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INQUIRY LEVELS AND SKILLS IN ZAMBIAN HIGH SCHOOL CHEMISTRY SYLLABUS, TEXTBOOKS AND PRACTICAL EXAMINATIONS

Abstract. *This study analyzed the Zambian high school chemistry syllabus, textbooks, and practical examinations for inquiry levels and skills. The chemistry syllabus was explicit on inquiry skills and levels. Experiments in the chemistry textbooks and practical examinations were mostly at confirmation and structured inquiry levels respectively. Very few experiments were at guided inquiry level and none at open inquiry level in the textbooks and practical examinations. However, the course materials emphasized the same inquiry skills. There were no guidelines on inquiry-based teaching in the course materials. As such, this is a potential obstacle to the implementation of inquiry science teaching. Implications for science teaching, learning, and curriculum design have been discussed.*

Key words: *inquiry, chemistry, syllabus, textbooks, examinations.*

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Introduction

Inquiry-based science teaching promotes inquiry and problem-solving skills among students (Germann, Haskins & Auls, 1996) and reflects science as it is practiced by scientists (National Research Council [NRC], 1996). As such, inquiry-based science teaching has been accentuated in science education reforms and standards (American Association for the Advancement of Science [AAAS], 1993; NRC, 1996). Beyond the reforms and standards, science curriculum materials are expected to meet the challenges of improving scientific inquiry skills among students by providing balanced and fairly equal proportions of the following inquiry levels: *Confirmation, Structured, Guided and Open-ended* (Tafoya, Sunal & Knecht, 1980) and inquiry skills for *Planning and conducting experiments, Analyzing and interpreting data, and Applying techniques to new situations* (Tamir & Luneta, 1981). As a result, science educators have analyzed science textbooks and laboratory manuals to establish the representation of inquiry levels and skills (Eltinge & Roberts, 1993; Germann, Haskins & Auls, 1996; Lunetta, & Tamir, 1980; Pizzini, Shepardson & Abell, 1991; Okebukola, 1988; Tafoya, Sunal & Knecht, 1980; Tamir & Luneta, 1981). In general, these studies found that most activities in science textbooks and laboratory manuals were at confirmation and structured inquiry levels. Very few activities were at guided inquiry level and even fewer at open inquiry level. In addition, science textbooks and laboratory manuals emphasized lower inquiry skills such as fol-



lowing step-by-step procedure, observing and recording data. Consequently, students were not given opportunities to formulate a hypothesis, to design or to conduct their own experiments.

It is evident in the literature that science educators have mainly examined science textbooks and laboratory manuals for inquiry levels and skills. To date, no study has examined and reported the representation of inquiry levels and skills in science syllabi and public practical examinations. Yet, in many countries like Zambia with a centralized education system, national science syllabi are the main guides for science instruction and preparing public examinations. Therefore, this study goes beyond the previous studies by including the chemistry syllabus and public chemistry practical examinations in the analysis for inquiry levels and skills. The analysis of the Zambian high school chemistry course materials for inquiry levels and skills is desirable, not only to Zambian science educators but also to science educators elsewhere, who have implemented, or plan to implement a similar chemistry course at the high school level. It was also assumed that the findings would provide some implications for science teaching, learning and curriculum design. This study was guided by two questions: What inquiry levels and skills are emphasized in the Zambian high school chemistry course? To what extent are inquiry levels and skills emphasized differently in the course materials?

Zambian high school chemistry education

High school education starts in grade ten and ends in grade twelve. Chemistry is a compulsory subject and all students take it for three years in high school. The chemistry textbooks and syllabus are the main resources for chemistry teaching and learning in high schools. Each chemistry teacher is given three chemistry textbooks (Chemistry 10, 11, and 12) and one copy of the national chemistry syllabus as a guide for scope and depth of the content to be taught. Each student is given a copy of the chemistry textbook and returns it after each grade. There are five periods of chemistry instruction in a week per class and each period is forty-five minutes long. 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 taken more than 142 hours of chemistry instruction. At the end of their grade twelve, students sit for national examinations, equivalent to the Ordinary-Level standard in the British system for certification, admission to post-secondary school education, training, and employment. In the chemistry 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 chemistry teachers and chemistry lecturers from a local national university in conjunction with the Examination Council of Zambia. Examiners use the national chemistry textbooks and syllabus as guides for preparing examinations.

