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Abstract. *This study investigated the balance and emphasis of scientific literacy themes in Zambian high school physics course in an attempt to find out its potential of contributing to preparation of scientifically literate citizens. Results show that the national syllabus and examinations emphasized the investigative nature of science while textbooks placed most emphasis on basic knowledge of science. Although the interaction of science, technology and society theme was accentuated in the syllabus, it was less emphasized in textbooks and absent in some examination papers. However, the physics course has potential of contributing to the preparation of scientifically literate citizens.*

Key words: *scientific literacy, physics course, syllabus, textbooks, examinations.*

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A QUANTITATIVE ANALYSIS OF ZAMBIAN HIGH SCHOOL PHYSICS TEXTBOOKS, SYLLABUS AND EXAMINATIONS FOR SCIENTIFIC LITERACY THEMES

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Introduction

Scientific literacy (SL) is one of the main goals of science education and its emphasis is reflected in science education reforms and national educational policies around the world (Lumpe, & Beck, 1996; Wilkinson, 1999). For example, in Zambia one of the goals of education presented in the National Education Policy (NEP) adopted by the Ministry of Education in 1996 is to produce "a learner capable of appreciating the relationship between scientific thought, action and technology on the one hand, and sustenance of the quality of life on the other" (NEP, 1996, p. 5). The NEP serves to underscore that a scientifically literate person should have a range of investigative skills and understanding of nature of science and the interaction between science, technology and society in order to function in a modern society. Beyond education reforms and national educational policies, science curriculum materials are expected to meet the challenges of improving SL by providing curriculum balance which stresses fairly equal proportions of the following themes: (a) basic knowledge of science (Theme I), (b) investigative nature of science (Theme II), (c) science as a way of thinking (Theme III) and (d) interaction of science, technology and society (Theme IV) (Chiappetta, Sethna, & Fillman, 1993). As such, science educators have analyzed science textbooks to



establish the representation of these four themes of SL (Chiappetta, Sethna & Fillman, 1991 & 1993; Bojouade, 2002; Lumpe & Beck, 1996; Wilkinson, 1999). In general, these studies reported that science textbooks possessed little balance in their approach to the four themes of SL. Most textbooks emphasized the basic knowledge of science theme, which includes facts, theories and laws followed by investigative nature of science theme. Very little text was devoted to science as a way of thinking and even less was devoted to interaction of science, technology and society theme. It is evident in the literature that, to date, studies on this important topic in science education have only examined textbooks and ignored science syllabi and public examinations. Yet, in many developing countries like Zambia, with centralized education system, national syllabi serve as main guides for writing textbooks, science instruction and preparing public examinations. If SL is an implied aim of science teaching, then it ought also to form an important part of the aims of the national science syllabus, textbooks and examinations. This study, therefore, investigated the balance and emphasis on SL themes in Zambian high school physics syllabus, textbooks and grade twelve public examination papers in an attempt to find out whether or not the national physics course has the potential to contribute to the preparation of scientifically literate citizens. This study went beyond previous studies by examining physics syllabus and examination papers for SL themes representation and compared with those in the textbooks. This study was guided by the following questions: What content is emphasized in the national physics syllabus, textbooks and examinations relative to the four themes of SL mentioned above? Does the national high school physics syllabus differ from the physics textbooks and public examinations with regard to their treatment of the four themes of SL? Does the national physics course have the potential to contribute to the preparation of scientifically literate citizens?

Zambian high School Science Curriculum

High school education starts in grade ten and ends in grade twelve. Students' admissions to high school are based on their performance in the public Junior high school examinations, which they take at the end of grade nine. Before students start their grade ten, school administrators use grade nine science and mathematics examination results to put students in either humanities or science streams. However, physics is a compulsory subject in both streams and all students are required to take it in three years of high school. Each stream has other subjects that students are required to take. Each student is required to take a minimum of six and maximum of nine subjects including physics in the stream of his or her choice to meet the first condition for high school certification, the other condition is passing the public examinations. There are five periods of physics instruction in a week and each period is forty-five minutes long. There are three school terms in a year (January to April, May to August and September to December) and each is thirteen weeks long. By the end of their grade twelve students will have taken more than 140 hours of physics instruction. At the end of their grade twelve students sit for public examinations, equivalent to the Ordinary-Level (O-Level) standard in the British system, for certification, admission to post-secondary school education, training and employment. The national physics examinations are prepared by experienced high school physics teachers and physics lecturers from a local university in conjunction with Examination Council of Zambia. The examiners use the syllabus and textbooks as a guide for preparing examinations. The national physics textbooks that are used in schools were written by Zambian science educators following the physics syllabus.

Methodology of Research

Data sources

Data sources were one high school physics syllabus, three physics textbooks (Physics 10, 11 and 12) (see reference list for details) and fifteen public physics examination papers (Papers 1, 2 and 3) that were written by high school students between 2000 and 2004. The physics syllabus was written in 1996 by Zambian science educators in conjunction with Curriculum and Development Center (CDC), adopted by the Ministry of Education and implemented in schools in 2000. The



physics examination Paper 1 has forty multiple choice questions to be answered in one hour while physics paper 2 is a theory paper in which students are required to write short answers and essays in two and half hours. Physics paper 3 is a two-hour practical examination in which students are asked to perform four experiments and write a report on each.

