, the values in Table 3 above can be considered good enough to justify reliability element in this study.

### *SL Themes in Biology Curriculum Materials*

Table 4 provides a summary of the mean percentage coverage of SL themes in biology textbooks, syllabi, and examination papers. Table 4 shows that all the three biology textbooks emphasized the basic knowledge of science (60-79%) theme of SL. The investigative nature of science (12-30%) was the second most covered theme in the books. The biology textbooks, however, deemphasized science as way of knowing (6%), and the interaction between science, technology and society (2-4%) themes. The two biology syllabi (Biology 5090 and BHSS) covered the four themes of SL differently between the aims and assessment objectives, and the content objectives. With respect to the aims and assessment objectives, both syllabi emphasized more on the investigative nature of science (38.1 & 50%), and science as a way of knowing themes (29.2 & 33.3%), followed by the interaction of science, technology, and society (14.6 & 21.4%). The basic knowledge of science theme (6.3 & 7.1%) was the least emphasized.

Table 4. Percentage coverage of SL themes in biology curriculum materials.

| Biology curriculum materials | | SL Themes | | | |
|---|---|---|---|---|---|
| | | I | II | III | IV |
| Textbooks | Biology 10 (N=769) | 60.0 | 30.0 | 6.0 | 4.0 |
| | Biology 11 (N=792) | 77.0 | 16.0 | 5.0 | 2.0 |
| | Biology 12 (N=786) | 78.6 | 12.1 | 5.5 | 3.8 |
| Biology 5090 Syllabus | Introductions, aims, & assessment objectives (N=48) | 6.3 | 50.0 | 29.2 | 14.6 |
| | Content objectives (N=166) | 65.0 | 26.0 | 4.0 | 5.0 |
| Biology High School Syllabus (BHSS) | Introductions, aims, & assessment objectives (N=42) | 7.1 | 38.1 | 33.3 | 21.4 |
| | Content objectives (N=251) | 65.0 | 27.0 | 6.0 | 2.0 |
| Examinations | Biology Paper 1 (2000-2004) (N=200) | 28.5 | 35.5 | 36.0 | 0.0 |
| | Biology Paper 2 (2000-2004) (N=200) | 12.5 | 32.0 | 54.5 | 1.0 |
| | Biology Paper 3 (2000-2004) (N=90) | 2.2 | 75.5 | 22.2 | 0.0 |

Note. I- Basic knowledge of science; II- Investigative nature of science; III- Science as a way of knowing; IV- Interaction of science, technology and society; N=Number of analyzable units identified.

In contrast, the content objectives in both syllabi emphasized the basic knowledge of science theme (65%), followed by investigative nature of science theme (27%). The content objectives, however, deemphasized science as a way of knowing (4-6%), and the interaction of science, technology, and society (2-5%).

The trend of SL themes coverage among biology examination papers was the same though the extent to which each theme was covered varied from one paper to another. Overall, the biology examinations emphasized the investigative nature of science (32-75.5%) and science as a way of knowing themes (22.2-54.5%), followed by the basic knowledge of science (2.2-28.5%) theme. The interaction of science, technology, and society theme was ignored in the biology examination papers analyzed.

## Discussion

The four significant findings in this study are: unbalanced representation of the four SL themes across and within the biology high school course materials; similarity in the coverage of SL themes in the biology textbooks and syllabi content objectives; lack of curriculum and instructional validity in the national biology examinations with respect to the four themes of SL covered in the textbooks and syllabi content objectives; and the discrepancy in the coverage of the SL themes between the aims and assessment objectives, and the content objectives in the syllabi. These findings are discussed below.