Methodology of Research

Data sources

Data sources were one high school chemistry syllabus, three chemistry textbooks (Chemistry 10, 11 and 12) and six chemistry practical examination papers that were administered to high school students between 2001 and 2006. The chemistry syllabus and textbooks were written by Zambian chemistry educators in conjunction with Curriculum Development Center (CDC), and were implemented in schools in January 2000. The chemistry syllabus has five main sections: introduction, general aims, topics, content, and assessment objectives. There are twelve main topics namely: particulate nature of matter, experimental techniques, language of chemistry, periodic table, acids, bases and salts, mole concept, chemical reactions and energy changes, metals, electrochemistry, organic chemistry, non-metals and chemistry, society and the environment. Under each topic, there are content statements and notes to teachers. The topics in the textbooks are the same as those in the syllabus. Each textbook is used in one grade. Chemistry examination paper 3 is a one and half hours laboratory-based examination in which students are asked to perform two experiments and write a report on each. Therefore, a total of twelve experiments in the practical examinations papers were examined for inquiry levels and skills.



Analysis frameworks and procedures

Inquiry levels in the chemistry course materials were determined by using the framework and procedure developed by Tafoya, Sunal and Knecht (1980). The framework has four inquiry levels: Confirmation, Structured, Guided, and Open. Confirmation inquiry level activities require students to verify concepts through a known answer and given procedure that the students follow. Structured inquiry level activities present students with a problem in which they do not know the results, but they are given a procedure to follow in order to complete the activity. Guided inquiry level activities provide the student only with a problem to investigate. Students are given a chance to determine the procedure to use and the data to collect. Open inquiry level activities allow students to formulate hypotheses or problems and the procedure for collecting data for interpretation and drawing conclusions. The units of analysis in the chemistry textbooks were the experiments. In the syllabus, the units of analysis were introduction, general aims, notes to teachers, and content and assessment objectives. In the practical examinations all the experiments, questions and background information were analyzed. These units were read and matched with the characteristics of inquiry levels outlined in the framework. For the textbooks and practical examinations, a total score was obtained for each inquiry level and expressed as a percentage.

The high school chemistry course materials were further analyzed for inquiry skills using a modified Inquiry Task Inventory (Tamir & Luneta, 1981). The framework has inquiry skills in four sections: *Planning and design; performance, analysis and interpretations and application*. The units of analysis in the course materials included, experiments, instructions, aims, questions, procedures, diagrams, figures, tables and content statements, and assessment objectives. These units of analysis were read and a check was placed in the appropriate inquiry skill in the framework. If a statement in the analyzable unit called for more than one inquiry skill, more than one check was made. For each inquiry skill the checks were tallied and expressed as a percentage in each course material. Two chemistry educators independently analyzed the chemistry course materials for inquiry levels and skills using the procedures described above. An intercoder agreement coefficient was calculated using Cohen's Kappa (Cohen, 1960). This coefficient factors in chance agreement and represents a measure of reliability.

Results of Research

Intercoder agreement

The percentage agreement between the two raters for the high school chemistry course materials analyses ranged from 85% to 93% with a corresponding range of kappa values from 0.82 to 0.92. These statistics suggest a high degree of agreement between the two raters in categorizing inquiry levels and skills in the chemistry course materials. Values above 75% indicate excellent percentage agreement while kappa values below 0.4 indicate a poor interrater coefficient (Chiappetta, Sethna & Fillman, 1991).

Inquiry levels and skills in the chemistry syllabus

As shown in the excerpts below the high school chemistry syllabus emphasized both inquiry skills and levels:

This syllabus aims at stimulating pupils' curiosity and sense of enquiry... During the course students should know how to: follow instructions [Structured & confirmation Inquiry levels]; use techniques, apparatus and materials; observe, measure and record [Inquiry task section 2- Performance]; plan investigations [Inquiry task section 1- Planning and Design; Open Inquiry]; interpret and evaluate observations and results [Inquiry task section 3- Analysis and Interpretation]; evaluate methods and suggest possible improvements [Inquiry task section 4- Application; Guided inquiry] (High school chemistry syllabus, p. vii-viii).



Similarly, the assessment section states that the chemistry practical examinations will focus on assessing students' knowledge, understanding and application of:

...scientific apparatus and instruments and their safe operation [Inquiry task section 2- Performance]; translating information from one form to another manipulate numerical data, plotting results graphically, identify patterns and draw inferences from information'give reasonable explanations for patterns and relationships, [Inquiry task section 3- Analysis & Interpretation], make predictions and hypotheses, and experimental methods evaluation and possible improvements [Inquiry task sections 1 & 4, Guided inquiry] (High school chemistry syllabus, p.x-xi).

However, the chemistry syllabus had no suggested inquiry activities or guidelines on how to implement inquiry-based science teaching.

