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Inquiry-based science education: A scenario on Zambia's high school science curriculum

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Abstract

This paper is aimed at elucidating the current state of inquiry-based science education (IBSE) in Zambia's high school science curriculum. Therefore, we investigated Zambian teachers' conceptions of inquiry; determined inquiry levels in the national high school science curriculum materials, which include syllabi, textbooks and practical exams; and determined the extent to which inquiry tasks and skills are emphasized in the science curriculum materials. Based on the results, we have proposed ways in which IBSE in Zambia can be improved, particularly in teacher preparation curriculum, assessment and pedagogy. The major results emerging from this study were that teachers' have a narrow conception of inquiry; there is a discrepancy in the coverage of inquiry levels in syllabi, textbooks and practical exams; and there is much emphasis on lower inquiry tasks and skills in textbooks and exams. These findings laid a basis for our proposed plan for improved inquiry-based science education in Zambia, as discussed herein. It is anticipated the proposed plan on IBSE will prove useful to Zambian science teachers, teacher educators, professional development providers and curriculum developers in resituating Zambian's science curriculum to be in line with current IBSE models.

Key words: *inquiry, science curriculum, syllabi, textbooks, practical exams*

Introduction

The concept of inquiry-based science education (IBSE) was well articulated by Joseph Schwab during the 1960s, when he protested the teaching of science as a presentation of scientific facts (Schwab, 1962). Schwab envisioned a school science curriculum that would represent the scientific endeavor as engaged in by practicing scientists, including posing questions, designing experiments, collecting, analyzing and interpreting data, and drawing conclusions. The idea of IBSE became almost universally appealing, though some educators conceived it as very difficult to implement in real classrooms. However, later on in the 1990s, many science education reforms around the world put much emphasis on the importance of students' knowing scientific inquiry methods and having the basic understanding of science

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and skills needed for making informed decisions about scientific issues affecting their lives (National Research Council [NRC], 1996). Consequently, IBSE is currently being accepted as an overarching instructional approach across science curricula in several developed countries such as United States (NRC, 1996), and England (Millar & Osborne, 1998). Similarly, IBSE is also being adopted among some developing countries such as Lebanon (National Center for Educational Research and Development, 1997), and Israel (Tomorrow98, 1992), Zambia (Curriculum Development Center [CDC], 2000; Ministry of Education [MOE], 1996).

In the midst of the science education reform movement, several issues concerning IBSE have emerged such as what classroom inquiry is/involves, teachers' conceptions of inquiry, and how IBSE should be implemented by teachers and presented in science curriculum materials. The National Science Education Standards (NSES) of the United States present generalized conceptions of IBSE whose undercurrent theme advances a distinction between *Inquiry as means* and *Inquiry as ends* (NRC, 1996). According to the NSES, a working definition of IBSE is provided through descriptions of five essential features of inquiry teaching and learning which are *engaging in scientifically oriented questions (EQ), giving priority to evidence (EV), formulating explanations based on evidence (EX), evaluating explanations in connection with scientific knowledge (EK), and communicating explanations (EC)* (see NRC, 2000, pages 24–27). These features of inquiry emphasize that school science needs to engage students with ill-defined, real-world problems, instead of well-defined idealistic problems; involve students in long-term projects, instead of short-term, discrete activities; and situate inquiry in complex socio-technological contexts (Duschl & Grandy, 2005; Gott & Duggan, 1996). Additionally, these features reflect what scientists do and what scientifically literate citizens need to know and be able to do (AAAS, 1989; Bell & Linn, 2000; Driver et al., 2000; Duschl & Osborne, 2002; Hodson, 1998; Millar & Osborne, 1998).

Even though the NSES have outlined essential features of IBSE and how school science should engage students, science education research has shown that teachers' conceptions of inquiry, and the extent of inquiry implementation by teachers and presentation of inquiry in curriculum materials is disproportionate with visions of inquiry put forth in reform documents (Abd-El-Khalick et al., 2004; Anderson, 2002; Crawford, 2000; Kang, et al, 2008; Roehrig & Luft, 2004; Rowell 2004; Rop, 2002; Wallace et al., 2004). For instance, Crawford (2000) and Wallace et al (2004) found that teachers form individualized conceptions and have different levels of knowledge about inquiry and IBSE.

Other researchers have found that IBSE has not been widely adopted and enacted by many high school science teachers (Roehrig & Luft, 2004; Rowell, 2004). The possible sources of the barriers to enactment of the envisioned IBSE range from the technical to the political factors, and from factors associated with science teachers and to those related to the culture of school science (Anderson, 1996, 2002). In another study, Abd-El-Khalick et al (2004) conducted an interpretive study undertaken at an international science education meeting, with renowned science educators as participants representing six countries which are Australia, Israel, Lebanon, Taiwan, USA and Venezuela. As such, Abd-El-Khalick et al's study is important to researchers who are trying to understand how different countries conceptualize inquiry science teaching and learning. The participants were asked to provide perspectives from their countries in response to the following questions: How is inquiry philosophically conceived and practically defined in your national or state curriculum (if any)? Is inquiry enacted in the curriculum, curricular materials, science teaching, and assessment practices? If yes, how and to what extent? What factors and conditions, internal and external to the educational setting, facilitate or impede inquiry-based science education in your country or state? Table 1 shows a summary of the results.

Table 1. International perspectives of IBSE, based on Abd-El-Khalick et al. (2004) study

David Treagust (Australia)

- Conceptions: Term "inquiry" is not used. Instead the word "investigation" is overtly used, and emphasizes that students investigate scientific phenomena using process skills to answer the questions about the natural & technological world.
- Extent of enactment: Developed Australian Science Curriculum Council (1998) document comprising five outcomes which are investigating, communicating scientifically, science in daily life, acting responsibly, and science in society; teachers are required to link outcomes in their lesson plans for conceptual understandings and science process.
- Impeding factors: External exams at end of Year 12 drives lab work to a less open-inquiry in nature; not all primary teachers have confidence to teach science in an effective, inquiry-based manner.

Rachel Mamlok-Naaman & Avi Hofstein (Israel)

- Conceptions: Involve conceiving problems, formulating hypotheses, designing experiments, gathering and analyzing data, and drawing conclusions about scientific problems or natural phenomena.
- Extent of enactment: Developed comprehensive chemistry education reform in 1997 (Tomorrow 98) emphasizing inquiry chemistry labs for high school students; in 5 years, 100 experiments were designed; in addition, student assessment tools, long-term & intensive professional development for teachers, and implementation of these activities in a number of high school classrooms were developed.
- Impeding factors: Lack of prolonged commitment and concerted efforts of all parties such as curriculum developers, researchers, teacher education programs, administrators, teachers & students; lack of financial and administrative support from the Ministry of Education.