### *SL Themes Coverage in the Textbooks and Syllabi*

The results show that the biology textbooks and content objectives in the two syllabi emphasized the basic knowledge of science, and the investigative nature of science themes of SL. The greater emphasis on basic knowledge of science theme than the other three themes in Zambian biology textbooks matches the findings reported in earlier studies (Chiappetta, Sethna & Fillman, 1991b,c; Chiappetta, Sethna, & Fillman, 1993; Lumpe & Beck, 1996; Mumba, Chabalengula & Hunter, 2006; Wilkinson, 1999). The focus on both themes in the biology textbooks and syllabi demonstrates the integration of the content and inquiry activities. This outcome may be attributed to the fact the old biology syllabus (Biology 5090) served as the guiding template when modifications were being made. Therefore, recent changes made to these materials are not that different from the original documents. However, the interaction of science, technology and society theme of SL was not adequately represented in both biology syllabuses.

### *Curriculum and Instructional Validity in Biology Examinations*

The results suggest that the national biology examinations lacked both curriculum and instructional validity with respect to the four themes of SL covered in the textbooks and syllabi content objectives. The term curriculum validity is used herein to refer to the extent to which an assessment tool tests the content, in this case the SL themes, covered in the textbooks and syllabi (Haertel & Calfree, 1983; Wise & Reidy, 2005). On the other hand, instructional validity refers to the extent to which the assessment tools cover the content, in this case the SL themes, that is assumed to have been taught by teachers (Messick, 1989; Yoon & Resnick, 1998). In practice, evidence of curriculum and instructional validity is often gathered by examining the official curriculum materials used in instruction and matched with the items in the examinations, and asking the teachers what they taught and how they taught the content (Haertel & Calfree, 1983). Such a practice should clearly demonstrate congruence between content, instructional practice, and assessment. Unfortunately, in the present study, there is incongruence between the SL themes prescribed in the textbooks and syllabi and the SL themes that were assessed in the biology examination papers. That is, the textbooks and syllabi emphasized the basic knowledge of science theme, whereas the examination papers deemphasized the basic knowledge of science, but emphasized science as a way of knowing and investigative nature of science themes of SL.

The incongruence between what was taught and what was assessed raises the question of whether this is a problem or not. We argue that the emphasis on science as a way of knowing, and investigative nature of science in the biology examination papers is not entirely a problem. Science as a way of knowing relates to how scientific knowledge is produced, and the characteristics of such knowledge. This implies that the biology examinations provide students with the meta-cognitive tools to reflect upon science as an enterprise. The biology examinations also provide students with tools to develop skills for observing and identifying cause-and-effect relationships. Wilkinson (1999) also states that "if more emphasis is placed on the investigative nature of science, science as a way of thinking, and the interaction of science, technology, and society in examinations, then we might see a corresponding increase in emphasis given to these areas by teachers and textbook authors" (p. 396).

However, the lack of curriculum and instructional validity found in the national biology examinations is not consistent with appropriate assessment practices in K-12 science education and is counter productive to effective promotion of SL among students. Recently, some researchers reported on the importance of curriculum and instructional validity in K-12 assessment tools (DeBoer, 2004; Wise & Reidy, 2005). Wise and Reidy stressed that examinations must have both aspects if they are to test the knowledge and skills which students have learned in a course. It is, therefore, common sense to state that if the SL themes covered in biology textbooks and syllabi are not adequately covered in the examinations, the opportunity to promote SL among students becomes questionable. It is for this reason that attention to issues of validity, with respect to SL themes, is important in the Zambian biology curriculum materials analyzed in this study.

Despite the need for curriculum and instructional validity in assessment tools, research shows some particular concerns for high school assessment and why many teachers fail to address them in their courses. Many teachers lack appropriate training in assessment (Airasin & Madaus, 1983) and misinterpret content outlined in textbooks and syllabi (Shepard, 1995). Are these the same reasons for lack of curriculum and instructional validity in Zambian biology examinations with respect to SL themes? This incongruity between Zambian biology examinations and textbooks and syllabi may be attributed to four factors. First, the national biology examinations are mostly prepared by biology lecturers from a local university. These examiners may not be familiar with the distribution of emphasis in SL themes in the textbooks and syllabi. Since the biology examinations are also used for admission to the local university, one would assume that the examiners would want to assess high school students on how they can apply science concepts and perform independent science activities. As such, it may not be surprising that examinations covered the investigative nature of science and science as a way of knowing themes more than the other two themes of SL.

