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SCIENCE TEACHERS’ UNDERSTANDING AND PRACTICE OF INQUIRY-BASED INSTRUCTION IN UGANDA

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Abstract

High school students in Uganda perform poorly in science subjects despite the Ugandan government's efforts to train science teachers and build modern science laboratories in many public high schools. The poor performance of students in science subjects has been largely blamed on the inability by many science teachers to teach science through Inquiry-Based Instruction (IBI) to motivate the students to learn science. However, there have been no empirical studies done to establish the factors that influence science teachers' understanding and practice of IBI in Uganda. Most of the published research on IBI has been conducted in developed countries, where the prevailing contexts are very different from the contexts in developing countries such as Uganda. Additionally, few studies have explored how professional development (PD) training workshops on inquiry and nature of science (NOS) affect chemistry teachers' understanding and practice of IBI.

My purpose in this multi-case exploratory qualitative study was to explore the effect of a PD workshop on inquiry and NOS on chemistry teachers' understanding and practice of IBI in Kampala city public schools in Uganda. I also explored the relationship between chemistry teachers' NOS understanding and the nature of IBI implemented in their classrooms and the internal and external factors that influence teachers' understanding and practice of IBI. I used a purposive sampling procedure to identify two schools of similar standards from which I selected eight willing chemistry teachers (four from each school) to participate in the study. Half of the teachers (those from School A) attended the PD workshop on inquiry and NOS for six days, while the control group (those from School B) did not. I collected qualitative data through semi-structured interviews, classroom observation, and document analysis. I analyzed these data by structural, conceptual and theoretical coding approach.

I established that all the participating chemistry teachers had insufficient understanding of IBI at the beginning of the study. However, teachers from School A improved their understanding and practice of IBI after attending the PD workshop. I also found that the participating chemistry teachers' NOS epistemological views were, to some extent, related to the nature of IBI implemented in their classroom. The main internal factors the participating teachers perceived to influence their understanding and practice of IBI were their attitudes and teaching experience, whereas the external factors were lack of motivation, lack of necessary instructional materials, mode of assessment, class size, the nature of pre-service and in-service training, support from peer teachers and limited time in relation to many lessons and much content to cover Based on the above findings, I conclude that the current science teacher training in Uganda may not be improving science teachers' understanding and practice of IBI, and most of the factors are beyond their control (external). Hence, there is an urgent need for teacher educators and policymakers in Uganda to address the internal and external factors influencing science teachers' understanding and practice of IBI to improve the teaching and learning of science subjects. Additionally, more quantitative and qualitative studies should be done among teachers of different disciplines to establish how the above factors and others affect teachers' understanding and practice of IBI in developing countries like Uganda.

Keywords: *Science teacher education, Understanding, Practice of inquiry, Inquiry-based instruction, professional development workshop, Nature of Science*

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Dedication

This dissertation is the result of a period that I was less present for my family in the roles of father, guardian, helper, comforter and husband. Therefore, I dedicate this dissertation to my wife Stella Kayaga, and my children: Clement Ssempala, Michael Kimuli Ssempala, Gabriel Walusimbi Ssempala and Magdalene Nakimuli Ssempala, for enduring these four years of my absence and also encouraging me to keep going with my studies. I also dedicate this dissertation to my grandfather, Fredrick Kiwotoka (RIP); my grandmother, Esther Namakoye Kiwotoka (RIP); my father, Clement Ssempala (RIP); and my aunt, Clementina Natenza, who played a great role in my education and life in general by instilling in me discipline, patience, and the value of hard work, all which have enabled me to attain this highest level of education.

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Abbreviations and Acronyms

ADB	African Development Bank
B. ED	Bachelor of Education
BSc/Edu.	Bachelor of Science/ Education
Dip.Edu.	Diploma in Secondary Education
IBI	Inquiry –based Instruction
IRB	Institutional Review Board
JICA	Japan International Co-operation Agency
K-12	Kindergarten through grade 12
MoES	Ministry of Education and Sports
NCDC	National Curriculum Development Center
NGSS	Next Generation Science Standards
NOS	Nature of Science
NRC	National Research Council
PD	Profession Development
SESEMAT	Secondary Science and Mathematics
STEM	Science, Technology, Engineering and Mathematics
UK	United Kingdom
UACE	Uganda Advanced Certificate of Education

UCE	Uganda Certificate of Education
UNCST	Uganda National Council for Science and Technology
UNEB	Uganda National Examination Board
US	United States

Chapter 1: Introduction

Background and Context

The effective use of scientific inquiry is one hallmark of outstanding science teachers. Science teachers who use this approach develop within their students an understanding that science is both a product and a process (Akben, 2016; Dailey & Robinson, 2016; Herron, 1971; Lotter, Rushton & Singer, 2013; Miranda & Damico, 2015; Saden & Zion, 2009). Not only do students of these teachers learn the rudimentary knowledge and skills possessed and employed by scientists, but they also learn about the nature of science (NOS) (Abd-El-Khalick, 2013; Akben, 2015). There are many reasons why established in-service science teachers fail to teach using inquiry, some of these reasons include a lack of competence, lack of a strong knowledge of science and the inability to use experimental skills. Many science teachers also have a naïve understanding of scientific inquiry and are therefore not able to teach authentic inquiry (Cavas, Holbrook, Kask & Rannikmae, 2013; Crawford & Capps, 2012: Windschlt, 2004). Among these reasons is that science teachers often do not, themselves, possess a holistic understanding of scientific inquiry and the nature of science (Lebak, 2015; National Research Council, 2000; Osborne, 2014). This in all likelihood stems from the nature of traditional science teaching at college/university level that commonly uses didactic-teaching-by-telling approach (Miranda & Damico, 2015; Vesenka, et al. 2000). In many teacher education programs, little attention is given to how the processes of scientific inquiry should be taught (Meyer et al., 2013). It is often assumed that once teacher candidates graduate from an institution of higher learning, they understand how to conduct scientific inquiry and effectively pass on appropriate knowledge and skills to their students. Hence, there is a critical need to synthesize a framework for the most effective promotion of inquiry processes among students at all levels.

Inquiry exists within different contexts – scientific inquiry, inquiry-based learning and inquiry-based teaching (Hasson & Yarden, 2012; Heron, 1971; Marshall & Smart, 2013). Lederman (2004) defined inquiry as the process by which scientific knowledge is developed, whereas Hassard (2005), defined inquiry as a term used in science teaching that refers to a way of questioning seeking knowledge or information or finding out about the phenomenon. According to the National Research Council (NRC) (2000), the essential features of classroom inquiry are:

1. Learners are engaged by scientifically oriented questions;
2. Learners give priority to evidence;
3. Learners formulate explanations from evidence to address scientifically oriented questions;
4. Learners evaluate their explanation in light of alternative explanation; and
5. Learners communicate and justify their proposed explanation (p.35).

Inquiry-based instruction is based upon constructivist views of learning where students develop their ideas. Research shows that inquiry-based instruction increases motivation, conceptual understanding, critical thinking, science content understanding and positive attitudes towards science (Geier et al., 2008; Lloyd & Contheras, 1985; Narode et al., 1987; Patrick et al., 2009; Rakov, 1986). Science teachers can use inquiry to help precollege students develop informed NOS understandings, and teachers with informed NOS understanding are better positioned to enact inquiry learning (Abd-El-Khalick, 2013). Minner et al.'s (2010) meta-analysis of research on inquiry-based teaching demonstrated that this is an effective teaching method.

Despite this endorsement and reported benefits of inquiry instruction, many science teachers do not understand what inquiry is (Demir & Abel, 2010). Demir and Abel (2010) found that beginning teachers often left out evidence, explanation, justification, and communication. Another study by Capps and Crawford (2012) discovered that few highly-motivated teachers could describe what inquiry-based instruction was; most equated it with hands-on learning. Brown et al. (2006) found that college professors had an incomplete view of inquiry instruction; they often left out features such as explanations and justifications.

Few studies have explored how explicit-reflective professional development workshop on inquiry and NOS affect high school chemistry teachers' understanding and practice of inquiry-based instruction in developing countries. Explicit-reflective refers to the approach of training where nature of science is directly explained to the learners by giving clear examples of nature of science by use of the history and philosophy of science episodes, and also giving learners the opportunity to reflect the implication of these historical and philosophical episodes to the development, teaching and learning of scientific knowledge (Abd-El-Khalick, 2012, Lederman & Lederman, 2012). Most of the research studies have been carried out to establish the understanding and practice of inquiry-based instruction by science teachers in developed countries, primarily in general science and for prospective elementary science teachers. For this study, I decided to focus on chemistry teachers because teachers are a critical factor in improving a child's ability to learn and chemistry is an important field of science and is central to the understanding of all other branches of science (Brown & Lemay, 1977; Brown et al., 2012; Johnstone, 2009). This study aimed to address the gap in knowledge about the factors influencing chemistry teachers' understanding and practice of inquiry-based instruction in developing countries using an exploratory multi-case study design.

Uganda and her Education System

Uganda education system. Uganda is a former British protectorate that obtained independence on October 9th, 1962 (54 years ago). Since independence, Uganda has never reformed her education system. The education system is: 7 years of primary school; six years of secondary school [four years of lower secondary and two years of upper secondary] and three to five years at university depending on the program of study. Hence, if a child starts primary school at six years, s/he is expected to graduate at the age of 22 years if he/she takes a three-year course at university (6+16 = 22 years). Currently, Uganda is planning to reform her lower secondary education curriculum to make it similar to the curriculum in developed countries like US and UK. The teachers will be expected to teach science using an inquiry approach to facilitate the students' understanding of the nature of science. However, there is no empirical research to establish the factors that influence chemistry teachers' understanding and practice of inquiry based instruction, and the relationship between science teacher's nature of science views and the nature of inquiry implemented in the classroom.

Science teacher education programs in Uganda. Currently in Uganda, high school (secondary) teachers are trained at three different levels/categories; the first level is the diploma, which is a two-year course that is undertaken after six years of secondary education (the Ugandan education system refers to these teachers as Grade V teachers); the second level is the bachelor of science education degree (graduate level), which takes three years after secondary school; and the third category is the post-graduate diploma in education (post-graduate level), which normally takes a total of four years (three years bachelor of science and one year of post-graduate diploma in education). The science teachers with a diploma are expected to teach lower secondary because their knowledge of subject content is considered appropriate for lower level classes, whereas the graduate and post-graduate teachers can teach both lower and upper secondary.

In-service science teacher training in Uganda. Since the introduction of science policy in 2000 where science subjects were made compulsory (physics, chemistry and biology) in lower secondary (form 1 to form 4), students have continued to perform poorly in science subjects (Uganda National Examination Board - UNEB Report, 2014). Originally, these subjects were optional for students in lower secondary. The poor performance is always blamed on lack of science equipment/apparatus and poor teaching methods by science teachers (UNEB Report, 2014). To mitigate the above problems, in 2002 the government secured a loan from the African Development Bank (ADB) to construct modern laboratories in public secondary schools. Also in 2004, the Ministry of Education, Science, Technology, and Sports, with the support of the Japan International Co-operation Agency (JICA), started the In-service Science and Mathematics teacher training program (SESEMAT). Despite all the above efforts, learners have continued to perform poorly in sciences, especially chemistry and the number of students taking science subjects at upper secondary has not increased. For example, one of the main universities in Uganda, Makerere University, admitted only twenty (20) students for the Bachelor of Science Education (Majoring in Chemistry) compared to 2800 students (Bachelor of Arts Education). It is against this backdrop that I conducted this study to investigate the effect of explicit-reflective professional development workshop on inquiry and NOS on science teachers' understanding and practice of IBI. In addition, the study explored the relationship between science teachers' NOS understanding and nature of IBI implemented in their classroom, and the factors science teachers' perceive to influence their understanding and practice of IBI in Uganda.

Problem Statement

Currently, inquiry in the science classroom is advocated and expected by science educators yet surprisingly rare and enigmatic (Atar, 2011; Crawford & Capps, 2012; Lebak, 2015; Mansour, 2015). More than a decade into the 21st century, many researchers claim that inquiry is not very commonly observed, and most certainly is not the central organizing theme in most science classrooms, even in developed countries like the US (Capps & Crawford, 2012; Clinton, 2013; Herrington et al., 2016; Lucero, Valcke & Schellens, 2013). Other countries, such as Singapore, have reported a similar state of affairs related to the status of inquiry science teaching (e.g., Kim & Tan, 2011; Sun & Xie, 2014). When observers look into many science classrooms, teachers are still delivering science concepts and principles through primarily lecture mode and students will likely, but not always, be passively listening and taking notes. If a lesson involves a laboratory experience, students will likely run through the procedure, step-by-step, to verify a known result. The laboratory lesson may resemble the kind of tightly structured traditional science teaching practice found in many classrooms of the last century (Crawford & Capps, 2012; Miranda & Domico, 2015). Many science educators can list and describe *what inquiry is not*, yet there remains a great deal of confusion about how to precisely characterize *what inquiry is* and *what it means to teach science as inquiry* and all the ramifications (Clinton, 2013; Schmidt & Fulton, 2016).