Saouma Boujaoude (Lebanon)

- Conceptions: Students develop an understanding of, and ability to engage in, scientific inquiry.
- Extent of enactment: Developed a new national science curriculum (NCERD, 1997) in 1997 that emphasizes inquiry; However, BouJaoude (2002) study found that only 12% of general curriculum objectives addressed scientific inquiry & that curriculum lacked a coherent framework regarding inquiry; As such, enactment is still slow as science instruction is still traditional in nature: largely limited to a didactic chalk-and-talk approach coupled with occasional verification-type lab experiences.
- Impeding factors: Curriculum: absence of clear framework of inquiry confuses teachers as whether they have to teach science as inquiry or science through inquiry or both; limited scope for inquiry definition in that it restricts inquiry to a collection of discrete science process skills implemented sequentially through "Scientific Method."; curriculum seems to highlight hands-on inquiry to the neglect of minds-on component.
- Teaching, textbooks quality, and assessment practices: assessments & teaching styles not aligned with emphasis given to inquiry in new curricular documents; textbook writers and publishers do not emphasize inquiry

Hsiao-Lin Tuan (Taiwan)

- Conceptions: emphasizes that all students should develop inquiry and research abilities, including applying science process skills in order to construct science concepts and problem solving abilities.
- Extent of enactment: In 1999, Ministry of Education developed new curriculum standards implemented since 2001, but extent to which inquiry is enacted in textbooks & assessments vary across grade levels.
- Textbooks: Elementary books are activity-oriented , emphasizing science concepts and process skills; Junior high books present science content & provide structured inquiry experiences that build on students' interests and curiosity; Senior high books and lab manuals are separate, with manuals prescribing traditional experiments intended to reinforce what students learn in regular science sessions.
- Assessment: At elementary & secondary school, mostly paper-and-pencil tests are used to gauge student linguistic & logical thinking abilities rather than performance skills; In lab work, students are assessed via reports rather than performance activities;
- Impeding factors: Teachers' dispositions; replacing traditional content-based exit exams with competency-based tests puts teachers under pressure from students, parents, and school administrators to teach both types of tests so that students pass both test.
- -teachers complain that teaching science concepts through inquiry would take too much instructional time, and reduces their efficacy.

Table 1. (continued)

Norman Lederman (USA) • Conceptions: Current NSES reforms (NRC, 1996) place extensive emphasis on scientific inquiry in which students are expected to master a set of inquiry-related skills and develop understandings *about* inquiry. • Extent of enactment: Nearly all states have emulated the NSES by developing science learning standards; more attention to scientific inquiry in both instruction & students' activities; However, most state standards omit the understandings *about* inquiry and Nature of Science (NOS), though these are central to achieving scientific literacy as defined in current reforms; assessment practices tend to focus on science process skills. • Impeding factors: Teaching focuses more on performance of inquiry skills, and not on understandings about inquiry, NOS & foundational subject matter - leading to citizenry which cannot develop knowledge and skills to make informed decisions regarding everyday science-related personal and societal issues; widespread misconceptions that students will develop understandings about scientific inquiry and NOS simply by doing science/or inquiry-oriented activities; approach for teaching *about* inquiry and NOS implied in the NRC (1996) document mistakenly assumes that students learn *about* inquiry and NOS implicitly.
Mansoor Niaz (Venezuela) • Conceptions: Secondary education does not present clearly articulated conceptions of scientific inquiry; However Ministry of Education emphasizes science process skills and incorporation of various aspects of inquiry based on activities on local problems (e.g., environmental issues). • Extent of enactment: IBSE implementation has not taken place due to a lack of a clear framework for inquiry in the science curriculum resulting in conveying contradictory messages to teachers in curricular materials. • Impeding factors: Absence of an articulated/informed conception of IBSE in curriculum will not ensure its implementation in classroom.

According to Table 1, three aspects emerge. Firstly, many reform documents in the six countries conceived *inquiry* to include: scientific processes; scientific method; experimental approach (conceiving problems, formulating hypotheses, designing experiments, gathering and analyzing data, and drawing conclusions); problem solving; deriving conceptual understandings; and hands-on activities. Secondly, the extent of inquiry implementation in the classrooms is highly contextualized, and varies from nation to nation. Abd-El-Khalick et al (2004) argue that the contextualization of inquiry is a factor that determines how one nation describes its goals for science education (e.g. content, process, NOS) and how an inquiry approach to science education can (or cannot) help achieve these goals. So far most developed nations such as United States, England and Australia have devised well-conceived and thought-out policy statements on science education (e.g. NRC, 1996; Goodrun, Hackling & Rennie, 2000; Millar & Osborne, 1998) that attempt to organize science curricula such that both goals (preparing future scientists and educating students to be scientifically literate) can be achieved. Additionally, these nations have also integrated and enacted IBSE as a teaching and learning approach in pursuing these two goals.

Given the extent to which some developed nations have reached so far with regard to IBSE, the authors of this paper were motivated to find out how a developing country like Zambia is faring on this subject. We were also motivated to conduct this study by the dearth of research on IBSE in Zambia. Like most developed countries discussed above, Zambia also undertook a major science education reform in 1996 aimed at incorporating IBSE in high school science curriculum (MOE, 1996). Some changes were made to Zambia's high school national science curriculum materials (syllabi, textbooks and practical examinations for biology, chemistry and physics) in 1998: First, the new syllabi for biology, chemistry and physics emphasize the "development of skills of enquiry" among students (CDC, 2000). Second, the new national science textbooks for biology chemistry and physics written by Zambian educators in 1996 include contextualized examples and illustrations and provided activities that were inquiry in nature. Third, the national practical exams for biology, chemistry and physics include assessing students' performance on inquiry tasks and skills (CDC, 2000). The new curriculum was first implemented in schools in the year 2000.

Despite these changes to Zambia's science curriculum, there has been no holistic evaluation of ISBE from teachers and curriculum materials perspectives. However, one study investigated levels of inquiry and inquiry tasks in Zambian chemistry curriculum (Mumba et al, 2007a). As such, there is no information on the following: Zambian teachers' conceptions of classroom inquiry; levels of inquiry addressed in biology and physics curriculum materials; and distribution of inquiry tasks and skills in syllabi, textbooks and practical exams for biology and physics.

Therefore, the four major purposes of this paper are to: investigate Zambian teachers' conceptions of inquiry; To determine inquiry levels in biology and physics high school curriculum materials which include syllabi, textbooks and practical exams; determine the extent to which inquiry tasks and skills are emphasized in Zambian science curriculum materials (and will use the already existing data for chemistry from Mumba et al [2007a] study); and propose ways in which IBSE in Zambia can be improved, particularly in teacher preparation, professional development programs, and in curriculum, assessment and pedagogy.