Inquiry levels in chemistry textbooks

As shown in Table 1 below most experiments in the chemistry textbooks were at confirmation inquiry level followed by structured inquiry level and less at guided inquiry level and nothing at open inquiry level. Most experiments had more than one inquiry level. The number of experiments decreased from the Chemistry 10 to 12 textbook.

Table 1. Percentage of inquiry levels in chemistry textbooks.

Textbook	Inquiry levels			
	Confirmation	Structured	Guided	Open
Chem10 (N=58)	86	8	6	0
Chem11 (N=30)	71	15	4	0
Chem12 (N=29)	76	19	5	0

N= Number of experiments in each textbook

Inquiry levels in chemistry practical examinations

Table 2 shows that most experiments in the practical examinations were at structured level followed by confirmation level, less at guided level and nothing at open inquiry level. However, there were no experiments at guided inquiry level in 2002 and 2003.

Table 2. Percentage of inquiry levels in chemistry practical examinations.

Exam Year	Inquiry levels			
	Confirmation	Structured	Guided	Open
2001(N=2)	20	77	3	0
2002(N=2)	5	93	2	0
2003(N=2)	3	97	0	0
2004(N=2)	50	50	0	0
2005(N=2)	27	69	4	0
2006 (N=2)	49	50	1	0

N= Number of experiments in each examination paper. Note: Most experiments had more than one inquiry level

Inquiry skills in chemistry textbooks

As shown in Table 3 below, the chemistry textbooks emphasized lower level inquiry skills with those



in performance section receiving the most emphasis followed by those in analysis and interpretation section. Very few inquiry skills in the planning and design and application sections were emphasized in the practical examinations. The number of experiments decreased from grade 10 to 12, hence the number of inquiry skills decreased.

Table 3. Percentage distribution of inquiry skills in chemistry textbooks.

Inquiry task and skill	Textbooks		
	Chem. 10 (N=226)	Chem. 11 (N=189)	Chem. 12 (N=126)
1.0 PLANNING & DESIGN			
1.1 Formulates a question, defines a problem	0.0	0.0	0.0
1.2 Predicts experimental results	0.0	0.0	0.0
1.3 Formulates hypothesis to be tested	0.0	0.0	0.0
1.4 Designs observations/measurements	2.0	1.2	0.9
1.5 Designs experiment	0.0	0.0	0.0
<i>Subtotal</i>	2.0	1.2	0.9
2.0 PERFORMANCE			
2.1 Manipulates apparatus	23.9	20.3	24.1
2.2 Measures/observes	26.0	30.1	32.2
2.3 Draws/labels diagrams	0.2	0.5	0.0
2.4 Records results	15.1	10.6	12.0
<i>Subtotal</i>	65.2	61.5	68.3
3.0 ANALYSIS & INTERPRETATION			
3.1(a) Transform results into standard form	2.3	3.8	2.8
3.1(b) Graphs data	3.5	2.7	2.2
3.2(a) Determines qualitative relationship	4.3	5.2	3.6
3.2(b) Determines quantitative relationship	11.0	9.9	8.1
3.3 Determines accuracy of experimental data	0.1	0.0	0.0
3.4 States limitations/assumptions/precautions	0.2	0.5	0.0
3.5 States conclusion/proposes a generalization	2.4	5.0	3.0
3.6 Explains relationships	7.2	10.1	9.7
<i>Subtotal</i>	31.1	37.2	29.6
4.0 APPLICATION			
4.1 Predicts on basis of obtained results	1.7	0.0	0.0
4.2 Predicts beyond the data/uses given data	0.0	0.1	1.2
4.3 Applies technique to new problem	0.0	0.0	0.0
<i>Subtotal</i>	1.7	0.1	1.2

N= Number of codes identified in each chemistry textbook.

Inquiry skills in chemistry practical examinations

Table 4 shows that the practical examinations mostly emphasized inquiry skills for performing experiments, analyzing and interpreting data. In the performance section, the inquiry skills emphasized were manipulating apparatus, observing, and recording results. In the analysis and Interpretation section students were mainly asked to determine quantitative relationships and state conclusions while



in the planning and design section students were only asked to design tables for data. However, there was some consistency in the coverage of inquiry skills in the practical examinations across the period considered for this study.

Table 5. Percentage distribution of inquiry skills in practical exam papers.