Research indicates that many science teachers hold inaccurate conceptions of scientific inquiry, inquiry-based instruction and NOS (Herrington et al., 2016; Kukkonen et al., 2016; Lederman & Lederman, 2012; Meyer et al., 2013; Shih et al., 2016). This distorted view of inquiry has created formidable barriers to the enactment of inquiry-based instruction in high school (K-12) classrooms. Many teachers believe that cookbook investigations and other hands-on activities implemented to break the monotony of lectures or powerful presentation are reflective of inquiry-based instruction (Lederman & Lederman, 2012) Most of the published research on inquiry is done in developed countries like the US, UK, and Canada whose contexts are different from the developing countries like Uganda. Windschitl (2002) classified the challenges and constraints teachers have when attempting to implement constructivist reform pedagogies into "four domains of dilemmas: conceptual, pedagogical, cultural, and political" (p. 68). Science teachers in developing countries may be facing totally different conceptual, pedagogical, cultural and political dilemmas compared to their colleagues in developed countries like the US, UK, and Canada. As such, the research carried out on inquiry in developed countries may not address the challenges in science classrooms in developing countries like Uganda due to different cultural and political dilemmas. Also, few studies have been done to investigate how explicit, reflective professional development workshop on inquiry and NOS affect chemistry teachers' understanding and practice of inquiry based instruction. In addition, most of the studies on science teachers understanding and practice of inquiry focus on elementary prospective general science teachers and are not discipline specific. Therefore, this study attempts to address this gap in literature as far as the factors affecting in-service high school chemistry teachers' understanding and practice of inquiry based instruction in a developing country.

Purpose of the Study

The primary purpose of this multi-case exploratory qualitative study was to explore the effect of an explicit, reflective professional development (PD) workshop on inquiry and NOS on chemistry teachers' understanding and practice of inquiry-based instruction in Kampala city public schools in Uganda. This study also explored the relationship between chemistry teachers' NOS views and the nature of inquiry implemented in their classrooms. Lastly, the study explored the internal and external factors that influence chemistry teachers' understanding and practice of inquiry-based instruction in Uganda.

Research Questions

The study was guided by the following research questions:

1. How do in-service chemistry teachers understand and implement inquiry-based instruction before attending an explicit, reflective professional development workshop on inquiry and NOS?
2. How do in-service chemistry teachers understand and implement inquiry-based instruction after attending an explicit, reflective professional development workshop on inquiry and NOS?
3. To what extent does chemistry teachers' NOS understanding relate to the nature of inquiry-based instruction implemented in their classrooms?
4. What are the perceived external and internal factors that influence chemistry teachers' understanding and implementation of inquiry-based instruction in Kampala city public high schools?

Theoretical Constructs

Inquiry. Inquiry is defined by the National Science Education Standards (NSES) (2000) as "the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an appreciation of how scientists study the natural world" (p. 23). This definition highlights a complex interaction between *doing science, learning science concepts* and *learning about the nature of science* (NOS). These three facets of inquiry are embedded within the constructs scientific inquiry, inquiry-based learning and inquiry-based instruction (Anderson, 2007; Keys & Bryan, 2001; Herrington et al., 2016), which are often confused by science teachers. A disambiguation of these terms may prove essential in addressing some of the misconceptions about inquiry held by science teachers and students alike.

Scientific inquiry. Scientific inquiry refers to "the diverse ways in which scientists study the natural world and propose explanations based on evidence derived from their work" (NRC 2000, p. 23). In other words, when scientists carry out investigations to construct scientific knowledge, they are engaging in scientific inquiry. Scientists study natural phenomena by making careful observations, collecting and analyzing empirical data, and providing a scientific explanation for their findings (Keys & Bryan, 2001; Minner et al., 2010). While science teachers are not expected to replicate this complex form of inquiry in the classroom, an understanding of the process involved in the development of scientific knowledge will likely promote students' interest in science (Minner et al., 2010). Also, the central premise of inquiry-based instruction (IBI) is that students approach learning in a way that parallels the strategies used by scientists and attitudes demonstrated during scientific inquiry (Bass et al., 2009). To develop these skills and attitudes in students, it seems reasonable to expect science teachers to become familiar with the processes of science as practiced by scientists. Exposing science teachers to authentic inquiry experiences, therefore, facilitates the design of classroom inquiry experiences that stimulate the practices of science (Capps et al., 2012). Classroom inquiry experiences will likely engage students in an inquiry-based approach to learning.

Inquiry-based learning. Inquiry-based learning refers to skills, knowledge and dispositions that are to be developed in students because of their engagement with classroom inquiry (Capps et al., 2012). Central to reform documents are the content standards, which emphasize three components of the educational outcomes of student learning science (NRC, 1996, 2000, 2012). These include (1) knowledge and understanding of core scientific concepts, (2) ability to do science, and (3) understanding the NOS. As such, students learn science by seeking to answer questions about the natural world through science processes such as *observing, predicting*, and *making inferences.* Embedded in the notion of inquiry-based learning is the understanding that students engage in some of the same activities and thought processes as scientists who are constructing scientific knowledge. It is acknowledged that engagement in inquiry practices contributes to effective learning, motivation, and increased interest in science as a human endeavor (Michael et al., 2008; Sandoval & Reiser, 2004; Windschitl, 2003). Teachers play a critical role in implementing the kind of instruction that will facilitate such learning.

Inquiry-based Instruction (IBI). Inquiry-based instruction has recently been conceptualized in the new Framework for K-12 Science Education (NRC, 2012) as those practices scientists engage in during the development of scientific knowledge (Capps & Crawford, 2013; NGSS, 2013). Teachers implementing IBI are expected to guide students through inquiry processes that mirror the practices of scientists. Inquiry-based instruction is, therefore, characterized by students who are (1) engaging with scientific questions, (2) planning and conducting investigations, (3) generating explanations by connecting evidence and scientific knowledge, (4) applying scientific knowledge to new problems, and (5) participating in critical discourse and argumentation with their peers (Bass, et al., 2009; NRC, 2000; NGSS, 2013). These features of IBI reflect the responsibility of science teachers as they help students to construct their knowledge while developing the skills and dispositions characteristic of scientists (Minner et al., 2010). Teaching science as inquiry is a complex task that challenges the majority of teachers, who require considerable professional development and support (Crawford, 2012; Luft, 2001).

Researchers agree that engaging science teachers in authentic professional development activities will improve confidence and expertise with the enactment of IBI (Blanchard et al., 2009; Dresner & Worley, 2006; Rahm et al, 2003; Windschitl, 2003). However, for professional development to be useful to the science teachers, it should be designed basing on the science teachers' pedagogical, conceptual, cultural and political dilemmas (contexts).

Level of inquiry-based instruction. Based on the level or degree of students' involvement in the active learning process, three different settings of inquiry-based instruction can be differentiated. Differences, relating to the way the experimental procedural or design is developed can also be considered. Table 1 shows these settings.

Table 1. Different settings of inquiry teaching (Cavas, et al., 2013)

Mode of Inquiry-based Instruction	Question investigated by	Procedure prescribed/ designed by	Procedure for data analysis/ interpretation and making conclusion
1. Structured Inquiry	Presented by teacher	Presented by teacher	Procedure is teacher directed and prescribed; Student interpreted
2. Guided Inquiry	Usually presented by teacher	Usually designed or selected by students	Usually, teacher guided, but student interpreted.
3. Open Inquiry	Posed by students	Designed by students	Student-led procedures and interpretation

1. The *structured inquiry* relates to a teaching approach that involves an active teacher, but passive students: the students' activities are directed and guided by the teacher. The students are given little freedom to do something by themselves. In the structured inquiry, the students investigate a teacher-presented question through an exactly prescribed procedure, often coming from the textbook or worksheet. Although the student is usually asked to interpret the outcomes, this tends to follow the reasoning in narrow subject matter context (Cavas, 2012; Cavas et al., 2013).

2. *Guided inquiry* involves the teacher, for the most part, in presenting the investigation question, but usually allows students to design or select procedures. Its strength over structured inquiry is that it includes student-created design/planning involvement as well as interpreting findings and drawings conclusions. This form of inquiry teaching does involve students in taking some responsibilities for their activities and is a step on the way to full involvement of students as is the case in the open inquiry (Cavas, 2012, Cavas et al., 2013; Zion, 2007).
3. In *open-inquiry,* also called *authentic inquiry,* the teacher takes the responsibility to define the knowledge framework in which the inquiry is to be conducted, but leaves the students with the task of considering a wide variety of possible inquiry questions. During open inquiry, the students investigate topic-related questions through student-designed procedures and take responsibility for data collections, analysis, reporting and the drawing of conclusions. The students experience decision making throughout each stage of the inquiry practice (Cavas, 2012, Cavas et al., 2013; Zion, 2007).

Nature of Science (NOS). The construct “nature of science” (NOS) has been advocated as an important goal for studying science for more than 100 years (Central Association for Science and Mathematics Teachers, 1907). NOS is the epistemology of science underlying the practices imbedded in investigations, field studies, and experiments, the values and beliefs inherent to the scientific enterprise, and the development of scientific knowledge (Abd-El-

Khalick, 2013). According to the Next Generation Science Standards (NGSS) (2013), there are eight tenets of NOS understandings students should learn in the classroom, namely:

> (1) Scientific investigations use a variety of methods, (2) Scientific knowledge is based on empirical evidence, (3) Scientific knowledge is open to revision in light of new evidence, (4) Scientific models, laws, mechanisms, and theories explain natural phenomenon, (5) Science is a way of knowing, (6) Scientific knowledge assumes order and consistency in natural systems, (7) Science is human endeavor, and (8) Science addresses questions about the natural and material world. (NGSS Lead States. p. 16)

Discussion about what ideas should be considered under the rubric of NOS often include concerns about the list of the tenets above. Some scholars worry that the list of NOS aspects end as “mantras” for students to memorize and repeat (Matthews, 2012, p. 68). Other scholars (Allchin, 2011; Clough & Olson, 2008; Irzik & Nola, 2011; Wong & Hodson, 2009, 2010) think the list provides too simplistic a view of NOS. However, the list serves as an important function, as it helps to provide a concise organization of the often-complex ideas and concepts it includes (Abd-El-Khalick, 2013). Irzik and Nola (2011) produced a depiction of NOS that they claimed is much more informative and comprehensive than the list. However, what they presented is basically the same as the list, but formatted in a matrix as opposed to the linear format of the list.

Due to the critical role science teachers play in developing learners’ NOS understanding, there has been a lot of research to assess and improve science teachers’ NOS understanding since 1950 (Clough & Olson, 2008). Most of the early research studies in the 20th century utilized the quantitative approach (closed instruments) to assess science teachers’ NOS understanding (e.g., Aikenhead, 1974; Ogunniyi, 1982; Pomeroy, 1993; Welch, 1966; Wilson, 1954). However, researchers in the 21st century are utilizing both quantitative and qualitative approaches to assess science teachers’ NOS understanding (e.g., Bartos & Lederman, 2014; Wahbeh & Abd-El-Khalick, 2014). The two main approaches used by science educators to improve science teachers' NOS understanding are the (1*) implicit approach,* which suggests that an understanding of NOS is a learning outcome that can be facilitated through process skills in instruction, science content course work and doing science, and (2) *explicit approach*, which suggests that understanding of NOS can be increased if learners are provided with opportunities to reflect on their experiences (Abd-El-Khalick & Lederman,2000). There is an ongoing debate among scholars about which of the two approaches is more effective.

Theoretical Framework

Many sources of information are available regarding placing inquiry-based teaching and learning into practice. Piaget's cognitive constructivism theory (1967) and Vygotsky's social cognition theory (1978) have shaped inquiry-based instruction.

As constructivist approaches permeated much of educational practice in the 1970s, constructivism became particularly prominent in science education through the focus on inquiry (Minner, Levy & Century, 2010). Constructivist theory explains how knowledge is constructed given that new knowledge should have contact with existing knowledge that has already developed by previous experiences (Creswell, 2007; Ishii, 2003; Kim, 2001). The constructivist approach emphasizes that new knowledge is constructed by learners through active thinking, an organization of information, and the replacement of existing knowledge.

However, there is another complementary framework that must be considered along with constructivism. Vygotsky (1978) studied social cognition, and he concluded that learning is a social construct that is facilitated by language via social discourse. Vygotsky (1978) placed an emphasis on the idea that social interaction was crucial for students to construct answers for themselves. The work of Prewat (1997) concluded that social cognition allows learners to construct their reality of new knowledge through human activity.