Zambian high school science curriculum & IBSE

In Zambia, high school science education starts in grade ten and ends in grade twelve. Biology, Chemistry and Physics are compulsory science subjects and all students take them for three years in high school. Each subject has a national syllabus, three sets of textbooks (one for each grade level), and three sets of national exams. These materials are used by all teachers, students and schools, because Zambia has a national science curriculum. Textbooks and syllabi are the main sources of science teaching and learning for both teachers and students in high schools. These are also used as guides when examiners are preparing national exams. Each science teacher is given the subject-specific textbooks and a copy of the subject-specific syllabus as a guide for scope and depth of the content to be taught. All students are given copies of the biology, chemistry and physics textbooks for their current grade, and are required to return the books at the end of each grade.

The current syllabi and textbooks for biology, chemistry and physics were written by Zambian science educators in conjunction with Curriculum Development Center (CDC), and were implemented in schools in January 2000. Each syllabus has five main sections: introduction, general aims, topics, specific content under each topic, and assessment objectives for theory and practical exams. The topics are spread over a period of three years from grade 10 to grade 12. Under each topic, there are content statements that guide the breadth and scope of the content as well as notes to teachers. The topics in the textbooks are aligned to those in the syllabus.

Each science subject has three national exam papers, paper 1 (multiple choice theory), paper 2 (short answer and short essay theory) and paper 3 (a practical exam with 2 questions in biology and chemistry, and 4 questions in the physics exam). The biology and chemistry exams are about one and a half hours long, whereas the physics one is about two hours. These exams require students to manipulate apparatus, measure, observe, record data, analyze data and provide short answers to the exam questions.

There are five periods of each science subject 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 each science instruction.

At the end of their grade twelve, all students sit for the national examinations, equivalent to the Ordinary-Level standard in the British system for certification, admission to post-secondary school education, training, and employment. In each science subject (biology, chemistry and physics), 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 hands-on laboratory experiments. These examinations are prepared by experienced high school science teachers and science lecturers from the University of Zambia, in conjunction with the Examination Council of Zambia. Examiners use the national science textbooks and syllabi as guides for preparing examinations.

Since Zambia has a national science curriculum, it implies that all science teachers have to use the same syllabi for each science course and teach science as stipulated by the curriculum reform. As one would imagine, such changes are likely to bring along a host of issues associated with the enactment of IBSE ranging from teachers' conceptions of what inquiry based teaching is/involves, their role in the implementation of inquiry teaching, to how the curriculum, assessment and pedagogy should be structured in order to promote inquiry based science education among Zambian students.

Research data and analysis

In order for us to have a strong basis for proposing improved IBSE in Zambia, we needed empirical data on inquiry levels and skills addressed in the national science curriculum materials which include syllabi, textbooks and practical examinations. We already had data for inquiry levels and skills coverage in chemistry curriculum materials from Mumba et al (2007a), but none for inquiry coverage in biology and physics curriculum materials. As such, there was a need to analyze the coverage of inquiry in these two subjects using the same procedures employed previously for the chemistry course (Mumba et al., 2007a).

Data from curriculum materials

Data sources were two syllabi (biology and physics); six textbooks (three for each subject for grade 10, 11 and 12); and twelve practical exam papers (six papers each for biology and physics) that were administered to high school students between 2001 and 2006. We chose to analyze exams for this period because this was the first six-year period when the new syllabi and revised exams were implemented in high schools. As such, this was the best period to determine the extent to which inquiry was implemented in these materials. Note that the chemistry materials were previously analyzed in a different study (Mumba et al., 2007a).

Inquiry levels in the syllabi, textbooks and exams 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, but 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 syllabi were aims and assessment objectives; in the textbooks, it was the experiments/activities; and in practical exams, it was all the experiments, questions and background information that 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 science curriculum materials were further analyzed for inquiry skills using a modified Inquiry Task Inventory (Tamir & Luneta, 1981). The framework has inquiry tasks and 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.

Data for teachers' conceptions of inquiry

The data on teachers' conceptions and understanding of inquiry was collected from 12 pre-service high school science teachers. These participants were enrolled in a science teacher preparation program at a university in Zambia. Five, three and four of them were pursuing a bachelor's degree in biology, chemistry and physics education, respectively. All participants were in their third year of study.

To identify the characteristics that teachers use to define inquiry, we adopted and administered an open-ended survey designed by Kang et al (2008). The survey consisted of ten short teaching scenarios representative of inquiry activities or teaching, in which teachers were asked to classify the following ten teaching scenarios as representative of inquiry activities or teaching, and provide reasons for their choice. Additionally, the survey also consisted of an open-ended task that required them to write a narrative describing an ideal inquiry science lesson, describing the roles of the teacher and students, as well as lesson objectives, classroom environment and assessment. The 10 scenarios were considered:

Having students gather data for a local nonprofit organization;
Giving students a white powder and asking them to determine what the powder is;
Asking students to develop and answer their own questions about a local wetlands area;
Having students follow a procedure to complete a lab;
Asking students to use what they know about a local forest to decide whether an old-folks home should be built on that land;
Having students classify substances based upon their observable properties;
Having students use graphics on the Internet to explain how gas molecules move;
Having students make presentations of data collected during a lab;
Asking students to improve on a basic design (make an airplane fly further, make a motor spin faster, etc.);
A class discussion about the arrangement of the periodic table.

Kang et al selected these 10 scenarios because they closely represented the five essential features of inquiry stated in the NSES (NRC, 2000). The five essential features were: engaging in scientifically oriented questions (EQ), giving priority to evidence (EV), formulating explanations based on evidence (EX), evaluating explanations in connection with scientific knowledge (EK), and communicating explanations (EC).

We used these features as a framework to analyze teachers' responses using a content analysis method (Patton, 1990). We also identified teacher-defined characteristics of inquiry that were consistent with the five essential features of inquiry cited above. Each of these features has detailed characteristics that were used in analyzing and categorizing teachers' ideal inquiry lessons, as shown in Table 4.

The data we collected and analyzed were used to propose a critical analysis of how the curriculum, assessment and pedagogy should be structured to promote inquiry based instruction; and how Zambian science teacher education programs can prepare teachers to teach science by inquiry.

Results on current state of IBSE In Zambia

This section presents the findings on teachers' conceptions of classroom inquiry, inquiry levels, and inquiry tasks/skills emphasized in Zambian high science curriculum materials which include national syllabi, textbooks and practical exams. We decided to provide this information because there has been no comprehensive study done so far on these aspects. These results will then serve as an empirical basis for us to propose how the curriculum, assessment and pedagogy should be structured to promote inquiry based instruction; and how Zambian science teacher education programs can prepare teachers to teach science by inquiry.