Procedure

The analysis of the physics course materials was carried out following a valid and reliable procedure developed by Chiappetta, et al. (1991). Evidence for content validity for the themes comes from the fact that Chiappetta et al. derived the four themes for SL based on numerous literacy documents. The four themes of SL are:

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, etc. This theme 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.
3. *Science as a way of Thinking*: Check this category if the intent of the text is to illustrate how certain scientists in particular went about finding out. This aspect of the nature of science represents thinking, reasoning and reflection, where the student is told about how the scientific enterprise operates.
4. *Interaction of Science, Technology, and Society (STS)*: 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. In addition, it involves social issues and careers. Nevertheless, the student receives this information and generally does not have to find out. (Chiappetta, Sethna, & Fillman, 1991, p. 943-944).

The units analyzed in the syllabus were introduction, aims, suggested teaching approaches, content statements and assessment objectives. In textbooks, the units analyzed included text paragraphs, activities, introduction, aims and objectives sections, tables, charts, review questions, and photographs. All the questions, diagrams and tables in the examinations were analyzed. These units of analysis were read and placed into one of the four themes of SL. Then the number of units of analysis for each theme was determined and expressed as a percentage of total number of units of analysis for each document. In this way, the percentages of the four themes of SL were obtained for each physics course material. Two physics educators independently coded the documents for the four SL themes. An intercoder agreement coefficient was calculated using Cohen's Kappa (Cohen, 1960). This coefficient factors in chance agreement and represents a measure of reliability. The mean percentages of SL themes are reported in Table II below.

Results of Research

Intercoder Agreement

Table 1 below shows that percentage agreement ranged of 85% to 93% for the physics course materials analyses with corresponding range of kappa values from 0.82 to 0.92 were achieved. These statistics suggest a high degree of agreement between the two raters in categorizing the content into four themes of SL. Chiappetta et al (1991) stated that values above 75% indicate excellent interrater agreement while kappa values below 0.4 indicate a poor coefficient.



Table 1. Intercoder Agreement Coefficients for each Physics course material.

Course Material	Percent Agreement	Kappa
Syllabus	89	0.88
Book 10	93	0.92
Book 11	88	0.86
Book 12	85	0.82
Paper 1 Examination (N=5)	89	0.88
Paper 2 Examination (N=5)	91	0.90
Paper 3 Examination (N=5)	87	0.85

Note: This data is from two raters who conducted the coding. N= Number of Exam. papers

SL themes in the Introduction, Aims and Assessment sections of Physics Syllabus

The four themes of SL were explicitly emphasized in the introduction and the general aims of the national high school physics syllabus as shown below:

During this course pupils should acquire knowledge and understanding of facts, ideas, and experimental techniques (CDC, 1996 p. ix-x) (SL Themes I & II).

The syllabus aims at stimulating pupils' curiosity and sense of inquiry which will in turn not only provide suitable basis for further study of the subject but also provide pupils with sufficient knowledge and understanding to make them become useful and confident citizens. The essence of such an inquiry is related to problem solving and reflecting on scientific enterprise (CDC, 1996, p. ix). (SL Themes II, III & IV)

...education system should aim at producing a learner capable of appreciating the relationship between scientific thought, action and technology on the one hand, and sustenance of the quality of life on the other. This syllabus has taken into consideration environmental issues with emphasis on applications of physics in everyday life (CDC, 1996, p. vi). (SL Theme IV)

The assessment section also states that the physics examinations should focus on assessing students' knowledge, understanding and application of: scientific phenomena, facts, concepts, theories, laws, terminology, use of symbols, quantities and units (Theme I); scientific apparatus and instruments and their safe operations, hypothesizing, plotting and interpreting graphs (Theme II); experimental methods evaluation and possible improvements (Theme III); and scientific and technological applications with social, economic and environmental relevance (Theme IV).

SL Themes in Physics Syllabus, Textbooks and Examinations

Table 2 shows that all the four themes of SL were represented in the national physics syllabus in varying degrees with investigative nature of science (Theme II) receiving more representation than any of the other three themes. The physics textbooks placed most emphasis on basic knowledge of science with an overall mean of 72% followed by the investigative nature of science (19%), less on science as a way of thinking (6 %) and even less on interaction of science, technology and society (3%).

Physics examinations mostly emphasized the investigative nature of science (64%), followed by science as a way of thinking (20%) and the basic knowledge of science (16%), and to the relative neglect of interaction of science, technology and society (1%).



Table 2. Mean Percentage of Themes of SL Found in Physics Course Materials.

Physics Course Material	Themes of SL			
	I	II	III	IV
Syllabus (N= 261)	27	36	21	16
Book 10 (N=769)	60	30	6	4
Book 11 (N=792)	77	16	5	2
Book 12 (N=786)	79	12	6	4
Mean	72	19	6	3
Paper 1 Examinations (N=200)	24	55	22	0
Paper 2 Examinations (N= 286)	25	46	28	4
Paper 3 Examinations (N=215)	0	91	9	0
Mean	16	64	20	1

Note. N = Number of analyzable units identified. Themes of SL: I= Basic Knowledge of Science; II= Investigative Nature of Science; III= Science as a Way of Thinking; and IV= Interaction of Science, Technology and Society.