The National Science Foundation (NSF) (2006), NGSS (2013) and science education researchers (Bybee et al., 2006; Minner, Levy, & Century, 2010) have emphasized the importance of teachers helping students build their knowledge. Constructivist approaches emphasize that an individual constructs knowledge through active thinking, an organization of information and integration of existing knowledge (Cakir, 2008).

Both constructivism and social cognition theories are useful in developing lessons in an inquiry-based classroom (Jonassen, 1994). Collaborative learning among learners and teachers has been studied, and instructional models around social cognition have been shown to be effective in developing an inquiry-based learning environment (Kim, 2001; Lave & Wenger, 1991; McMahon, 1997).

The constructivism theory has implications for the learning experience, such as how students develop thinking skills, develop communication and social skills, transfer skills to the real world, and promote intrinsic motivation to learn. Hence, in-service chemistry teachers may construct their understanding about inquiry-based instruction as they participate in the professional development workshop on inquiry and NOS. On the other hand, the school setting is very social place. Teachers interact with teachers, students interact with students, and teachers interact with students. Bandura believes that human functionality is viewed as a series of interactions among personal factors, behaviors, and environmental events (Windschitl, 1999). Social cognitive theory studies the individuals within a social or cultural context, and focuses on how people perceive and interprets information they generate themselves (intrapersonal) and from others (interpersonal) (Stern, 1994). Many teachers believe that behavior occurs because of reinforced practice, but social cognitive theory is based on the premise that cognitive processes guide learners' behavior instead. Learning occurs actively through actual performance, observing models, listening to instruction, and engaging with a variety of materials. Therefore, in-service chemistry teachers engaged in the microteaching of inquiry-based lessons during the professional development workshop are likely to affect their understanding and practice of inquiry-based instruction accordingly.

Overall, I used the constructivism theoretical lens to examine how in-service chemistry teachers understand and practice inquiry-based instruction before and after attending the professional development workshop, whereas I used the social cognitive theoretical lens to explore the internal and external factors affecting in-service chemistry teachers' understanding and practice of inquiry-based instruction in Kampala city high schools.

Assumptions

This study was based on several assumptions. The first assumption I made is that the teachers will be willing to learn the new approach of NOS and inquiry during the professional development workshop. The second assumption is that the participating teachers will have well-prepared schemes of work and lesson plans for the researcher to obtain enough documents to analyze the teachers' intentions accordingly. The third assumption is that participants will be open and honest in describing their understanding and practice of inquiry-based instruction. This assumption was important because teachers' understanding and perceptions about inquiry often influence their instruction in the classroom. I utilized purposive sampling to obtain willing participants who satisfied the above assumptions.

Scope and Limitations

Scope. The scope of this study involves its boundaries. The scope of this study included the chemistry teachers in Kampala city (Uganda) public high (secondary) schools. In addition to this scope, time, resources and location delimited this study. In relation to time, I collected data during the third school term of 2016 year (September-December 2016). In addition, I was the only researcher who was involved in data collection and analysis. Hence, I had limited time and financial resources. However, the city is the cosmopolitan area in Uganda with a variety of school and teachers, and hence the collected data was adequate to produce reliable and valid findings/conclusions.

Limitations. The limitation of this study is related to the qualitative research design of the eight cases. Because I was the only person responsible for all data collection and analysis, the potential of researcher subjectivity was expected. Therefore, I used strategies recommended by Marriam (2009) and Yin (2009), including triangulation, member check, audit trial and peer review of field notes, to address this potential for researcher bias.

Significance of the Study

This study contributes to the current understanding of how chemistry teachers understand and practice inquiry-based instruction in developing countries. In addition, this study provides information to guide future educational policies that are necessary to improve the teaching and learning of science in developing countries. The study also provides insights for science educators who want to implement quality professional development programs for science teachers in school systems. This study is beneficial to educational leaders and policy makers by informing them about the required improvements of inquiry-based professional development programs to better serve science teachers as well as support current reform of science education.

Chapter 2: Literature Review

This discussion of the reviewed literature is divided into five main sections: meaning of inquiry, development of inquiry-based instruction, science teachers' understanding of inquiry-based instruction, science teachers' practice of inquiry-based instruction, and factors influencing science teachers' implementation of inquiry-based instruction.

Meaning of Inquiry

Introduction. According to Webster (2011), *inquiry* is an "act or an instance of seeking for truth, information, or knowledge; investigation; research; or query" (p. 1167), while the root word *inquire* means "to ask for information about, to make an investigation or search, to seek information or questioning" (p. 1167). However, in the field of science education, there is a lack of agreement on the meaning of inquiry (Martin-Hauson, 2002; Minstrell & Van Zee, 2000; Osborne, 2014). Since its inception, the term *inquiry* has been in an identity crisis (Barrow, 2006) and is thought of as a vague term. Although the standard and the companion documents in the US have described inquiry, teachers still seem uncertain about the term. Research has found that some teachers describe inquiry as discovery learning projects (Dass, Head & Rush, 2015: Demir & Abell, 2010), hands-on activities (Philippou, et al., 2015: Wilcux, Kruse, & Clough, 2015), authentic problems (Capps & Crawford, 2013; Chowdharay et al., 2014) or classroom discussion and debate (Herrington, et al., 2016), while others equate inquiry with increased level of student direction, allowing students to ask their questions, to determine which data to collect, or to design a procedure (Cavas, 2012; Kanga & Wallance, 2010; Morrison, 2013). Although each of these characteristics may be part of an inquiry experience, they do not give a full picture of the potential of inquiry in a science classroom. Inquiry is not simply hands-on science lab activities that verify what has been taught, discovery learning, a formula for teaching, or a set of skills to be practiced (Lakin & Wallace, 2015; Humber & Moore, 2010; NRC, 2000, 2006; Trumbel et al., 2011). Inquiry, as described by the standards, puts emphasis on learners working under the guidance of experienced teachers to construct understandings of scientific concepts through interactions with a scientific question and data.

Barman (2002) presented his interpretation of inquiry as a teaching strategy and a set of student skills (i.e., individual process skills). Lederman & Flick (2002) and Lederman (2003) identified the third component of inquiry as that of knowledge about the inquiry. Minstrell and Van Zee, (2000) listed several different definitions of inquiry: encouraging inquisitiveness (habit of the mind), teaching strategy for motivating learning, hands on and minds on, manipulating materials to study the particular phenomenon and stimulating questions by students. Minstrell and Van Zee (2000) considered an inquiry complete when "we should know something we did not know before we started. Even when our investigation fails to find the answers, at least, the inquiry should have yielded a greater understanding of factors that were involved in the solution" (p. 473). Meanwhile, inquiry was defined by the National Science Education Standards (NSES) as "the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an appreciation of how scientists study the natural world" (NRC, 1996, p. 23). This definition highlights a complex interaction between doing science, learning science concepts and learning about the NOS. These three facets of inquiry are embedded within the constructs scientific inquiry, inquiry-based learning and inquiry-based instruction, which are often confused by science teachers (Anderson, 2007; Habók & Nagy, 2016; Ramnarain, 2016).

"Inquiry is the dynamic process of being open to wonder and puzzlements and coming to know and understanding the world" (Galileo Educational Network, 2015, p. 1). French and Russell (2002) wrote that inquiry-based instruction relates to a student's learning as a scientist.

This type of instruction places the onus of responsibility on the student to engage in the scientific processes to learn about a topic and perform activities.

Summary. Inasmuch as the literal meaning of inquiry is known and clear, science educators for the last hundred years have failed to reach a consensus on the term inquiry as is used in science education. This influences prospective and in-service science teachers' understanding and practice of inquiry-based instruction (Osborne, 2014). Hence, there is a need for science educators to reach a consensus about the meaning of inquiry. Examination of the development of inquiry-based instruction may provide insights towards this consensus.

Development of Inquiry-Based Instruction (IBI)

Introduction. Inquiry-based instruction has evolved for more than 500 years since the 1500's during the days of Socrates (Ross, 2013; Sawyer, 2012), in modern era in the 20th century with Dewey's ideas (1910, 1938, 1944) and later to the learning cycle (3E and 5E model) by Karplus and Atkins in 1950's-1970's (Fuller, 2003; Simpson, 2012; Sunal, 2013), to the current science practices (NRC, 2012). The major reason why inquiry is continuously evolving is because of a lack of clarity by many science teachers of what it means to teach science through inquiry-based instruction (Osborne, 2014). Hence, science education researchers have continuously tried to conceptualize the concept of inquiry with the hope of helping science teachers to understand and practice IBI to improve the teaching and learning of science (NRC, 2012; Osborne, 2014).

In this review of the literature on the development of IBI, I will analyze the growth and development of inquiry-based instruction by looking at the following five major areas: the ancestry of IBI, the Middle Ages and the Renaissance, the Modern Era, the learning cycle and the shift from inquiry to science practices. The ancestry of inquiry based instruction or the Socratic tradition propagates logical, but simple questioning and probing to uncover the underlying truth. It creates a learning environment where a teacher and a student can learn from each other, and, in a structured and formal way, interact with a topic to find answers and in the end, understand the issue in question. In looking at the development of inquiry, I note that the term can be traced back to the 13th century and means to seek in a formal questioning environment to achieve verifiable answers. The Modern Era is mainly supported by the work of John Dewey, who was one of the key proponents of the progressive movement in education and encouraged the use of inquiry in the teaching of science in primary schools. He also encouraged active teaching where students learned to solve problems using personal experience and knowledge to solve problems and inherently learn how to live and make decisions subsequently strengthening their potential.

The research into Dewey's work and ideas produced what is known as the learning cycle that was created, and conceptualized by Robert Karplus, a theoretical physicist and Myron Atkin a science educator in 1962. It involves the exploration of an idea, the invention of new concepts to define an idea and discovery of new ways to apply these new concepts to the new situation. Lastly in the shifting from inquiry to science practices learners are taught not only the theory of inquiry, but are also encouraged to practice and engage with it while learning science. In this discussion, I look at a comparison between the essential features of inquiry and the K-12 framework, which focuses on science and engineering practices, and analyze the shift from forming and testing hypotheses to testing and retesting theoretically grounded models.

The ancestry of inquiry-based instruction. Inquiry-based instruction has a strong historical precursor in the questioning methods employed by Socrates (Ross, 2013). Starting with the notion that the only thing he knew was that he knew nothing, Socrates would engage in a systematic and disciplined questioning process to discover basic truths about the inner workings of the natural world and ethical questions related to such enduring concerns as the nature of justice. By posing seemingly-held simple questions, Socrates showed that many commonly-held assumptions were *flawed* and *illogical*. Socratic inquiry cannot be seen as teaching in any traditional sense involving transmitting knowledge from someone who is more knowledgeable to those who possess less knowledge. Ross (2013) wrote that "in the Socratic method, the classroom experience is shared dialogue between teachers and students in which both are responsible for pushing the dialogue forward through questioning" (p. 1). Thus, both the teacher and the students ask probing questions that are meant to clarify the basic assumptions underpinning a truth, claim or the logical consequences of a thought.

Understanding the Socratic tradition helps us to recover several elements that seem to be missing in how some people understand inquiry-based learning. The Socratic tradition does not involve giving students free rein to the topic they wish to explore with minimum guidance from the teacher. Rather, the Socratic method creates a space where teacher and students are in dialogue to pursue answers to questions that are worth thinking about deeply. Inquiry was not made sporadically or as a mechanical step-by-step formal method; it was a way of living ethically in the world (Ross, 2013).

The Middle Ages and the Renaissance. While this spirit of inquiry within the Western tradition may have emerged in Ancient Greece, the term itself can be traced back to the middle of the 13th century through the Latin word, 'inquirer', which literary means "to seek for" (Friesen, 2009). The spirit of seeking answers to the mysteries of the universe based not on established tradition or superstition, but rather observation, experimentation and empirical verification, gained momentum during the early 1500's in Northern Italy (Ross, 2013). Key Renaissance figures such as Galileo Galilei and Leonard da Vinci were emblematic of the quest for knowledge that spread to the rest of Europe in the late 16th century and spurred on through the creation of new technologies (Sawyer, 2012). This spirit of inquiry and scientific discovery took hold on a wider scale during the European Enlightenment beginning the 18th century.

The modern era: John Dewey. In the modern era, this historical thread of inquiry found a home in the work of John Dewey in the early part of the 20th century. As one of the key leaders of the progressive movement in education, Dewey (who had worked as a science teacher) encouraged K-12 teachers to use inquiry as the primary teaching strategy in their science classroom (Barrow, 2006). Modeled on the scientific method, the particular process of inquiry Dewey (1910) advocated involved, "sensing perplexing situations, clarifying the problem, formulating a tentative hypothesis, testing the hypothesis, revising with rigorous tests, and acting on situations" (Barrow, 2006, p. 266). Dewey was critical of transmission-based pedagogy that emphasized acquiring facts at the expense of fostering modes of thinking and attitudes of mind related to the ways scientific knowledge is created (Barrow, 2006).