Teachers' conceptions of classroom inquiry

Tables 2, 3 and 4 below shows teacher and student roles, conceptions of inquiry based on ten different teaching scenarios, a comparison of teachers' inquiry lesson narratives to the five inquiry features of NSES, respectively.

According to Table 2, the majority of the participants (75%) view teachers as facilitators in an inquiry science classroom. To the contrary, many of these participants (67%) view the students' role as that of collecting data using teacher-provided experiments. The higher order skills of letting students plan experiments, identify questions to investigate and apply knowledge are rarely viewed as crucial student roles in inquiry classrooms.

Table 2. Teacher and student roles in ideal inquiry lessons written by participants

Classroom aspect	%
Teacher roles	
-facilitator/guider for students (9)	75
-provide materials (3)	25
-pose guiding questions (2)	17
-present new scientific information (2)	17
-ensure student safety (1)	8
Student roles	
-conduct experiments (observe, hypothesize etc.) to collect data (8)	67
-explain phenomena/concepts (4)	33
-apply knowledge (3)	25
-explore the concept (3)	25
-identify/research on problems/questions of interest (3)	25
-plan experiments (1)	8
-find/discover solutions (2)	17

Note: Number in parenthesis shows actual number of respondents.

Table 3. Teacher conceptions of inquiry evident in teaching scenarios, in percentages

Teaching scenario & inquiry feature being addressed	Is scenario representative of inquiry activity or teaching?					
	Yes	No	Both	Reasons for yes	Reasons for no	Reasons for both
Having students gather data for a local nonprofit organization **(EV)**	83	17	0	-collect/research/gather data alone (7) -observe data & explain it firsthand (2) -know how & why data is collected (1)	-data collected is not for classroom use (2)	
Giving students a white powder and asking them to determine what the powder is **(EV)**	92	0	0	-discover/explore/test on their own (5) -observe the powder (2) -make inferences/deduce what it is (2) -ask questions, predict & conclude (2)		
Average	***87***	***17***	***0***			
Asking students to develop and answer their own questions about a local wetlands area **(EQ)**	92	8	0	-design own questions & investigate them (9) -use questions to develop explanations (2)	No observation made as it is pencil-and-paper approach (1)	
Having students follow a procedure to complete a lab **(EQ)**	67	25	17	-follow directions, but look for answers (3) -draw own conclusion from lab (2) -still involved in inquiry lab skills (3)	No student input in procedure (3)	-**yes** if used own procedure & **no** if given (1) -**yes** if answer unknown & **no** if known (1)
Average	***80***	***16***	***17***			
Asking students to use what they know about a local forest to decide whether an old-folks home should be built on that land **(EX)**	75	33	0	-explores topic with own questions (2) -apply own knowledge to make decision (2) -thinking critically about solution (3) -analyze previous data to base decision on (2)	-did not collect empirical data or no experiment done (4)	
Having students classify substances based upon their observable properties **(EX)**	83	25	0	- use hands-on activity to determine classes (2) -using observations to compare/contrast (2) -determine using senses/reasoning (6)	-no experiment done (it is not scientific) (3)	
Average	***79***	***29***	***0***			
Having students use graphics on the Internet to explain how gas molecules move (**EK**)	83	17	8	-generate explanations using technology (7) -demonstrate gas motion with simulations (2) -involves critical thinking (1)	-no hands-on experiment(2)	YES if answer unknown & NO if known (1)
Asking students to improve on a basic design (make an airplane fly further, make a motor spin faster, etc.) **(EK)**	100	0	0	-conduct research/test to determine factors that work best (4) -determine/think of factors to improve (5) -develop explanations/critical thinking on new improvements (3)		
Average	***92***	***17***	***8***			
Having students make presentations of data collected during a lab **(EC)**	75	25	0	-presentation tells methods of data collection, analysis, results & conclusions (7) -students explain observations & results (2)	-no data analysis & findings (3)	
A class discussion about the arrangement of the periodic table. **(EC)**	42	50	8	-communicate & explain ideas (2) -talk & listen to others (3)	-teacher-oriented (1) -no hands-on activity (5)	-YES if students talk & NO if not (1)
Average	***59***	***38***	***8***			

Note: Number in parenthesis shows actual number of respondents; Engaging in scientifically oriented questions (EQ), Giving priority to evidence (EV), Formulating explanations based on evidence (EX), Evaluating explanations in connection with scientific knowledge (EK), Communicating explanations (EC).

Table 4. Teacher conceptions of inquiry evident in their inquiry lesson narratives

Essential features of inquiry & variations, by NSES	**Teachers & their ideal inquiry lessons**												
	T1 (Ecosystem)	T2 (Senses)	T3 (Lifecycle)	T4 (Leaves)	T5 (Plants)	T6 (Oxidation)	T7 (Matter)	T8 (Solutions)	T9 (Magnets)	T10 (Density)	T11 (general)	T12 (general)	% (actual #)
1. Learner engaging in scientifically oriented questions (EQ)													
Learner engages in question provided by teacher, materials or other source	**X**	**X**	**X**	**X**		**X**	**X**		**X**	**X**			**75 (9)**
Learner sharpens or clarifies question provided by teacher, materials, or other source					**X**								
Learner selects among questions, poses new questions													
Learner poses a question													
2. Learner gives priority to evidence in responding to questions (EV)													
Learner given data and told how to analyze													**83 (10)**
Learner given data and asked to analyze													
Learner directed to collect certain data	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Learner determines what constitutes evidence and collects it													
3. Learner formulates explanations from evidence (EX)													
Learner provided with evidence													**75 (9)**
Learner given possible ways to use evidence to formulate explanation	**X**					**X**	**X**			**X**			
Learner guided in process of formulating explanations from evidence				**X**	**X**								
Learner formulates explanation after summarizing evidence		**X**	**X**						**X**				
4. Learner connects explanations to scientific knowledge (EK)													
Learner given all connections													**8 (1)**
Learner given possible connections										**X**			
Learner directed toward areas and sources of scientific knowledge													
Learner independently examines other resources and forms that links to explanations													
5. Learner communicates and justifies explanations (EC)													
Learner given steps and procedures for communication			**X**	**X**									**42 (5)**
Learner provided broad guidelines to use to sharpen communication		**X**							**X**	**X**			
Learner coached in development of communication													
Learner forms reasonable and logical argument to communicate explanations													

T= Teacher; X= indicates the aspect addressed in each lesson; Number in parenthesis shows actual number of respondents.