Second, the purpose of each biology examination paper may influence the SL theme to be emphasized. For example the biology Paper 2 examinations are intended to test for students' application of the content knowledge and skills to new situations. Therefore, the questions would place less emphasis on the basic knowledge of science theme which involves a mere recall of information.

Third, the design of the questions in terms of what students are required to do may play a role in deemphasizing the basic knowledge of science theme. For example the biology Paper 1 examinations, despite being in multiple choice format, are accompanied by diagrams, tables, and graphs which require students to either use the diagrams and given information to answer the questions, or to use inductive and deductive reasoning, or to find cause-and-effect relationships between or among variables given in the questions. Therefore, most of the questions did not ask for the recall of information per se. The biology Paper 3s, being practical examinations mostly emphasized the investigative nature of science.

The fourth factor could be that the examiners are not interpreting the representation of SL themes in the syllabi and textbooks in the same way as the writers of these materials would. As such, the examiners are designing questions that are not based on the coverage of each SL theme in the syllabi and textbooks. However, the questioning in the examinations is consistent with the National Education Policy [NEP], (Ministry of Education, 1996) which demands that students be challenged and tested above the knowledge level in order to prepare a scientifically literate citizenry.

In order to assess students' understanding and application of the elements embedded in each of the four themes of SL, biology examiners should also consider whether the questions accurately represent the SL themes prescribed in the curriculum materials.

*SL Themes Coverage in Biology Syllabi*

The investigative nature of science and science as a way of knowing were the most emphasized SL themes in the aims and assessment objectives of both syllabi. On the other hand, the basic knowledge of science and investigative nature of science themes were the most covered in the content objectives of both biology syllabi. As mentioned above, examiners mostly use the syllabi and textbooks to prepare examinations. However the difference in emphasis of the SL themes between the aims and assessment objectives sections and the content objectives in the syllabi could be one of the factors that can explain why there are curriculum and instructional validity problems in the national biology examinations. It appears biology examiners use the aims and assessment objectives in the syllabi to set the questions, thereby making the examinations emphasize more the investigative nature of science and science as a way of knowing themes than the other two themes of SL. The aims and assessment objectives of the syllabi were the only units of analysis that covered the interaction of science, technology and society theme to a considerable degree among the biology curriculum materials analyzed. However, the examiners paid little attention to this theme in the examination papers.

## Conclusions and Recommendations

The results show that the four themes of SL were disproportionately covered among the Zambian high school biology curriculum materials. In addition, the nature and extent to which the four SL themes were represented in each biology course material varied. The basic knowledge of science and investigative nature of science received more coverage in the biology textbooks and in the syllabi content objectives. On the other hand, science as a way of knowing, and investigative nature of science themes received the most coverage in the biology examinations, and aims and assessment objectives sections of the two syllabi. The interaction between science, technology and society theme was the least covered theme across the biology curriculum materials.

Based on these findings and those reported in previous studies, curriculum design and research recommendations are suggested. We suggest that the authors of science teaching materials should be encouraged to develop curriculum materials which address the four themes of SL in order to promote full SL among high school students. Examiners and teachers who are responsible for preparing assessment tools should align examination items with the SL themes prescribed in textbooks and syllabi, in order to address the issue of curriculum and instructional validity in the examinations.

The analysis of science curriculum materials alone is not adequate to unveil the holistic picture of how SL themes are covered in the Zambian high school biology curriculum. Therefore, we recommend future research to find out how the four themes of SL are addressed by biology teachers during instruction. Wei and Thomas (2005) postulate that in addition to document analyses, interviews with key informants involved in designing the curriculum materials can help realize the idea of embedding SL themes within a high school science curriculum. Therefore, there is an additional need to investigate the perceptions of science textbooks authors, syllabi writers, and examination writers about the extent to which SL themes should be covered in these curriculum materials.

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