As Dewey's thinking on education evolved, he broadened the scope of topics and subjects in which to engage students with inquiry. Dewey (1938) encouraged students to formulate problems related to their experiences and augment their emerging understanding with personal knowledge. Dewey believed that teachers should not simply stand in front of the class and transmit information to be passively absorbed by students. Instead, students must be actively involved in the learning process and given a degree of control over what they are learning. The teacher's role should be that of *facilitator* and *guide.* It is important to emphasize that this process did not involve anything goes, free-for-all exploration; it was to be guided by empirical approaches to knowledge creation. From the curricular perspective, Dewey, like Socrates, believed that active inquiry should be used not only to gain knowledge and disposition but also to learn how to live. I argue that this is in line with the current goal of scientific literacy that emphasizes producing responsible citizens who can make informed decisions about controversial science and technology issues for the good of humanity, instead of just training future practicing scientists and students to pursue STEM careers.

Dewey (1944) felt that the purpose of education was to help students realize their full potential, to strengthen democracy, and to promote the common good. It may be surprising to note that many years ago Dewey felt that science should be for common good, but the question is, why has science education continued to focus on learning content for the sake of learners getting good grades or becoming engineers or doctors? This may be mainly due to the factory model of education that encourages traditional ways of teaching, disregarding Socrates' and Dewey's ideas about inquiry.

It was not until the 1950s that inquiry-based instruction would undergo a rebirth in the United States, with a space satellite known as Sputnik bringing inquiry back to the forefront of education practices (Barrow, 2006; Bybee, 2006; Chiappetta, 1997; Simpson, 2012). Throughout the 20th-century, science teachers predominantly used expository teaching methods consisting of the presentation of science concepts through lecture and reading. After a thorough explanation of the concepts, the teachers would then take their students to verify the conceptual understanding in the laboratory (Simson, 2012). When the Soviet Union launched Sputnik in the late 1950s, scientists, science teachers, and government leaders in the US became concerned that Americans had fallen behind in mathematics, science and critical thinking skills (Barrow, 2006; Bybee, 2006; Simpson, 2012).

The learning cycle. It was just after the launch of Sputnik that research into Dewey's ideas produced the learning cycle. Robert Karplus, a theoretical physicist, and Myron Atkin, a science educator, became involved in science education in the 1950s, and they were both interested in connecting psychology to the design of science teaching. Karplus volunteered to help elementary schools in Berkley where he observed science lessons and was not impressed by the methods being utilized in the science elementary classroom (Fuller, 2003; Simpson, 2012). Karplus collaborated with Atkin, and this led to the creation of the learning cycle. The learning cycle was created by Karplus and fully conceptualized by Atkin and Karplus (1962) as "guided discovery". It was later in 1967 that Karplus and his colleague Herbert first coined the term learning cycle that consisted of three phases: exploration, invention, and discovery (Barman, 1993; Bybee, 2006; Goldston, Dantzler, Day, & Webb, 2013).

The learning cycle involves students in a sequence of activities beginning with the exploration of an idea or skill, leading to guided exploration of the idea or skill, and culminating in the expansion of the idea or skill through additional practice and trials in new setting (Sunal, 2015). During the exploration phase of the learning cycle, students have an initial experience with the phenomenon being studied. Later, students are introduced to new terms associated with the concepts that are the object of the study in the *invention* phase. In this phase, the teacher is more active, and learning is achieved by exploration. Lastly, in the *discovery* phase, students apply concepts and use terms in the related, but new situation. Learning is achieved by replication and practice such that new ideas and ways of thinking have time to stabilize (Bybee, 2006). The learning cycle may be effectively used with all students at all levels to accomplish many purposes as it is designed to adapt instruction to help students in several ways. It allows students to apply knowledge gained in the classroom to new areas or situations because students are more aware of their reasoning. As a result of being able to test their conception and knowing how to produce and apply procedures, students can see where their knowledge is applicable in other areas and gain more confidence (Sunal, 2015).

The learning cycle was used in the Science Curriculum Improvement Study (SCIS) in the US in the 1970s and proved to be successful in different educational settings (Bybee, 2006). In the 1980s, the Biological Science Curriculum Study (BSCS) added two new stages to the beginning and end of the learning cycle: *engage* and *evaluation* (Bybee, 2006). This is now known as the 5E learning cycle, including the phases of engagement, exploration, explanation, elaboration and evaluation in the teaching and learning process.

Shifting from inquiry to science practices. A historical view of inquiry in science classrooms reveals three phases—learners doing inquiry, learners learning core science concepts through inquiry, and learners learning the nature of a scientist's inquiry (Sadeh & Zion, 2009). As we entered the 21st century, Anderson (2002) proposed there were three main areas of dilemmas that affected the implementation of inquiry: technical dilemmas, political dilemmas, and cultural dilemmas. Several researchers explored ways to ameliorate these situations (Atkins & Salter, 2014; Duschl, Schweingrubers, & Shouse, 2007; Hassan & Yarden, 2012; Miranda & Damico, 2015; Marshall & Smart, 2013; Lotter, Rushton & Singer, 2013; Saden & Zion, 2009).

The most recent iteration of classroom inquiry in the US occurs in the new K-12 Framework (NRC, 2012) and Next Generation Science Standards (The NGSS Lead States, 2013).

Authors of the K-12 Framework addressed the inconsistencies of various views of inquiry in the past. In the K-12 Framework, the term "inquiry" appears only a few times, related to engaging students in doing inquiry, inquiry as a pedagogy or teaching about what scientists do (scientific inquiry). Striving to rebrand inquiry, the term "science practices" is used throughout the documents. Like the researchers and philosophers in the 20th century, authors of the 21st century K-12 Framework place emphasis on immersing children in the investigation as the centerpiece for learning science. The K-12 Framework strongly emphasizes that students experience, design and carry out investigations to learn about what scientists do, as well as the epistemology of science (NRC, 2012). "As in all inquiry-based approaches to science teaching, our expectation is that students will themselves engage in the practices and not merely learn about them secondhand," (NRC, 2012, p. 30).

As I review 21st century science education from the historical perspectives, the thirst to engage in doing science reminds me of ideas put forth by philosophers, curriculum developers, and educators of the past century. So, I may ask, what is different about the K-12 Framework and the NGSS of the term "science practices" compared with inquiry in the NSES "essential features"? Is this just another way to rethink what it means to teach science as inquiry? On the contrary, Osborne (2014) argued that inasmuch as the scientific practices in the K-12 Framework are remarkably similar to the list of the ability to inquiry in the NSES (1996), the difference lies in the greater clarity of goals about what students should experience, what students should learn, and an enhanced professional language for communicating meaning in the scientific practices than inquiry. The primary challenge in teaching science as inquiry has been a lack of common understanding of what real teaching science through inquiry is, and mixing doing science with the learning of science (Osborne, 2014). The K-12 Framework strongly emphasizes that students' experiences design and help them to carry out investigations to learn about what scientists do and the epistemology of science (NRC, 2012).

In the introductory pages of the K-12 Framework (NRC, 2012) the first dimension, Science and Engineering Practices, includes: a) Asking questions (for science) and defining problem (for engineering), b) developing and using models, c) planning and carrying out investigations, d) analyzing and interpreting data, e) using mathematics and computational thinking, f) Constructing explanations (for science) and designing solutions (for engineering), g) engaging in arguments from evidence, and h) obtaining, evaluating and communicating information. A comparison of these practices with teaching inquiry in earlier reform documents in the US is shown in Table 2.

Table 2. A comparison of the abilities to do scientific inquiry (NRC, 1996, 2000) with the set of scientific practices found in the Framework for K-12 Science Education (NRC, 2012)

NSES (NRC, 1996, 2000): Essential feature of inquiry	K-12 Framework (NRC, 2012): Science, and Engineering practices
1. Identify questions that can be answered through scientific investigation.	1. Asking questions (for science) and defining problems (for engineering)
2. Design and conduct scientific investigations.	2. Planning and carrying out investigations
3. Use appropriate tools and techniques to gather, analyze, and interpret scientific data.	3. Analyzing and interpreting data,
4. Develop descriptions, explanations, predictions, and models using evidence.	4. Developing and using models
5. Think critically and logically to make the relationship between evidence and explanations.	5. Engaging in arguments from evidence
6. Recognize and analyze alternative explanations and predictions.	6. Constructing explanations (for science) and designing solutions (for engineering),
7. Communicate scientific procedures and explanations	7. Obtaining, evaluating and communicating information
8. Use mathematics in all aspects of scientific inquiry.	8. Using mathematics and computational thinking

One distinguishing feature of the new K-12 Framework and NGSS is greater emphasis on scientific modeling and argumentation. The new documents propose a shift from simply having students form and test hypotheses to testing and revising theoretically grounded models. The idea involves students going beyond experiencing inquiry by interpreting and evaluating data as evidence to developing arguments, explanation and models (Osborne, 2014). This emphasis on engaging in argumentation is not entirely a new one. For example, Abell, Anderson, and Chezem (2000) envisioned elementary teachers supporting children in learning science in this way: “The active quest for information and production of new ideas characterizes inquiry-based classrooms” (p. 65). Abell et al. (2000) recognized that although elementary classrooms may have moved beyond traditional instruction to hands-on instruction, this does not necessarily mean that it is inquiry instruction. More than a decade ago, those authors described inquiry as argument and explanation. Additionally, the essential features of inquiry number 4 (Develop descriptions, explanations, predictions, and models using evidence) in Table 2 above emphasize modeling during inquiry-based learning. Hence, it seems that conceptually there is not a big difference between inquiry and science practices, except the emphasis on integrating science and engineering practices discussed below. However, studies to establish whether science teachers understand and practice science practices better than inquiry should be conducted among the in-service science teachers who have experienced both in US contexts before we conclude that science practices are clearer than inquiry.

Another distinguishing feature of the K-12 and NGSS, as compared with historical writing about teaching science as inquiry, is the focus on *integration* (Osborne, 2014). The K-12 Framework emphasizes that learning science and engineering involves teachers providing students opportunity to learn about the "integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and engineering design" (NRC, 2012, p. 11). The vision is that teachers design learning environments in a range of classrooms in which the notions of core science concepts, crosscutting concepts, and science practices are intertwined.

Osborne (2014) argued that inquiry failed because of a lack of common understanding of what was the real teaching of science through inquiry, and mixing doing science with learning science through inquiry. He asserted that the main goal of science education was to help students understand a body of existing consensually-agreed and well established old knowledge, but not to discover or create new scientific knowledge. He, therefore, encouraged science educators to move from inquiry to scientific practices because the scientific practices had a greater clarity of goals about what students should experience, what students should learn, and an enhanced professional language for communicating meaning than inquiry (Osborne, 2014). However, I do not entirely agree with Osborne (2014)'s argument that teaching science with inquiry failed because the approach mixed learning science with creating new scientific knowledge. This is mainly because, according to the constructivist theory of learning, learners are required to construct their scientific knowledge. In my view, Osborne's argument that the goal of science education is, "to help students understand a body of existing, consensually agreed and well established old knowledge" (Osborne, 2014, p. 178) may position science as canonical knowledge. I think this is a positivist view of the nature of science, which is contrary to the contemporary view of scientific knowledge as reliable, but tentative (Lederman & Lederman, 2012).

Summary. The preceding discussion demonstrates that inquiry-based instruction and learning are invariably beneficial in science education. It also indicates that, nevertheless, teachers remain unclear about its exact nature. Indeed, the nomenclature of the approach is being transformed to science practices in the hope that teachers will be able to teach science more successfully. This is the case even in the most developed countries like the US, where the approach has been promoted for over 100 years. Accordingly, the review brings a question to mind: how do science teachers in the less developed countries understand and practice inquiry-based instruction? The significance of the question derives from the fact that science is hoped to accelerate the development of these countries, the inference being that it should be taught/ learned following the most effective approaches, of which the inquiry approach is among.

However, review of literature available on the topic leads to the conclusion that scholarship on the subject has focused primarily on the experience of the most developed countries. For instance, I have not come across any study that establishes how science teachers in Africa understand the science practices. Therefore, this study is proposed to bridge this knowledge gap by interrogating science teachers' understanding and implementation of inquiry-based instruction, taking the case of chemistry education in Uganda.