With respect to participants' conceptions of inquiry based on teaching scenarios, Table 3 revealed that they perceived classroom inquiry in this descending order: Learner connects explanations to scientific knowledge (EK) [92%]; Learner gives priority to evidence in responding to questions (EV) [87%]; Learner engages in scientifically oriented questions (EQ) [80%]; Learner formulates explanations from evidence (EX) [79%]; and Learner communicates and justifies explanations (EC) [59%]. A striking observation to note in Table 3 is that many participants believed that if students were not involved in some kind of hands-on activity or experiment, then it was not inquiry.

Contrary to trends revealed in teaching scenarios, Table 4 shows that teachers' inquiry lesson narratives portrayed a different picture of their conception about inquiry in this order: Learner gives priority to evidence in responding to questions (EV) [83%]; a tie between Learner engages in scientifically oriented questions (EQ) and Learner formulates explanations from evidence (EX) [both at 75%]; Learner communicates and justifies explanations (EC) [42%]; and least Learner connects explanations to scientific knowledge (EK) [8%].

Levels of inquiry in science curriculum materials

As shown in Table 5, all three syllabi's experimental skills and investigation objectives mostly emphasize structured inquiry and guided inquiry to a lesser degree. The excerpts from the biology high school syllabus illustrate this:

Experimental skills and investigations assessment objectives require students to follow a sequence of instructions; use techniques, apparatus and materials; make and record observations; interpret and evaluate observations and experimental data (High School Biology Syllabus, p. vii).

Table 5. Percentage of inquiry levels in syllabi, textbooks & practical exams

Curriculum materials		**Levels of inquiry**			
		Confirmation	**Structured**	**Guided**	**Open**
Syllabi Experimental skills & investigations objectives)	Biology		X	X	
	Chemistry		X	X	
	Physics		X	X	
Textbooks	Biology (N=117)	65	15	10	0
	Chemistry (N=130)	77	14	5	0
	Physics (N=125)	70	20	7	0
	Averages	***71***	***16***	***7***	***0***
Practical examinations	Biology (2001-2006) (N=12)	20	15	60	0
	Chemistry (2001-2006) (N=12)	26	80	2	0
	Physics (2001-2006) (N=24)	28	74	4	0
	Averages	***25***	***56***	***22***	***0***

N= Total number of experiments/activities. Most experiments/activities had more than one inquiry level
X=indicates the inquiry level stated in syllabi

Although structured and guided inquiry are emphasized in the syllabi experimental skills objectives, the syllabi content objectives and notes to the teacher do not suggest any inquiry activities or guidelines on how to implement inquiry-based science teaching.

To the contrary, nearly all experiments in textbooks are at confirmation/verification level, with a few at structured inquiry level. For instance, 77% of experiments in chemistry books are confirmatory with only 14% and 5% at structured and guided inquiry, respectively.

With respect to practical exams, inquiry levels varied from subject to subject. For example, most exam questions in biology (60%) are at guided inquiry level, whereas 80% of the chemistry and 74% of physics questions are at structured inquiry level. In the six years analyzed, all questions in biology required students to describe the procedure to conduct the tests, whereas in chemistry and physics, step-by-step procedures were provided to students.

Inquiry tasks & skills in curriculum materials

Tables 6, 7 and 8 present the inquiry tasks and skills emphasized in syllabi, textbooks and practical exams, respectively.

Table 6 shows that all science syllabi emphasized higher level inquiry skills of analysis and interpretation the most (47.8%), followed by performance skills (25.6%), planning and design (15.6%), and the least emphasized skills were in application (11.4%).

To the contrary, Table 7 shows that all science textbooks emphasized lower level inquiry skills with those in performance (65.6%) receiving the most emphasis, followed by those in analysis and interpretation (49.8%), then application (2.5%) and lastly those in planning and design (1.5%).

Table 6. Percentage distribution of inquiry tasks & skills in syllabi

Inquiry task and skill	**Syllabi (Experimental skills objectives)**			***M***
	Biology (37) [a]	**Chemistry (40)**	**Physics (38)**	
1.0 PLANNING & DESIGN				
1.1 Formulates a question, defines a problem	0.0	0.0	0.0	
1.2 Predicts experimental results	2.8	7.5	8.0	
1.3 Formulates hypothesis to be tested	2.8	5.0	5.3	
1.4 Designs observations/measurements	0.0	2.5	2.6	
1.5 Designs experiment	0.0	2.5	2.6	
1.6 Describes a procedure for the experiment	0.0	2.5	2.6	
Subtotal	**5.6**	**20.0**	**21.1**	15.6
2.0 PERFORMANCE				
2.1 Manipulates apparatus/specimens	8.3	7.5	8.0	
2.2 Measures/observes	8.3	7.5	8.0	
2.3 Draws/labels diagrams	5.6	2.5	2.6	
2.4 Records results	8.3	5.0	5.3	
Subtotal	**30.5**	**22.5**	**23.9**	25.6
3.0 ANALYSIS & INTERPRETATION				
3.1(a) Transform results into standard form	5.2	7.5	8.0	
3.1(b) Graphs data	2.8	2.5	2.6	
3.2(a) Determines qualitative relationship	8.8	5.0	5.3	
3.2(b) Determines quantitative relationship	13.9	12.5	13.1	
3.3 Determines accuracy of experimental data	8.8	2.5	2.6	
3.4 States limitations/assumptions/precautions	2.8	2.5	2.6	
3.5 States conclusion/proposes a generalization	2.8	2.5	2.6	
3.6 Explains relationships	11.1	7.5	8.0	
Subtotal	**56.2**	**42.5**	**44.8**	47.8
4.0 APPLICATION				
4.1 Predicts on basis of obtained results	5.6	5.0	5.3	
4.2 Predicts beyond the data/uses given data	2.8	5.0	2.6	
4.3 Applies technique to new problem	2.8	2.5	2.6	
Subtotal	**11.2**	**12.5**	**10.5**	11.4

[a] Total number of inquiry skills identified in syllabi

Interestingly, though not surprising Table 8 shows that practical exams emphasized inquiry skills in the similar pattern as in textbooks. However, examinations differed from other materials in the coverage on the last two inquiry skills. That is, performance skills were the most emphasized (67.9%), followed by analysis and interpretation (35.1%), planning and design (5.5%), and lastly application (4.5%).