Inquiry task & skills	Year					
	2001 (N=190)	2002 (N=188)	2003 (N=186)	2004 (N=190)	2005 (N=189)	2006 (N=194)
1.0 PLANNING & DESIGN						
1.1 Formulates a question, defines a problem	0.0	0.0	0.0	0.0	0.0	0.0
1.2 Predicts experimental results	0.0	0.0	0.0	0.0	0.0	0.0
1.3 Formulates hypothesis to be tested	0.0	0.0	0.0	0.0	0.0	0.0
1.4 Designs observations/measurements	0.7	0.5	0.1	0.4	0.6	0.2
1.5 Designs experiment	0.0	0.0	0.0	0.0	0.0	0.0
<i>Subtotal</i>	0.7	0.5	0.1	0.4	0.6	0.2
2.0 PERFORMANCE						
2.1 Manipulates apparatus	32.0	29.0	25.2	24.3	31.1	23.5
2.2 Measures/observes	33.2	35.6	35.0	37.1	33.2	41.3
2.3 Draws/labels diagrams	0.1	0.8	3.3	4.5	0.9	2.2
2.4 Records results	11.1	13.8	21.1	12.4	16.1	10.9
<i>Subtotal</i>	76.4	79.2	80.1	78.3	81.3	77.9
3.0 ANALYSIS & INTERPRETATION						
3.1(a) Transform results into standard form	0.2	0.4	0.7	1.0	0.6	1.1
3.1(b) Graphs data	1.8	0.9	1.8	0.5	1.0	0.0
3.2(a) Determines qualitative relationship	0.3	0.1	0.4	0.2	1.3	0.5
3.2(b) Determines quantitative relationship	9.4	11.1	9.0	10.0	8.6	9.3
3.3 Determines accuracy of experimental data	0.0	0.0	0.1	0.3	0.0	0.0
3.4 States limitations/assumptions/precautions	0.2	0.0	0.3	0.1	0.4	0.0
3.5 States conclusion/proposes a generalization	8.3	5.2	3.8	4.5	2.2	0.3
3.6 Explains relationships	4.1	2.6	3.1	4.7	4.0	0.1
<i>Subtotal</i>	22.8	20.3	19.2	21.3	18.1	11.3
4.0 APPLICATION						
4.1 Predicts on basis of obtained results	0.0	0.0	0.6	0.0	0.0	0.3
4.2 Predicts beyond the data/uses given data	0.1	0.0	0.0	0.0	0.0	0.0
4.3 Applies technique to new problem	0.0	0.0	0.0	0.0	0.0	0.0
<i>Subtotal</i>	0.1	0.0	0.6	0.0	0.0	0.3

N= Number of codes identified in each examination paper for each year.

Discussion

The unbalanced representation of inquiry levels and skills in Zambian high school chemistry textbooks and practical examinations is similar to those reported in previous studies (Germann, Haskins & Auls, 1996; Tamir & Luneta, 1981; Lunetta, & Tamir, 1980; Pizzini, Shepardson & Abell, 1991; Eltinge & Roberts, 1993; Okebukola, 1988; Tafoya, Sunal & Knecht, 1980). However, there was consistency in the coverage of inquiry level and skills in each Zambian high school chemistry course material. In addition, most experiments in the practical examinations were one inquiry level higher than those in the textbooks.



The emphasis on lower inquiry levels and skills in the chemistry course materials implies that during chemistry lessons and practical examinations students commonly work as technicians following explicit instructions provided. As such, they are not given opportunities to identify or formulate problems or hypothesize and test them based upon their understanding of the concepts involved. Science instruction organized exclusively around confirmation and structured levels of inquiry and lower inquiry skills emphasizes a teaching approach that portrays scientific knowledge as fact, which can only be found if one scientific method is followed (Eltinge & Roberts, 1993). The lack of guidelines or detailed information on inquiry-based teaching in the syllabus and textbooks poses a substantial challenge to teachers who have not received training on inquiry teaching. This is another potential obstacle to the adoption or implementation of inquiry-based science teaching.

The uniformity in inquiry skills representation in the textbooks and syllabus is a desirable feature and allows teachers to easily predict the type of experiments that will be in the practical examinations and the skills required to pass the examinations. Unfortunately, some teachers will only teach certain inquiry skills and ignore others. In order to develop higher-order inquiry skills among students, the chemistry textbooks should have activities at open inquiry levels. In future research, teacher-made chemistry tests and laboratory activities should be examined for inquiry levels and skills. Chemistry classroom instruction observations should also be undertaken to find out the extent to which inquiry levels and skills are addressed during the lessons.

Conclusions

It can be concluded that the chemistry syllabus was explicit on inquiry skills and levels. Experiments in chemistry textbooks were mostly at confirmation inquiry level. On the other hand, experiments in the practical examinations were mostly at structured inquiry levels. There were no experiments at open inquiry level in the course materials analyzed. However, the course materials emphasized the same inquiry skills. There were no guidelines for inquiry-based teaching in the course materials.

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