Science Teachers' Understanding of Inquiry-based Instruction

Introduction. Inquiry is an act of investigation into something. To inquire is to find out, investigate, review or analyze. In the context of this study, my focus will be on science teachers' understanding of IBI. Teaching science through science inquiry is the cornerstone of good teaching. Regrettably, an inquiry approach to learning science is not the custom in schools as instructors are often still struggling to build a shared understanding of what science as inquiry means, and at a more practical level, what it looks like in the classroom. Science teachers have divergent views about what IBI is. Some teachers view inquiry as a process, not a vehicle of learning science content (Assay & Orgill, 2010). The prior learning or knowledge of some teachers affected their understanding of IBI (Eick & Reed, 2002; Luchmann, 2007). As pointed out by Wang (2016) teachers' understanding of inquiry was influenced by their culture yet at the same time it is worth noting that there is no shared understanding of IBI between many countries as seen in the case study in Rwanda (Mugabo, 2015).

Various studies highlight the difference between conceptions about inquiry science and beliefs about inquiry science. According to Morison (2013), "conceptions" are defined as ideas, thoughts, and understandings, whereas "beliefs" hold the connotation of conviction, trust, and faith. Teachers may hold a variety of ideas about inquiry (Demir & Abell, 2010; Kang et al.

2008), and the conception they hold about inquiry science may affect how they implement inquiry (Crawford, 2007; Jones & Carter, 2007, Lotter et al., 2007). It can be said that conception means opinion, views, feelings or beliefs, hence the need to find out how these affect teachers' implementation of inquiry, which we can call investigation.

Teachers' previous learning orientations and previous experiences may also impact their learning about inquiry (Eick & Reed, 2002). This is supported by Luchmann (2007), who stated that, "one of the main challenges in developing a teacher's ideas about reform is to reconcile the teacher's personal prior beliefs about the subject matter as well as learning and teaching developed as the result of their experiences as students in schools with the recommendation made for teaching inquiry science" (p. 823). This assertion implies that a teacher's previous experiences have a direct impact on his/her ability to implement inquiry yet at the same time the world is changing and may require new experiences which are in line with the changing needs of the students. The challenge, therefore, is adjusting to the new environment of implementing inquiry.

Researchers (e.g., Atar, 2011; Avsec & Kocijancic, 2016; Brickhouse, 1990; Cavas, 2012; Dass et al., 2015; Duschl & Wright, 1989; Gallagher, 1991) have found that teachers' ideas about the nature of science as an objective body of knowledge created by a rigid scientific method, hindered their teaching of an accurate view of scientific inquiry. Teachers with a more accurate understanding of the nature of science can implement a more problem-based approach to science teaching (Atar, 2011; Avsec & Kocijancic, 2016; Brickhouse, 1990; Mumba, et al., 2015). What is learned from literature is that implementation of proper inquiry is a function of teachers' understanding of the nature of science. Although different from the views of Atar (2011), Avsec & Kocijancic (2016), Brickhouse (1990), Mumba, et al. (2015), Larrivee (2008) recommended developing reflective practitioners who can infuse personal conceptions and values into professional identity, resulting in the development of a deliberate code of conduct. These personal factors may determine whether teachers feel strong enough to work to overcome any barrier to teaching inquiry science they may face. In addition, while science teachers have divergent views about IBI, this is further coupled with many challenges.

One of the challenges to IBI is that there are not many publications/articles describing full inquiry. For example, Assay and Orgill (2010) analyzed the articles published in *The Science Teacher* from 1998 to 2007 for explicit evidence of feature of inquiry to provide a picture of how inquiry is practiced in the everyday science classroom. Inquiry in this study was operationally defined by the essential features detailed in *Inquiry and National Science Education* (NRC, 2000). They established that few articles described full inquiry. Gathering and analyzing evidence were significantly more prominent than the other features of inquiry, which were present in less than 25% of the articles. Each feature was also rated for whether it was a student or learner-directed. They found out that most activities were teacher-directed. They concluded that this pattern might be related to teachers viewing inquiry more as a *process* than as a *vehicle* for learning science content. However, it is important to note that Assay and Orgill's (2010) study was based on the articles of research conducted in US contexts. Hence, their findings may not be generalized to all teachers, especially those in developing countries like Uganda.

Divergent views about what IBI still prevail as a challenge and what is learned here is that the lack of a common understanding is itself a hindrance. For example, in a study conducted by Ireland, Watters, Brownlee and Lupton (2011), the researchers used a phenomenological research method to examine 20 elementary school teachers' conceptions of inquiry teaching. The researchers defined inquiry as involving students in learning their way by drawing on direct experience fostered by the teacher and active engagement in experiences. The data consisted of interviews. The researchers reported three kinds of conceptions: (a) the experience-centered conceptions in which teachers focused on providing interesting sensory experiences to students, (b) the problem-centered conception in which teachers focused on engaging students with challenging problems, and (c) the question-centered conception in which teachers focused on helping students ask and answer their questions.

Another tension highlighted in this review is differences of teachers' perceptions of the nature of science and the lack of a common perception. For example, in investigating the relationship between three teachers' perceptions of nature of science (NOS) and inquiry teaching practices, Atar (2011) collected views of Nature of Science form C, online postings, interviews, emails, lesson plans, and videos of inquiry lessons. Improving teachers' conceptions of NOS appeared to impact positively on the use of inquiry practices; teachers with more sophisticated NOS views conducted a less structured inquiry and more student-centered activities. However, teachers who did not possess adequate content knowledge were reluctant to change their teaching practices. The inability of teachers to change their teaching practices still takes us back to the view that a teacher's previous experiences have a direct impact on his/her ability to implement inquiry; yet at the same time the world is changing and the teacher may require new experiences that are in line with the changing needs of the students.

The nature of science as a multi-disciplinary subject is also poses a challenge. For example, Breslyn and McGinnis (2011) examined the question, how do exemplary secondary science teachers' disciplines (biology, chemistry, earth science or physics) influence their conceptions, enactment, and goals for inquiry-based teaching and learning? Participants included 60 national board-certified science teachers. Researchers employed mixed methods, using portfolio texts and interviews to assess enactment and views of inquiry. The discipline in which these teachers taught was found to be a major influence on conception and enactment of inquiry. The classroom context did not appear to be as large a factor as the structure of the discipline. In the context of this study and because of these differences, a uniform view of how to implement inquiry in science may not be attained. Breslyn and McGinnis (2011) study provide the justification for studying science teachers' understanding and practice of inquiry-based instruction of specific disciplines like chemistry, biology and physics instead of just studying the general science teachers. Hence, this study is done to address that need accordingly.

Another challenge highlighted here is the level of effectiveness of teacher education programs to enhance IBI. In support of this assertion, Windschitl and Thompson (2012) studied the effectiveness of teacher education programs designed to enhance prospective teachers' knowledge of inquiry, in particular, their understanding of models and modeling. Data sources included observations, student artifacts, informal interviews, and questionnaires. Participants included 21 prospective secondary science teachers with an undergraduate degree in science, all in a secondary methods course. While prospective teachers could talk about models in a sophisticated way, they had a difficult time creating models themselves. Further, these prospective teachers viewed models as being separate from the process of inquiry, hence taking us back to the view that science teachers have divergent views about what IBI is.

In support of the views of Windschitl and Thompson (2012), Kang, Branchini, and Kelly (2013) examined what one cohort of eight pre-service secondary science teachers said, did, and wrote as they conducted a two-part inquiry investigation and designed an inquiry lesson plan. They identified success and struggles in pre-service teachers' attempts to negotiate the cultural border between a veteran student and a novice teacher. They argued that pre-service teachers could benefit from opportunities to navigate the border between learning and teaching science; such opportunities could deepen their conception of inquiry beyond those exclusively fashioned as either student or teacher. So, the key observation highlighted here is lack of deep conception of inquiry beyond which from the previous assertions is tangled with science teachers' divergent views about what IBI is.

Seung, Park, and Jung (2014) did not deviate much from the views of Windschitl and Thompson (2012), Kang, Branchini, and Kelly (2013) and pointed out that pre-service teachers and mentors have difficulty in connecting appropriate inquiry features to each teaching episode, which indicate their lack of understanding of inquiry (Seung et al., 2014).

It is also likely that there is limited understanding of what IBI is among the pre-service teachers and mentors. Seung *et al.* (2014), noted that even though mentors are normally experienced teachers, they have sometimes showed a lack of understanding about each feature of inquiry (Seung et al., 2014). Also, many elementary teachers, including the mentors in their study, do not teach science regularly in their classrooms since science is not included in state student achievement test. Seung et al.'s (2014) study is one of the few studies that has examined inquiry-based teaching and learning focusing directly on the five essential features (Asay & Orgill, 2010; Kang, et al., 2008). This study is useful in the sense that it calls for more exploration of what IBI is to come up with a common understanding. However, this study was conducted in the US context that is very different from many sub-Saharan African countries. For example, many classrooms in sub-Saharan African countries are crowded (contain more than 100 learners per classroom) due to the Universal Secondary Education and limited schools and teachers, hence, the findings from this study may not be useful in a country like Uganda.

It is sometimes hard for prospective elementary science teachers to make appropriate conclusions about whether obtained results support the hypothesis or not during inquiry. For example, another study in the US by Kim and King (2012) investigated 178 prospective elementary teachers' understanding of hypothesis testing with a developed questionnaire. The aim of the study was to examine prospective science teachers' understanding of the purpose of scientific inquiry. They found out that prospective elementary science teachers could not make appropriate conclusions about whether obtained results support the hypothesis or not. Rather, these prospective elementary teachers tended to draw out the conclusions based on their personal knowledge. They also noticed that most prospective science teachers viewed the purpose of the experiment as testing the prediction rather than testing the hypothesis; few prioritized rejecting the hypothesis as an essential process of learning and the majority associated the benefit of doing experiments with just hands-on experience. Very few of these prospective teachers took testing students' ideas into consideration. The researchers concluded that most prospective science teachers who participated in this study viewed inquiry teaching as a mere opportunity for students to be engaged in hands-on experience. Kim and King emphasized the point that even in developed countries like the US, most prospective science teachers misunderstand inquiry.

Like the work of Kim and King (2012), Korea, Youn et al. (2013) explored 15 Korean prospective elementary teachers' views of IBI. During a science methods course, prospective teachers implemented a peer teaching lesson, had a group discussion to reflect on five teacher educators' comments on their first peer teaching practice, and revised and re-taught the lesson as a second peer teaching practice. Youn et al.'s study established that prospective teachers changed their views of inquiry teaching from following the process of inquiry or completely unstructured discovery approach to facilitating students' inquiry learning with instructional guidance. This study emphasized the role of group discussion and reflection in improving prospective science teachers' views about inquiry-based learning. However, we may not be confident that these teachers are likely to practice inquiry-based instruction in real classroom contexts since this study was done in peer micro-teaching contexts, which are very different from the real classroom. Nevertheless, Youn et al.'s (2013) study is useful in providing a different cultural context about prospective science teachers' views on IBI

Issues of IBI also become complicated when it comes to Interdisciplinary Science Inquiry (ISI). For example, in a recent study Chowdhary, Liu, Yerrick, Smith and Brook (2014) examined the effect of university research experiences, ongoing professional development, and in-school support on teachers' development of interdisciplinary science inquiry (ISI) pedagogical knowledge and practice. They found out that there was a variation of ISI understanding and practice among the teachers because of a combination of teachers' experiences, beliefs, and participation. Hence, to help teachers develop ISI knowledge and pedagogy, barriers to ISI knowledge development and implementation must also be addressed. Professional developers must articulate clear program goals to all stakeholders, including an explicit definition of ISI and the ability to recognize ISI attributes during research experiences as well as during classroom implementation. They recommended program developers to take into consideration teachers' needs, attitudes, and beliefs, toward their students when expecting changes in teachers' cognition and behaviors to teach inquiry-rich challenging science (Chowdhary et al., 2014). In my view, the recommendation above in Chowdhary et al.'s study is important because it justifies the need for qualitative studies to address the challenges science teachers face when teaching science through inquiry. Hence, it asserts my argument for the need for more qualitative studies about the factors affecting science teachers' understanding and practice of inquiry in developing countries like Uganda, to establish the teachers' needs, attitudes and beliefs about inquiry. This will improve the teaching and learning of science through inquiry in these countries.

Generally, it can be said that there is limited knowledge of teachers' understanding of what IBI is in the US and in other countries. For example, in Finland, Sormunen, Keinonen, and Holbrook (2014) investigated science teachers' views on the Three-State Model (TSM), which had been introduced in schools to encourage students' intrinsic motivation to offer a meaningful inquiry-based learning environment and to use the science learning in socio-scientific decision making in Finish schools. Like any other science model, the TSM stimulates ideas of scientific inquiry. They collected data using focus group interviews. Their study established that many teachers needed assistance to enable them to implement the TSM in their classrooms and school contexts. They concluded that a teacher's voice is a crucial factor for adopting any PD towards teachers' ownership of new development. Sormunen et al.'s study supports my argument of the need for research in African countries to obtain the voice of classroom science teachers if we are to improve science education in developing countries. We cannot base on the voices of teachers in US, or German, or UK, or Finland to improve science education in Uganda.