Table 7. Percentage distribution of inquiry tasks & skills in textbooks

Inquiry task and skill	Biology (545) [a]	Chemistry (541)	Physics (490)	*M*
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	1.4	1.0	
1.5 Designs experiment	0.0	0.0	0.0	
1.6 Describes a procedure for the experiment	0.0	0.0	0.0	
Subtotal	**2.0**	**1.4**	**1.0**	1.5
2.0 PERFORMANCE				
2.1 Manipulates apparatus/specimens	25	23	20	
2.2 Measures/observes	30	29	20	
2.3 Draws/labels diagrams	0.5	0.2	1.0	
2.4 Records results	20.2	13	15	
Subtotal	**75.7**	**65.2**	**56**	65.6
3.0 ANALYSIS & INTERPRETATION				
3.1(a) Transform results into standard form	2.0	3.0	5.0	
3.1(b) Graphs data	4.0	3.0	10.0	
3.2(a) Determines qualitative relationship	10.5	4.4	2.0	
3.2(b) Determines quantitative relationship	12	30.2	15	
3.3 Determines accuracy of experimental data	1.2	0.0	5.0	
3.4 States limitations / assumptions / precautions	0.0	0.2	1.0	
3.5 States conclusion/proposes a generalization	5.0	3.5	8.2	
3.6 Explains relationships	15.2	9.0	12	
Subtotal	**48.7**	**53.3**	**47.4**	49.8
4.0 APPLICATION				
4.1 Predicts on basis of obtained results	2.0	0.6	1.5	
4.2 Predicts beyond the data/uses given data	2.0	0.4	1.0	
4.3 Applies technique to new problem	0.0	0.0	0.0	
Subtotal	**4.0**	**1.0**	**2.5**	2.5

[a] Total number of inquiry tasks/activities identified in high school textbooks

Table 8. Average % distribution of inquiry tasks & skills in practical exams

Inquiry task and skill	Biology practical		Chemistry practical		Physics practical		*M*
	A (110) [a]	B (117)	A (188)	B (191)	A (321)	B (381)	
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	5.5	4.0	1.3	1.2	7.5	4.0	
1.5 Designs experiment	0.0	0.0	0.0	0.0	0.0	0.0	
1.6 Describes procedure for experiment	3.3	6.0	0.0	0.0	0.0	0.0	
Subtotal	**8.8**	**10.0**	**1.3**	**1.2**	**7.5**	**4.0**	5.5
2.0 PERFORMANCE							
2.1 Manipulates apparatus/specimens	25.3	23.9	28.7	26.3	24.3	21.3	
2.2 Measures/observes	8.8	11.9	34.6	37.2	23.4	22.8	
2.3 Draws/labels diagrams	5.5	5.1	0.0	0.0	8.4	7.1	
2.4 Records results	5.5	6.8	23.0	19.7	20.6	17.3	
Subtotal	**45.1**	**47.7**	**86.3**	**83.2**	**76.7**	**68.5**	67.9
3.0 ANALYSIS & INTERPRETATION							
3.1(a) Transform results into standard form	6.6	5.1	1.3	2.7	8.4	5.5	
3.1(b) Graphs data	0.0	0.0	4.5	1.5	0.9	0.8	
3.2(a) Determines qualitative relationship	6.6	6.0	0.7	2.0	0.0	0.0	
3.2(b) Determines quantitative relationship	5.5	2.3	29.5	27.9	14.0	15.0	
3.3 Determines accuracy of experimental data	0.0	0.0	0.1	0.3	2.8	0.8	
3.4 States limitations/assumptions/precautions	0.0	0.0	0.0	0.0	2.8	0.8	
3.5 States conclusion/proposes generalization	3.3	5.1	17.3	7.0	0.0	1.6	
3.6 Explains relationships	9.9	7.7	9.8	8.8	2.0	1.6	
Subtotal	**25.3**	**21.1**	**63.2**	**50.2**	**30.9**	**20.6**	35.2
4.0 APPLICATION							
4.1 Predicts on basis of obtained results	1.1	2.6	0.6	0.3	5.6	1.6	
4.2 Predicts beyond the data/uses given data	100	5.0	0.1	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	
Subtotal	**11.1**	**7.6**	**0.7**	**0.3**	**5.6**	**1.6**	4.5

[a] A: 2001-2003; B: 2004-2006; Total number of inquiry tasks/skills identified in national practical exams

Discussion

The four major purposes of this paper were to: investigate Zambian teachers' conceptions of inquiry; determine inquiry levels in syllabi, textbooks and exams; determine the extent to which inquiry tasks and skills are emphasized in high school science curriculum materials (syllabi, textbooks and practical exams); and based on the results propose how the curriculum, assessment and pedagogy should be structured to promote inquiry based instruction; and how Zambian science teacher education programs can prepare teachers to teach science by inquiry. It was anticipated that the recommendations would be important to Zambian science teachers as well as curriculum developers in resituating Zambian's science curriculum to be in line with IBSE model.

Table 9 presents the overall results for the state of IBSE in Zambia. In general, the results show three major trends: (a) Teachers' have a narrow conception of inquiry; (b) Incongruence among inquiry levels emphasized in teachers' conception of inquiry, syllabi, textbooks and practical exams; and (c) Emphasis on lower inquiry tasks and skills in textbooks and exams. These findings are elaborated in the following subsections.

Table 9. Overview of teachers' conceptions of inquiry & inquiry skills emphasized in Zambia

Type of data collected	Data collection tool	Results summary More emphasis (%)…………………………………… Less emphasis (%)
Teachers' conceptions of classroom inquiry	Scenarios	EK (92)………. EV (87)……..… EQ (80)…..…. EX (79)……… EC (59)
	Narratives	EV (83)…… ………..EQ & EX (75)………..…EC (42)…………. EK (8)
Levels of inquiry	Syllabi	Structured………………………………………..Guided…………
	Textbooks	Confirmation (71)……...Structured (16)..... ….Guided (7)…..….Open (0)
	Practical exams	Structured (56)……...Confirmation (25)……..Guided (22)……..Open (0)
Inquiry tasks & skills	Syllabi	A&I (48)……….…..Perf (26)…..……....P&D (16)……….…...App (11)
	Textbooks	Perf (66)…………....A&I (50)…………..App (3)………..……..P&D (2)
	Practical exams	Perf (68)…………...A&I (35)………….App (6)……………….P&D (4)

Learner engaging in scientifically oriented questions (EQ); Learner gives priority to evidence in responding to questions (EV); Learner formulates explanations from evidence (EX); Learner connects explanations to scientific knowledge (EK); Learner communicates and justifies explanations (EC); P&D: Planning & Design; Perf: Performance; A&I: Analysis & Interpretation; App: Application

Teachers' narrow conceptions of classroom inquiry

Based on their inquiry lesson narratives, this group of teachers conceive inquiry as putting more priority on involving learners in gathering evidence (EV at 83%) and engaging students in questions (EQ at 75%) that can make them explain the evidence (EX at 75%). Unfortunately, these teachers do not strongly believe that learners should go further to communicate and justifies explanations (EC at 42%) and connect their explanations to scientific knowledge (EK at 8%).