Although physics paper 1 had multiple choice questions, examiners placed more emphasis on investigative nature of science (55%) than basic knowledge of science theme (24%), less emphasis on science as a way of thinking (22%) and 0% on interaction of science, technology and society theme. Physics paper 3 emphasized investigative nature of science (91%), less emphasis on science as a way of thinking (9%) and 0% on basic knowledge of science and interaction of science, technology and society themes of SL.

Discussion

The emphasis on basic knowledge of science in Zambian physics textbooks is consistent with previous studies (Chiappetta et al., 1991 & 1993; Boujaoude, 2002; Lumpe & Beck, 1996; Wilkinson, 1999) which reported that textbooks are facts-laden. Although Chiappetta et al. (1991) predicted that new science materials are likely to devote a higher proportion of their text to interaction of science, technology and society since this theme is attracting more attention in science education, the current Zambian physics textbooks and examinations placed the lowest emphasis on this theme. This finding suggests that in spite of the innumerable scientific and technological advancements that have occurred in physics over the past decades and that have greatly affected society, textbook authors and examiners have not included them in physics curriculum. This is likely to be an obstacle in promoting SL among students.

The results also suggest that the purpose of the textbooks is to provide scientific facts. However, the emphasis on the investigative nature of science and science as a way of thinking in the syllabus and examinations offers students with opportunities to develop science investigative skills and understanding of how scientific knowledge is produced and the characteristics of such knowledge. This implies that the syllabus and examinations provide students with the meta-cognitive tools to reflect upon science as an enterprise. What is more important with this finding is that learning is not complete if students can't reflect upon scientific knowledge and skills they acquire if they are to apply them in their lives. However, the disproportionate representation of SL themes in the physics course materials



may be attributed to the nature, purposes and the authors of these documents. The national physics syllabus was written as the main guide of science instruction in high school classrooms, hence the better representation of SL themes. Textbooks authors may have written their books to mainly delivery scientific facts. Physics paper 2 examinations are intended to assess students' application of scientific knowledge and skills to new situations. Physics paper 3 as laboratory-based examinations are aimed at assessing students' knowledge and skills for designing, conducting experiments and communicating the findings. The physics examiners most of whom are lecturers at a local university may not be interpreting the syllabus and textbooks during the examination preparation in the same way as the authors of these materials would.

For a complete understanding of SL themes representation in Zambian high school science education we recommended that further studies should be conducted to (1) examine the representation of the four themes of SL in other national courses such as Biology and Chemistry and (2) find out how the four themes of SL are addressed by teachers during science instruction.

Conclusions

The balance of SL themes in the national physics course tilts towards, in descending order, Themes II, III, I and IV. Although the interaction of science, technology and society theme was accentuated in the physics syllabus, it was least emphasized in textbooks and absent in some examination papers. The physics course has reasonable potential to promote SL among high school students. However, to serve its purpose as a compulsory science course it should place equal emphasis on SL themes.

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Резюме**КОЛИЧЕСТВЕННЫЙ АНАЛИЗ УЧЕБНИКОВ, ПРОГРАММ И ЭКЗАМЕНОВ ПО ФИЗИКЕ СРЕДНЕЙ ШКОЛЫ ЗАМБИИ В АСПЕКТЕ ТЕМ НАУЧНОЙ ГРАМОТНОСТИ****Фрацксон Мумба, Вивиен М. Чабаленгула, Вильям Гунтер**

Научная грамотность - одна из главных целей естественнонаучного образования, и акцент на это отражен в реформах естественнонаучного образования и национальной образовательной политики во всем мире.

В данном исследовании анализировалось какой баланс тем научной грамотности существует в программе по физике и трех учебниках по физике в средней школе Замбии. Также было проанализировано 15 письменных экзаменационных работ, написанных в период 2000 – 2004 года. Была осуществлена попытка узнать, имеет ли национальный курс физики потенциал, чтобы внести свой вклад в подготовку с научной точки зрения грамотных граждан.

Четыре темы научной грамотности: (a) элементарные знания науки (b) исследовательская природа науки, (c) наука как мышление, (d) взаимодействие науки, технологии и общества.

Анализ материалов курса физики был выполнен используя надежную и валидную процедуру, разработанную Chiarretta, и др. (1991).

Результаты показывают, что национальная программа и экзамены подчеркнули исследовательскую природу науки, в то время как учебники в большинстве делают акцент на элементарные знания научных тем. Хотя тема взаимодействия науки, технологии и общества было подчеркнуто в программе, это было менее подчеркнуто в учебниках и отсутствовало в некоторых экзаменационных работах. Однако, курс физики имеет определенный потенциал помочь подготовить с научной точки зрения грамотных граждан страны.

Ключевые слова: научная грамотность, курс физики, программа, учебники физики.

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