Science teachers' reflections on inquiry teaching before and during an in-service PD program have been found to differ. For example, a study in Finland by Kim et al. (2013) investigated science teachers' reflections on inquiry teaching before and during an in-service PD program by using a progress model of collaborative reflection. The audio-video data and their quantification allowed identification of the teachers' consistent prior beliefs and practices of inquiry teaching and their interwoven progress during the PD program. Their study established that the PD program played a greater role in improving science teachers' beliefs and practices of inquiry. They concluded that the PD program needs to facilitate both individual and collaborative reflections to enlarge teachers' prior beliefs of inquiry and to ensure their sustainable practices (Kim et al., 2013). Additionally, this study demonstrates the importance of having relevant PD programs to improve science teachers' ability to practice inquiry. Such studies need to be duplicated in the case of African countries to improve science teachers' beliefs and practice of inquiry.

In a recent study in Rwanda, Mugabo (2015) investigated the understanding of inquiry-based science teaching (IBST) of 200 high school teachers. He used a mixed-method approach, and data were collected using a science questionnaire administered to a purposeful sample of 200 science teachers, followed by illuminating semi-structured interviews with a sub-sample of 10 purposefully selected teachers. His study established that participants did not have a shared understanding of inquiry. Many of these science teachers associated inquiry teaching with a few of its specific characteristics while others had a very different understanding. Mugabo recommended that the working definition for inquiry should be provided in the Rwandan curriculum. We need more studies like these to improve science education in Africa. It should be noted that both the South Africa and Rwanda studies are based on the US standard documents (NRC, 1996, 2000, 2006, 2012, NGSS, Lead States, 2013), and most of the literature cited in these studies were mainly in the US This provides evidence that science education research in US has significantly influenced science education research/policies and curricula in Africa, however, it has not been able to change the classroom practice. Hence, more studies by African scholars are required to improve the classroom practice accordingly.

In another recent comparative study, Wang (2016) investigated the understanding of NOS and scientific inquiry (SI) of science teachers from Shanghai (China) and Chicago (USA) using a mixed-method approach. The purpose of the study was to compare the NOS and SI understanding of science teachers in Shanghai (China) and Chicago (USA). Ninety (90) high school science teachers from Shanghai (45) and Chicago (45) were chosen to do open-ended questionnaires and interviews. Wang analyzed the data using both quantitative and qualitative techniques, complementing the two enriched the study with both numerical and descriptive data. He established that, overall, the levels of American teachers' views of NOS and SI were better than Chinese. He concluded that Chinese teachers are affected by the thought of logical positivism philosophy, which regards the scientific cognitive process as a copying process, and science as a real reflection of the object (Wang, 2016). Using this philosophy, Chinese teachers tend to focus on "what is knowledge" and "what is the use of knowledge". Without considering the background of science learning experiences and teaching practices, teachers might have an imbalanced understanding of scientific knowledge (Wang, 2016). Meanwhile, science education in the US has emphasized teachers' understanding of NOS and SI for many years and achieves excellent results (Wang, 2016). Also, there are many reasons why Chinese science teachers' understanding of SI did not improve their understanding of NOS, such as the fact that they had little experience in doing inquiry, a culture of Confucian and so on, which originated from Chinese cultural traditions (Wang, 2016). Wang's study provides evidence of the influence of cultural and political dilemmas on teachers' understanding (conceptual dilemma) and practices (pedagogical dilemma). Wang's study was also sensitive to the influence of school context as he sampled schools from major cities in the two countries for better comparison. Hence, Wang's research points to the need for similar studies to discover the difference in political and cultural dilemmas between the developed and developing countries as it was realized in the case of China that the culture of Confucian influences science teachers' understanding of inquiry. In Africa, each country may have unique cultural influences that affect science teachers' conceptions of inquiry. These cannot be established by just conducting surveys, but by in-depth interviews and intensive classroom observation (qualitative methodology).

Summary. Research on teachers' understanding of IBI leads to the conclusion that different teachers may understand the approach differently. As a corollary, differences are notable in the different teachers' implementation of the approach and the outcomes of such application. Some of these differences are noted at the institutional, systemic or even regional levels. A key inference here is that information on the subject should be disaggregated by institution, and by national and regional context. It is prudent to continue to explore science teachers' understanding of IBI and expect that these play a part in teachers' intention and/or ability to successfully carry out IBI. However, as is clear from the literature, information on the case of the less developed countries is generally nonexistent. This has left an important gap in knowledge and practice, hence I explore it in this study focusing on the Ugandan context.

Science Teachers' Practice of Inquiry-based Instruction

Introduction. Various writers have indicated that there are many differences to science teachers' practice of IBI including differences in teachers' curricular interpretation (McNeill, 2009). In addition, while ICT is one of the tools used in Inquiry-based Learning (IBL), teachers' attitudes and beliefs in the use of ICT in IBL also differs (Sun & Xie, 2014). The reasons for this may be that science is a broad discipline with many sub-divisions such as biology, physics, agriculture and chemistry and every teacher in his respective discipline will certainly practice IBL differently.

My concern in this review was also on the issue of the relationship between teachers' qualifications and the practice of IBI. Capps and Crawford (2012) noted that teachers' qualifications were not a guarantee for practicing IBI. What is highlighted as a factor influencing practice of IBI was teachers' work experience and McNeill and Krajcik (2011) asserted that teachers with long teaching experience and students who actively engaged in the investigation greatly benefited from IBL. This was emphasized by other studies done in India (Madhuri et al., 2012) and Taiwan (Chang Wu, 2015) in which it was re-emphasized that teachers with more years of experience were more likely to embrace IBI than their counterparts with less years of teaching experience.

Science teachers' practice of inquiry-based instruction is also a function of their intentions and actual classroom practices regarding IBI. This is supported by the publication of the NSES (NRC, 1996), researchers Keys and Kennedy (1999) in which they examined the teaching practice of elementary teachers with an average of 11 years of experience. The intentions included: (a) planned instruction to explore questions that arose in context naturally from science activity, (b) intetion to help students take responsibility, (c) supporting children in constructing explanations and concepts from data, and (d) providing opportunities for students to apply scientific knowledge.

However, Keys and Kennedy (1999) noted many challenges for science teachers' practice of IBI including lack of time, the challenge of turning questions back to students, and teaching mandated concepts was difficult through inquiry. This study provides empirical evidence that even experienced science teachers face challenges in implementing IBI.

The literature reviewed also indicates that beliefs influence science teachers' practice of IBI. For example, Crawford (2000) documented and examined the beliefs and practice of an experienced rural public high school science teacher to determine how this teacher created an inquiry-based classroom environment. The researcher collected data for more than a year. The study focused on 20 students in an ecology class. Data included teacher interviews, notes of informal conversations, videotapes of classroom and field trips, interviews with eight randomly selected students, student products, and end-of-year anonymous student questionnaires. The key characteristics of how this teacher created an inquiry-based classroom that were also linked to their beliefs were: (a) situating instruction in authentic problems, (b) grappling with data, (c) students and teacher collaboration, (d) connecting students with the community, (e) the teacher modeling behaviors of scientists, and (f) fostering students in taking ownership of their learning. Crawford identified ten different roles that the teacher played in implementing IBI. In the context of this study, what is challenging is the measurement of beliefs. Nevertheless, Crawford's study provides evidence of how beliefs influence science teachers' practice of IBI.

Science teachers' practice of IBI is also a function of the characteristics of the classes in question. Crawford (2000) noted that with different characteristics of classrooms, some being elementary classrooms and others secondary classrooms, and the uniqueness of each teacher's background, particular school setting, and student populations, it is difficult to employ a uniform practice of IBI. The views of Crawford (2000) are important because different contexts may result in different outcomes.

More closely related to the views of Crawford (2000), is the quality of science student teachers' practice of IBI. For example, Maskiewicz and Winters (2012) in their longitudinal observations of one elementary teacher's fifth-grade classroom (children ages 11-12 years) found out that students can have a substantive and generative influence on the nature and form of inquiry carried out by the teacher in any given year, underscoring the importance of context. The change in students from one year to the next is a component of the context. What can be learned from the views of Maskiewicz and Winters (2012) is that application of science teachers' practice of IBI should be situational depending on the category of classes and students.

Science teachers' practice of IBI is also dependent on the available curriculum. For example, Fogleman, McNeill, and Krajcik (2011) examined 19 teachers' use of inquiry-oriented middle school science curriculum. Using hierarchical linear modeling, researchers aimed to determine the influence of teachers in curriculum adaptations on student learning. Data included curriculum surveys, videotape observations, and pre-and post-tests from 1,234 students. Researchers found that two variables significantly predicted students' learning: teacher experience and the amount of student initiation during instruction. Teachers who had taught the inquiry-oriented instruction curriculum previously had a greater student gain. Students who completed investigations had greater learning gains as compared with students whose teachers used demonstration or carried out the inquiry themselves. The research results imply: (a) it takes time for teachers to implement effectively innovative science curriculum, and (b) it is important that students engage actively in inquiry investigation.

The influence of curriculum on science teachers' practice of IBI is further highlighted by McNeill (2009) who studied the enactment by six middle-level teachers of an eight-week chemistry-based unit. The curriculum focused on students constructing arguments using an adapted version of Toulmin's model of argumentation. A total of 568 middle school students participated in the study. Data included videotaped classroom lessons, student pre- and post-tests, and teacher questionnaires. Findings revealed a significant teacher effect on students' learning about scientific explanations, evidence, reasoning, and content knowledge. The teacher who defined scientific explanation differently than in the curriculum had the lowest students' gains regarding scientific explanation. The study highlighted that different teachers carry out reform-based curricula in different ways, something curriculum designers need to consider. This study provides evidence that the teacher is a very important factor for the success of any curriculum innovation. In the case of Uganda, we have reviewed our curricula to resemble that in developed countries like US and UK, however, the science teachers have not been prepared to implement such curricula. Hence, this study explored how to improve the chemistry teachers' ability to implement IBI in their classroom.

In Spain, Pozueloso et al. (2014) investigated the implementation of an inquiry-based curriculum project entitled *Exploring Our World* within two Spanish primary schools. The aim of the study was to explore the conceptions, difficulties, obstacles and facilitative factors that influenced the teachers' attempt to introduce inquiry-oriented practices into their classrooms. Qualitative data were collected through interviews and classroom observation from the two science teachers of the two case study schools. The researchers established that participating teachers focused on three areas of need: a suitable working environment that enables and facilitates collaborative work, access to alternative materials, and greater social recognition and willingness of colleagues to cooperate, along with other types of support specific to each school community (Pozueloso et al., 2014). They concluded that the project had improved science teachers' ability to implement IBI through the PD activities. Pozueloso et al.'s study provides evidence of the importance of context-specific qualitative studies to improve the science teachers' ability to implement IBL by listening to the needs of teachers and addressing their concerns. More studies of this nature are required in African countries to address the problems science teachers face when trying to implement IBL in their classrooms.

Included in the review of this literature is another area of investigation related to the extent to which qualification and motivation influences science teachers’ practice of IBI. In a study by Capps and Crawford (2012) in the US, the researchers examined the teaching practice of inquiry of 26 qualified and highly motivated teachers. Although the teachers were qualified, few aspects of inquiry or nature of science were evident in the teachers’ lesson and this included motivation. In the context of this study, it can be said that proper application of science teachers’ practice of IBI is not only a function of qualification but also motivation is an incentive factor. Capps and Crawford indicated that, even in the US, it seems that many teachers do not practice inquiry-based teaching in their classroom which in the context of this study can be attributed to low levels of motivation. Hence, this study should inform the science education scholars in sub-Saharan African countries to conduct similar studies in their countries to inform their pre-service and in-service teacher training programs.

As pointed out earlier, science teachers’ practice of IBI is a function of teachers’ experience at work. For example, Ozel and Luft (2014) investigated the conceptions and use of inquiry during classroom instruction among beginning secondary science teachers. The 44 participants were beginning secondary teachers in their first year of teaching. To capture the participants’ conceptions of inquiry, the teachers were interviewed and observed during the school year. The interviews consisted of questions about inquiry instruction while observation documented the teachers’ use of inquiry. A quantitative analysis of data indicated that the teachers frequently talked about “scientific questions” and giving “priority to evidence”. The study found a constancy between the way new teachers talked about inquiry and the way they practiced it in their classroom. Overall, the study revealed that the beginning secondary science teachers tended to enact a teacher-centered form of inquiry, and could benefit from induction programs focused on inquiry.