Similar findings were document by Kang et al. (2008) who found that the features of EQ, EV and EX were well represented in the teachers' conceptions, with EK and EC rarely used to characterize inquiry. The teachers' much emphasis on students' generating explanations would tend to involve students on higher level thinking, whereas the rare use of EK as a characteristic of inquiry indicates a disconnection between science content and inquiry teaching. This problem was also documented by Abd-El-Khalick et al. (2004) in which Lebanese teachers were often confused as the curriculum framework tends to restricts inquiry to a collection of discrete science process skills implemented sequentially through *Scientific Method* to the neglect of the minds-on component (i.e. connect their explanations to scientific knowledge [EK]). Windschitl (2004) argues that the lack of explicit connection of inquiry to accepted scientific knowledge reflects the folk theories of inquiry in which science content is marginalized and classroom inquiry stops short of connecting technical procedures and results to scientific theories.

The low emphasis on EC in our study lends further evidence to the current suggestion to shift the nature of inquiry from its traditional emphasis on mere experimentation to building, testing, and revising theories or models (Driver et al, 2000; Duschl & Grandy, 2005). This new model of inquiry is reflected in the NRC (2000) emphasis on students' developing communication skills in which they can effectively support claims with evidence and engage in scientific argumentation. However, the data in our study showed that this new aspect of science inquiry is not widely recognized by many Zambian teachers (only 42% did).

Incongruence in inquiry levels in teacher conceptions and curriculum materials

The teachers' conceptions of inquiry that is limited mostly to EV and EX (collecting data and explaining that data) implies they would tend to teach using science activities at higher levels of inquiry such as guided level. However, the most important teaching materials, such as syllabi and textbooks, are at lower inquiry levels. For instance, science syllabi emphasize more structured activities whereas textbooks contain more confirmatory activities. To make matters worse, the practical exam questions are mostly at structured inquiry level where students follow a step-by-step procedure. As such, there is an incongruence between teachers' conception of inquiry and the inquiry levels demanded in syllabi, textbooks and exams.

Therefore, Zambia's practical exams lack both curriculum and instructional validity with respect to the inquiry levels emphasized in textbooks and teachers' conceptions of inquiry. The term curriculum validity is used herein to refer to the extent to which an assessment tool tests the content, in this case the inquiry levels, emphasized in textbooks and teacher conceptions of inquiry (Wise & Reidy, 2005). On the other hand, instructional validity refers to the extent to which the assessment tool covers the content, in this case inquiry levels, which is assumed to have been "taught" or employed by teachers (Messick, 1989; Yoon & Resnick, 1998). That is, the textbooks emphasized confirmatory level and teachers' inquiry conceptions correspond to guided inquiry level, but the practical exams are at a structured inquiry level. We argue that this incongruence is a problem in that students may not perform very well in their national practical exams, because their learning experiences are not in line with the inquiry skills demanded in the exams. We also believe that this incongruence may be a hindrance to the enactment and implementation of IBSE in Zambia, and is not consistent with the current reform efforts that aim at promoting IBSE in Zambia (CDC, 2000; MOE, 1996), as well as worldwide (e.g. NRC, 1996). Recently, Abd-El-Khalick et al. (2004) conducted a study in which they investigated factors impeding enactment and implementation of IBSE. Results of this previous study showed that in Australia, exams at the end of Year 12 are at different inquiry levels compared to those emphasized during teaching. A similar trend was also found in Lebanon where assessments, textbooks and teaching styles were not aligned with emphasis given to inquiry in the curricular documents. Therefore, it is important for Zambian science educators and curriculum experts to pay attention to issues of validity, with respect to inquiry levels in science curriculum materials if Zambia is to progress towards full implementation of IBSE.

Emphasis on lower inquiry skills in textbooks and exams

Based on our results, inquiry tasks and skills in textbooks and exams were emphasized in this descending order: performance, analysis and interpretation, planning and design, and application. Performance skills are lower level skills in that they simply require students to manipulate equipment compared to higher order skills, which require students to design experiments and apply data or techniques to new situations. The emphasis on lower inquiry tasks and skills in curriculum science materials implies that during science 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. Consequently, this dictates that science instruction is organized exclusively around lower levels of inquiry. As the data has shown in our study, teachers' conceptions of inquiry are at higher inquiry level, but these teachers are forced to teach at lower level as they use the books as major teaching guides. One of the reasons for this trend may be that the syllabi, which are the guides for the scope and breadth of the content and teaching objectives, do not have suggested inquiry activities, or guidelines on how to implement inquiry-based science teaching. This lack of guidelines or detailed information on inquiry-based science teaching poses a substantial challenge to teachers who have not received training on inquiry teaching. This can also be an obstacle towards the enactment or implementation of IBSE in Zambia.

From another perspective, though, it can be argued that the uniformity in inquiry skills emphasized in the textbooks and exams is a desirable feature as it ensures curriculum validity. It also allows teachers and students to easily predict the type of experiments that will be in the practical examinations and the skills required to pass the examinations. A downside to this is that some teachers may only teach certain inquiry skills and ignore others, especially the higher order skills. Again such a situation would be a hindrance to the enactment of IBSE.

Proposals for improving IBSE in Zambia

Based on the results presented above, we propose three areas that can be used as avenues for improving IBSE in Zambia. These include: science teacher preparation programs, professional development programs, and science curriculum review. These are explained further in the following subsections.

Science teacher preparation programs

The results show the Zambian pre-service science teachers had a narrow conception of inquiry. Their view of inquiry was restricted to a collection of discrete science process skills implemented sequentially through a *Scientific Method* (EV) to the neglect of involving students in connecting their explanations to scientific knowledge (EK). The best time and place to start making future teachers aware of conceptions about inquiry would be when they are in the science teacher preparation program, and in science education methods courses. Of course, this further implies that science education courses have to be revised so that they explicitly teach the currently acceptable conceptions of classroom inquiry. Therefore the areas science teacher educators can focus on could be: teaching fundamental aspects of the nature of science (NOS); and then moving on to developing appropriate conceptions for classroom inquiry among teacher trainees through exposing them to inquiry-types activities.

Explicit instruction on the nature of science (NOS)

Normally pre-service teachers have no educational background in the history or philosophy of science, nor do they have first-hand experience practicing science when they come to the teacher education program. As such, they tend to portray science as a collection of facts, principles and concepts with little or no instructional attention given to the processes by which scientific knowledge is made public and validated, as has been revealed in our study.

One implication of this dilemma is that without a firm understanding of the characteristics of science, teachers may be inhibited to involve students in activities that explore questioning, deviate from exact procedures, interpret data, or obtain a variety of explanations for the phenomena. Several authors have argued that teachers' understandings of the nature of science may create barriers to implementing inquiry-based instruction, because many teachers have a view of the nature of science as an objective body of knowledge created by a rigid ''scientific method'' (e.g. Brickhouse, 1990; Duschl & Wright, 1989; Gallagher, 1991; Wallace et al, 2004). Therefore, we propose that science teacher education programs offer coursework on the NOS in science education methods courses. Contrary to popular initiatives, which tend to introduce new courses to address this deficiency, we believe this can be achieved within the existing science education methods courses, at no cost.