In the same study by Ozel and Luft (2014), they found that experience in the classroom did not change the conception and enactment of inquiry among the beginning teachers. The researchers recommended that pre-service teachers need ample opportunities to build their knowledge and practice about the inquiry, and they need explicit instruction about the different features of inquiry. It is important that new teachers have access to well-designed science induction programs. These programs should focus on all features of inquiry. Clearly, more must be done to help new science teachers in their enactment and understanding of inquiry during their first year in the classroom. After all, this is the time in which teachers are exploring and establishing their ideas and methods about the inquiry. This study informs my study of the role of profession development in science teachers' conceptualization of inquiry.

The way teachers incorporate learning about scientific inquiry (SI) into laboratory work, also influences science teachers' practice of IBI. For example, a study in Germany by Stripel and Sommer (2015) explored how teachers incorporated learning about scientific inquiry (SI) into laboratory work in the chemistry classroom. Semi-structured interviews were conducted with 14 secondary school chemistry teachers (8 of whom had earned a Ph.D. in chemistry) from Germany. Their study established that teaching NOS was not a primary goal for teachers, and also some aspects of nature of scientific inquiry (NOSI) seemed to be more easily incorporated in the chemistry lesson, for example, critical testing and hypothesis and prediction. The teachers stated two main criteria to identify suitable chemical laboratory work for teaching NOSI: adaptable parameters and a low level of required content knowledge. Stripel and Sommer's

(2015) study is one of the few that are discipline specific and hence it may inform curriculum material development and give impetus to science teacher education and professional development of chemistry teachers in both developed and some developing countries with similar contexts like Germany. However, it is very rare to find secondary teachers in Africa who hold a Ph.D. like some of the participants in Stripel and Sommer (2015) study. Hence, the findings of this study may not be useful in such countries accordingly.

More closely related to the above is the assertion that science teachers' practice of IBI is based on the available learning platform. In support of this assertion, Sun and Xie (2014) in Singapore explored the Teacher Enactments (TEs) of science lessons supported by a web-based learning platform, namely collaborative science inquiry (CSI), by two experienced teachers in their respective teachings. The CSI system was built on a model-based inquiry framework investigated with computer-supported collaborative learning (CSCL) elements. The CSI lesson selected was on the topic of "Diffusion and Osmosis" in grade 7. Through examining the ways in which teachers instructed, questioned, and interacted with students, they identified the commonalities and differences in TEs that subsequently influenced students' conceptual understanding and their involvement in collaborative inquiry. They concluded that teacher attitudes and beliefs toward technology and their knowledge and skill predicted their technology use. There is little use of classroom enactment data to explore this issue more deeply (Sun & Xie, 2014). Sun and Xie's study is one of the few recent studies to explore the role of ICT in inquiry-based learning. I think more studies are needed in African countries, especially in a discipline like chemistry since Sun and Xie (2014) study focused on the biology topic. Hence, this study is important to provide the framework for similar studies in developing countries.

Nevertheless, most teachers use IBL to promote higher-order thinking skills among students. For example, in India, Madhuri *et al.* (2012) explored how IBL can be used to promote higher-order thinking skills among engineering students taking a chemistry module course in a university located in central India. The aim of the study was to find out how meaningful learning of chemistry can take place using IBI. The study established that engineering students developed critical thinking, problem-solving ability and integration of knowledge at the end of the chemistry module course taught through an inquiry-based approach. They conclude that inquiry-based pedagogy has better outcomes compared to a conventional recipe lab approach, and, it motivates engineering students by showing them the relevance of chemistry to engineering discipline. This study is important because it demonstrates the role of inquiry-based instruction in motivating learners to study a largely abstract subject like chemistry, and the relationship between science and engineering.

The need to enhance practical approach to learning can be said to be one of the reasons why teachers use IBL. In Taiwan, Chang and Wu (2015) investigated how experience in learning to teach SI using a practical approach affected teachers' attitudes, evaluation of the use of inquiry, and their actual design of IBI. The methodology used included an approach incorporating inquiry methodology combined with a technology-infused and engineering rich approach called "Intelligent Robotics" to help teachers learn and use a new approach to teaching scientific inquiry. The study established that teachers moved progressively from more teacher-centered thinking about teaching to student-centered thinking, and actions incorporating SI. The participating teachers also worked together in designing an interdisciplinary inquiry curriculum, providing an effective alternative to traditional rigid standard based curriculum and teacher directed instruction. Chang and Wu's study contributes to the engineering field by showing that teachers could move progressively from teacher-directed to student-centered actions incorporating inquiry. Also, it provides evidence of the role PD can play to improve science teachers' ability to practice inquiry, and assess students in inquiry lessons. Since Taiwan is between a developed and developing country, the findings of this study may apply to some developing countries with similar contexts (Ogunniyi & Rollnick, 2015).

It is evident that science teachers understand and practice inquiry in different countries (e.g., Englen, Eular & Maass, 2013; Tosa, 2015; Wang, 2016). Englen et al. (2013) conducted a comparative baseline study to establish teachers' beliefs and practice of inquiry across 12 European Countries. The purpose of their study was to explore the problems teachers anticipate when implementing IBL. They used a teacher questionnaire to collect data in 12 participating countries (Cyprus, Denmark, German, Hungary, Malta, Netherland, Norway, Romania, Slovakia, Spain, Switzerland and UK). Their study established that implementation of daily practices of IBL depends significantly on the country (respectively the region explored in the country), and therefore on the existing school system (Englen et al., 2013). However, their sample indicated that IBL does not seem to have a noticeable presence in the 12 European countries studied. They also noticed that teachers in Germany, UK and Netherland consider their teaching as teacher-oriented, whereas, teachers in Hungary, Romania, and Slovakia consider their teaching as more student-oriented. Also in some in some countries, notably in Germany, mathematics teaching is strongly teacher-centered, and the differences between mathematics and science teaching are much greater than in other countries. These researchers recommended more detailed micro studies to explain differences between countries. In my view, Englen et al. (2013) findings are very useful to compare how IBL is implemented in different countries. However, I think these researchers were limited by their sampling procedures for the schools used in the 12 countries.

The sample of the schools used may not have been representative of each country, and the researchers do not explicitly describe the contexts of the schools investigated (Englen et al. 2013). Nevertheless, more studies like these are required, especially in Africa, to inform science education policies in many developing countries with similar problems.

In another comparative study, Taso (2011) examined the similarities and differences in how the US and Japanese middle-school science teachers teach through science inquiry. Classroom practices were studied through observation in the US (N = 9) and Japan (N= 4). The observation data were coded and quantified based on a rubric that incorporated two dimensions: student self-directedness and depth of conceptual links. The results showed that little IBI was observed in either of the two countries for apparently different reasons; the observation data indicated scientific concepts under classroom discussion were not clearly identified in many of the US lessons, whereas the Japanese lessons often exhibited lack of teachers' support for students in constructing their understanding of scientific concepts (Taso, 2011). Teacher interviews were also conducted to examine US (N =9) and Japanese (N = 15) teachers' definition of IBI. The results indicated that most (79%) of teachers in the two countries thought that IBI involves both teachers and learners' exploration of scientific concepts.

The above finding by Taso (2011) implies that teachers' beliefs about the importance of student self-directedness in IBI might be acting as an obstacle for increasing IBI in both US and Japan. Although Taso's study had a small sample, it suggests critical elements that each of the countries might be missing for their implementation of IBI. Because both US and Japan are developed countries, Taso's study provides evidence that even science teachers in advanced countries still have problems with understanding and practicing inquiry-based teaching in this 21st century. Also, Taso's study provides evidence that science teachers' understanding and practice of inquiry teaching is influenced by context because the science teachers in these two countries had different reasons for not implementing IBI in their lesson. This supports my argument that research about inquiry in developed countries may not be directly utilized in African nations due to the very significant difference in school/classroom contexts between developed and developing countries.

Summary. It is important to investigate the actual practices of teachers in their classroom over multiple lessons using qualitative methodology in addition to assessing their beliefs and knowledge about the inquiry. Studies discussed illustrate the importance of researchers moving into the classroom to determine what is happening, with all the complexities of individual student abilities and predispositions, classroom physical structures, school context, and community. Different classrooms provide different contexts (e.g., urban and rural classrooms, developed and developing country classrooms). Considering that most of the studies discussed were conducted in developed countries, their findings may not apply in most developing countries accordingly. Hence, research should be done in developing countries about science teachers' understanding and practice of inquiry to address this knowledge gap in the literature.

Factors Influencing Science Teachers' Ability to Practice IBI

Introduction. In the context of this study, ability is the capacity or capability of science teachers to practice IBI. Research has shown that factors such as class size (Januszka & Dixon-Krauss, 2008; Jarman & Boyland, 2011; Johnson, 2011), classroom management (Doyle, 2009; Unal & Unal, 2012; Wong, Wong, Rogers, & Brooks, 2012), preservice preparation (Carrier, 2009; Tatar, 2012) and state assessments (Cocke, Buckley, & Scott, 2011; Judson, 2012; Rothstein, 2008), serve to reduce the amount of time that is spent on science in elementary grades, while professional development and a strong preservice program (Jones & Egley, 2007;

Miller, 2011; Pegg, Schmoock, & Gummer, 2010; Powell-Moman & Brown-Schild, 2011) can provide the encouragement and confidence that teachers need to implement inquiry-based science investigations. However, while the above findings were in reference to elementary schools, this study will focus on factors influencing science teachers' ability to practice IBI in secondary schools in Uganda, a gap that this study intends to fill. Nevertheless, some of the above factors may appear like those affecting science teachers' abilities to implement IBI in African countries, but with different magnitude. For example, the classroom management problems in the US may be very different from African countries due to the difference in a number of learners in classroom and culture of learners.

According to Crawford (2000), the classroom itself may be a barrier to implementing IBI. Accordingly, for teachers to adequately engage in IBI in science with their students, they may need to engage in new roles that require mentoring, guiding, or collaborating (Crawford, 2000). Roehrig and Luft (2004) found that beginning secondary teachers had five constraints that impacted their implementation of science IBI; these constraints were the teachers': (a) understanding of inquiry and nature of science, (b) strength of content knowledge, (c) pedagogical content knowledge, (d) beliefs about teaching in general, and (e) management and students' concerns. This last factor concerns the ability of students to engage in science IBI. Keys and Bryan (2001) also found this as a factor in teachers' implementation of IBI. Teachers may also have concerns about letting go of authority (Hayes, 2002) and dealing with students' requests for the "right" answers (Furtak, 2006). In the context of this study, focus was on the extent such factors are applicable to secondary schools in Uganda.

Other challenges and constraints were also discussed by Windschitl (2002) that teachers reported when attempting to implement constructivist reform pedagogies like IBI. Windschitl categorized them into four domains of “dilemmas”: *conceptual, pedagogical, cultural and political.* The *conceptual dilemma* is related to the teachers’ understanding of constructivism (i.e., the philosophical, psychological or epistemological basis) while the *pedagogical domain* is associated with approaches taken toward curriculum design and learning experiences that accommodate the demand of constructivism. The *cultural domain* includes new classroom roles and expectations of the teacher and students during classroom interactions, and the *political domain* describes relationship regarding the norms and routines of school and larger educational community.

Windschitl (2002) argued that acknowledging these challenges and constraints and addressing them within the design of professional development program may allow for more successful implementation among participating teachers. Hence, my study investigated these dilemmas in the Ugandan context, with the aim of improving the quality of in-service science teachers’ professional development courses accordingly.

Other problems prospective science teachers face when teaching science through inquiry were investigated by Kramer, Nessler, and Schluter (2015) who conducted an exploratory study in Germany. To draw the holistic picture of the problems, they identified problems from three different points of view leading to the research question: what problems regarding Inquiry-Based Science Education (IBSE) do prospective science teachers have from an objective, a subjective, and a self-reflective perspective? They used video analysis and observation tools as well as qualitative content analysis and open questionnaires to identify problems from each perspective.

They found out that the objectively stated problems were comprised of the lack of essential features of IBSE, especially concerning supporting learners' investigations and guiding analysis and conclusion. The subjectivity perceived problems were comprised of concerns about teachers' ability and learners' abilities, differentiated instruction and institutional frame conditions, while the self-reflectively noticed problems were mainly comprised of concerns about allowing inquiry, instructional aspects and learners' behavior (Kramer et al., 2015). They concluded that each of the three perspectives provide plenty of problems, partially overlapping, partially complementing one another, and partially revealing completely new problems. Kramer et al. recommended that science teacher educators consider these three perspectives in the training of prospective science teachers.