For argument's sake, we will use the science teacher preparation program at the University of Zambia (UNZA) because the authors were once lecturers in the program, and have a good understanding of science education courses that are offered in that program. The Department of Mathematics and Science Education at UNZA has two science methods courses for each science discipline (i.e. biology, chemistry and physics). The first course is an introduction to science teaching and is taken by students in their third year of study. The second course is an advanced methods course that students take in their fourth and final year of study. We believe it would be appropriate to introduce the NOS in the introductory course. Possible topics to include would be those laying a foundation on attributes of science and how students learn science. With this information, student teachers can then be introduced to current conceptions of classroom inquiry. Once students have grasped this foundational knowledge about inquiry, they can then be exposed to an application level of actually experiencing inquiry itself. This can only be taught well in a separate course such as a second methods course, which is already in existence at UNZA. A further elaboration on how teachers can be exposed to inquiry learning is provided in the next section.

Teacher experience with inquiry at first-hand

We believe that if science educators can involve and expose teachers in inquiry-type laboratories in the context of science topics they will teach in high schools, a conducive environment for them to experience authentic scientific inquiry would be created. When properly developed, these inquiry laboratories have the potential to enhance teachers' constructive learning, conceptual understanding, and understandings of possible benefits and difficulties of inquiry. In order to ensure that pre-service teachers are learning the current conceptions of inquiry, we propose that science teacher educators use well-developed frameworks such as the five essential features outlined in the NSES (NRC, 2000). Doing so would ensure that teachers understand all aspects of inquiry and remediate the deficiency in which most Zambian teachers conceived inquiry as an evidence- gathering venture. As they train, teachers should be involved in identifying problems, formulating hypotheses, designing experiments, gathering and analyzing data, and drawing conclusions about scientific problems or natural phenomena. In this regard, Hofstein and Walberg (1995) argue that this would be more effective if conducted in the context of, and integrated with, the development of scientific concepts and processes.

The science teacher education program at UNZA offers science pedagogy courses but does not explicitly teach inquiry based teaching. This is evident in the biology and chemistry education methods course syllabi, which the authors had an opportunity to use at UNZA. As such the graduating teachers go out to schools without any grounding in inquiry science teaching. Within a pre-existing course structure, where each subject discipline has two science methods courses, it is logical to rearrange the syllabi content in the methods courses such that the introductory class introduces concepts such as what science is, nature of science, and how students learn science. The second course should then introduce inquiry and current conceptions of classroom inquiry, IBSE, currently acceptable science teaching methodologies such as inquiry-based approaches, and hands-on experiences with inquiry teaching.

Learning without a context may be meaningless for student teachers – therefore as the discussion on inquiry is unfolding, there is a need for instructors to try to require students to use the topics in high school syllabi and textbooks when they are articulating themselves so that applicability is evident. This is very possible, because Zambia has a national science curriculum for all science subjects, so much so that learning in context would be easily achieved. Based on our findings that there is incongruence in inquiry levels emphasized in textbooks and exams, using these materials in training would help support and address these problems early. In order to assess student teachers' grasp of teaching science by inquiry, instructors can use peer teaching sessions and students teaching practice to do so. What is required is for teacher educators to have a well-defined framework of what classroom inquiry is/involves. Doing so would enable teacher educators to assess students at two crucial points – during training and during student teaching.

Professional development programs

Scientific knowledge is never static, as it changes when new information is discovered. This implies that these changes may influence how science is taught at any given time. Consequently, this may lead to changes in what constitutes best science teaching practices. Our point here is that teachers, who graduated before 2000 when the Zambian CDC revised the curriculum materials to include inquiry, may be unaware of the current teaching demands. To ensure that these in-service teachers are kept abreast with the new science teaching conceptions, there must be dynamic initiatives such as professional development programs in place. Zambia already has a system for professional development, though it might not be doing well on enlightening in-service teachers about new science teaching approaches, and how to tackle their teaching practices to suit the revisions made to the curriculum in 2000. Teacher professional development programs need to address the new view of inquiry that expands the notion of inquiry to include connecting student activities to developing theories or models and communicating through argumentation (Driver et al., 2000; Duschl & Grandy, 2005; Millar & Osborne, 1998). As noted in our study, Zambian teachers held a narrow view of classroom inquiry. When this extended view of inquiry is promoted explicitly in teacher professional development, classroom inquiry activities will become more conducive to students' obtaining the current view of science inquiry. Teacher professional development should focus on helping teachers to connect inquiry activities from syllabi, textbooks and past exam papers to scientific knowledge and communicating through argumentation. Doing so would provide teachers with an actual context and would be meaningful for their professional growth as facilitators in science education.

Science curriculum review board

Besides the current Curriculum Development Centre whose main job is to revise science curriculum, there is need to have a science curriculum review board which would look at the holistic picture on how inquiry levels and inquiry skills are juxtaposed in science teaching materials (i.e. syllabi and textbooks), assessment (practical exams) and pedagogy (teachers' teaching practices). So far our results have shown that there are incongruences in the inquiry levels and inquiry skills emphasized in teachers' conceptions, syllabi, textbooks and practical exams. Therefore, a science curriculum review board whose job would be to propose coherent frameworks for IBSE in Zambia is necessary at this time. This is because the extent to which curriculum, pedagogy and assessment practices complement each other is pivotal in enhancing the enactment and implementation of IBSE in Zambia. For example, lessons learned from Lebanon show that an absence of a clear framework of inquiry confuses teachers and restricts inquiry to a collection of discrete science process skills implemented sequentially through a scientific method (Abd-El-Khalick et al., 2004).

Additionally, to make this review board representative of concerted efforts, its membership should consist of classroom teachers, curriculum developers, people who prepare practical exams and teacher professional development providers.

Conclusion

This study revealed that Zambian pre-service science teachers have a narrow conception of inquiry, which emphasizes the collection of facts. Furthermore, this study showed that there is a discrepancy in inquiry levels and skills emphasis in science syllabi, textbooks and exams. Such discrepancies are potential obstacles to the implementation of IBSE in Zambia. Based on these findings, we have proposed that science teacher preparation programs must explicitly teach teachers the aspects of inquiry such as the NOS and involve them in hands-on inquiry tasks if they are to develop desired conceptions of classroom inquiry, and consequently implement inquiry ideas in their classrooms. With respect to ensuring that teachers see a bigger picture of how their teaching practice and what is suggested in syllabi, textbooks and exams complement each other, there must be avenues to do so. And in this regard, we believe professional development initiatives and science curriculum review boards can be utilized.

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