Another concern is science teachers' perceptions of intrinsic factors and extrinsic factors. For example, Ramnarain (2016) conducted a mixed methods study in South Africa to investigate science teachers' perceptions of intrinsic factors and extrinsic factors influencing implementation of inquiry-based science learning in township (underdeveloped urban area) high schools in South Africa. Quantitative data were collected using an adapted version of the Science Curriculum Implementation Questionnaire (SCIQ) (Lewthwaite, 2001). Ramnarain found a lack of professional science knowledge (content knowledge, pedagogical content knowledge, pedagogical knowledge, knowledge of students, curricula knowledge, and education purposes) as contributing towards teachers' uncertainty in IBI. Furthermore, extrinsic factors such as school ethos, professional support, resource adequacy, and time served as significant constraints in the application of IBI at the school. This study is useful in as far as the literature on the challenges in implementing of inquiry teaching and learning in secondary science, especially in African countries, is concerned.

However, Ramnarain (2016)'s study was limited in a sense in that he did not carry out classroom observation and it was not discipline specific. Classroom observation would have provided a clearer perspective on the teachers' experiences of implementing inquiry, casting more light on the factors influencing the way this implementation is done. Also, the data collection instrument adapted is somewhat outdated and, consequently, unable to provide cutting edge information on the subject. By collecting and analyzing data through interviewing chemistry teachers and observing their lessons, this study closed these gaps left by Ramnarain (2016) and thereby promote understanding of how IBI is understood and practiced in Kampala city schools whose teachers may be affected by these and other factors, which may not have been documented by past research on the subject.

Summary. Research indicates that a number of external and internal factors affect science teachers' ability to implement IBI. However, most of the previous studies have focused on general science prospective teachers in developed countries. Few studies have explored discipline specific in-service science teachers (e.g., biology, chemistry, and physics). There is no published study in literature that has explored the effect of an explicitly reflective professional development workshop on inquiry and NOS on chemistry teachers' understanding and practice of IBI in Uganda. Since no context is the same in any two countries (Englen et al., 2013; Pozueloso et al., 2014), studies done in developed countries like Spain (Pozueloso et al. 2014) and Germany (Striperl & Somer, 2015) may not apply fully to developing countries like Uganda. More so, due to the divergent beliefs of teachers about IBI in studies done in the US and Japan (Taso, 2011), there is a need to carry out studies in other countries.

Overall Summary of Literature Review

A major conclusion I deduced from the preceding review is that although the inquiry-based approach to the teaching and learning of science is beneficial and recommended, literature on the same is budding. Subsequently, conceptions of the same differ and relatively little is known about the ways in which IBI is understood and implemented by teachers. Moreover, the experiences of the less developed countries, like Uganda, are typically underreported in the scanty literature that has been published on the subject. Thus, information on the factors influencing implementation of the approach in these countries is nonexistent, to the detriment of efforts to improve the effectiveness with which science education is delivered. Therefore, there is a need to investigate science teachers' understanding and practice of IBI, with specific reference to the factors influencing both these variables. This study is proposed to respond to this need taking the case of chemistry education in Uganda.

Chapter 3: Research Methodology

Study Design

I employed a qualitative research approach and exploratory multi-case study design. According to Creswell (2014), a qualitative research approach is an approach to exploring and understanding the meaning that individuals in a group ascribe to a social or human pattern. Researchers who engage in qualitative research support a way of looking at research that honors an inductive style, focus on an individual meaning and importance of rendering the complexity of the situation (Creswell, 2014). Thus, since the purpose of the study was to examine the understanding of chemistry teachers in specific contexts, qualitative methodology was the best to use in providing a clear picture of an individual chemistry teacher's understanding of IBI.

According to Yin (2014), exploratory case study is used to explore those situation that the intervention being evaluated has no clear set of outcome. Therefore, the exploratory case study approach generated a deeper understanding of how the participating chemistry teachers in Kampala city public schools understood and practiced IBI before and after attending the explicit-reflective PD workshop on inquiry and NOS (Yin, 2014). New information about a lesser known topic learned from exploratory studies can add to the literature (Patton, 2015; Yin, 2014). Exploration studies can also provide information for other researchers to use in future studies (Yin, 2014). Hence, an exploratory approach was applicable because there are gaps in literature regarding high school science teachers understanding and practice of IBI and the effect of explicit-reflective PD workshop on inquiry and NOS on chemistry teachers' understanding and practice of IBI in developing countries such as Uganda.

According to Yin (2009, 2012, 2014), case studies are designs of inquiry in which the researcher develops an in-depth case, often of the program, event, and activity, process of one or more individuals. Time and activity normally bound cases and researchers to collecting detailed information using a variety of data collection procedures over a sustained period (Yin, 2009 2012, 2014). Since I carried out an in-depth study of eight teachers from two schools, the case design was appropriate for this research to get an in-depth understanding of how chemistry teachers in the Kampala City Public High Schools understand and practice IBI. The main two research questions in the study were "how" questions designed to understand the perspective of chemistry teachers' understanding and practice of IBI. Case studies are valuable for learning contemporary situation, allowing the research to capture meaningful data about a subject and then analyze it in greater depth (Yin, 2014). Case studies may not be generalizable; however, the results may be transferable to similar context (Patton, 2015: Yin, 2014). Hence, the finding from this case study may be useful in many developing countries like Uganda.

Participants

Kampala has a total of 21 public high schools that are made up of both mixed gender and non-mixed gender schools. The 21 high schools provided the sample pool for the two schools that were considered for the study. I utilized a purposive sampling procedure in which I identified two schools of similar standards from the sample pool. I recruited a total of eight willing chemistry teachers to participate in the study, of which four teachers were part of an active group (School A), while the other four were part of a control group (School B). I advised these teachers on the purpose and processes of the study and requested them to sign an informed consent form.

I emphasized confidentiality of information collected as the study was reliant on the teachers' willingness to participate freely, provide the required information, and attend an explicitly reflective training workshop on inquiry and NOS understanding. I also advised the participants during the briefing that in addition to the interview process and the professional development workshop, I will also be observing their teaching practice in class before and after the workshop so as to assess the impact of the PD workshop on their understanding and practice of IBI in the classrooms. I obtained permission to conduct research in Ugandan high schools from the Uganda National Council for Science and Technology (UNCST), and I sought the permission to observe the teachers in their work environment from the head teachers of the schools. Also, the study was approved by Syracuse University Institutional Review Board (IRB) before I proceeded to collect data in Uganda.

Data Collection

I collected data through semi-structured in-depth interviews, classroom observation and document analysis (schemes of work and lesson plans) from the eight chemistry in-service teachers in the two schools in two phases. I organized the explicit-reflective PD workshop on inquiry and NOS (intervention) for School A (Active group) after the first phase. Hence, data collection involved three main activities: Pre-PD interviews, classroom observation and document analysis (First phase), Explicit-reflective PD Workshop on inquiry and NOS (Intervention phase), and Post-PD interviews, classroom observation, and document analysis (Second phase). Below are the details of the of the three main activities of data collection.

Pre-PD interviews, classroom observation and document analysis (First phase). In the first phase, I conducted semi-structured interviews and observed at least two lessons each for all of the eight teachers to examine their understanding and practice of IBI before half of the group (four chemistry teachers in the active group from School A) participated in an explicitly reflective training workshop on inquiry and NOS understanding.

I based the interview protocol on the views of NOS form D+ (Lederman & Khishfe, 2004). I also administered the Myth of Science Questionnaire (Buaraphan, 2009) to participants to explore their understanding of NOS prior to (pre-test) and after (post-test) the inquiry and nature of science PD workshop. The understanding of inquiry interview questions were based on abilities to do scientific inquiry (NRC, 2000) and scientific practices (NRC, 2012) (see Appendix A).

I used a classroom observation guide adapted from Cavas, Holbrook, Kaska, and Rannikmae (2013) (see Appendix B) to observe at least two lessons for each teacher. I then conducted the PD workshop for the four teachers in the active school (School A), while those in the control group (School B) did not have any PD. I then continued to observe and interview both sets of teachers and investigated the effect of the PD workshop on their understanding and practice of IBI.

Explicit-reflective PD Workshop on inquiry and NOS (Intervention phase). I organized a six-day explicitly reflective training workshop for the four participants in the intervention group (School A). I decided to conduct the PD Workshop in School A because all the four School A participating teachers were free and available on Friday and Saturday, unlike the School B teachers, where Mr. Bbosa and Mr. Muhangi had enrolled for a Master of Science (Chemistry) Program, and hence were not available on Saturday because they were attending classes in Kyambogo University.

The training workshop was on inquiry and NOS understanding, guided by my understanding of their gaps in knowledge obtained from the first phase of interviews and classroom observation. The workshop took six days, and the chemistry teachers were involved in both minds-on and hands-on activities in these six days from 8:00 am to 5:30 pm (7 active hours) to enable them to appreciate the concept of inquiry and NOS. The workshop took place within the school for three weeks (Fridays and Saturdays). Friday was selected because these teachers did not have classes on Friday. Hence, it was possible for the chemistry teachers to be available for the professional development workshop within the school. The participating teachers were compensated for their transport and lunch on the Saturdays when they attended the professional development workshop. Meanwhile, the other set of four teachers (teachers in School B) did not undertake the training, but I still observed their lessons in the third phase to establish whether there were any changes in this control group caused by other factors other than the professional development workshop. This helped me to establish the effect of the professional development workshop on the chemistry teachers' understanding and practice of inquiry-based instruction in the active group.

I selected the PD workshop readings (content), activities and method of delivery based on a framing of constructivism and social cognition theories. Hence, I involved the participants in scientific inquiry and NOS activities. I also provided them with adequate readings to help them construct their understanding of IBI both through internal reflections and discussion by fellow participants. Additionally, participants' participation in micro-teaching helped them to develop the individual competency to implement IBI in their lesson by realizing the challenges and receiving the positive criticism from their colleagues. This was in line with social cognition theory where learning is achieved through language via social interactions. Luft and Hewson

(2014) argue that in the past PD workshops often used to emphasize professional learning where in-service teachers receive knowledge and skills from the skilled professional trainer. However, the current notion of professional learning is being advanced as complex and iterative interaction of the teacher, the school, and the learning activity. In this case, teachers are responsible for their learning, and are not recipients of skilled knowledge from a more knowledgeable skilled trainer. Hence, I made sure participants were able to construct their understanding of IBI and challenges of implementation through micro-teaching instead of just telling them the challenges second hand.

I decided to adopt the explicit-reflective approach because empirical evidence shows that an explicit-reflective framework is needed to achieve the goal of improving understanding of NOS among science teachers and students (Abd-El-Khalick, 2013). According to Abd-El-Khalick, (2013), the label "explicit" has curricular implication and entails the inclusion of aspects of NOS learning outcomes in any instructional sequence aimed at developing learners NOS understanding, whereas the label "reflective" has instructional implications in the form of structured opportunities designed to help learners examine their science learning experiences from within an epistemological framework. Specifically, such reflection would center on questions related to the development and validation, as well as characteristics of scientific knowledge (Abd-El-Khalick, 2013; Abd-El-Khalick & Akerson, 2009). Hence, during the PD workshop, I involved the participants in different NOS activities explicitly, and I gave them ample time to reflect about them about the chemistry content. This helped the participants to appreciate the interaction between inquiry as practice and NOS as the underlying epistemology dimension of inquiry (reciprocity of NOS and inquiry), content-situated NOS understanding, content -situated NOS and history of NOS understanding. These knowledge domains are necessary to help teachers to teach with and about NOS in IBI lessons.

I adapted the transformational model of PD that involves the combination of some processes and condition from action research, coaching/ mentoring, deficit and community of practice models (Kennedy, 2005). According to Loucks-Horsley et al. (2003), teachers "additive" learning is where teachers develop new skills or learn new things to integrate with what they currently know, whereas teachers' "transformative" learning is where teachers are engaged in strategies that produce changes in deeply held beliefs, knowledge, and habits of practice. Hence, the main purpose of the explicit-reflective PD workshop on inquiry and NOS was to produce changes in deeply held beliefs, knowledge, and habits of practice of the participating chemistry teachers in School A (active group). Luft and Hewson (2014) have argued that:

> Science teachers are an essential link between scientific oriented citizens of the present and the future. In order to prepare students for scientific and technological age of the 21^{st} century, teachers will need ongoing professional development opportunities. Education programs that are dynamic as the society in which teachers and students' lives will require new approaches and research on professional development. This research should suggest powerful and purposeful ways in which science teachers can enhance, refine or reconstruct their practice. (p. 889)

Luft and Hewson (2014) emphasized in this quote that research on PD need to provide ways how to help science teachers reconstruct their practice. Therefore, I involved the participating teachers in activities such as micro-teaching, planning IBI, preparing instructional pie, and so on, during the PD workshop (see Appendix C) to help them reconstruct their practice of IBI. Likewise, Wenning (2005) has argued that:

> Professional development probably will always be less effective than teacher preparation unless it identifies, confronts, and resolves the problems associated with expository teaching. Professional development activities must be of high saliency and prolonged if expected practices are to become the "coin of the realm." Activities should include placing teachers in the role of students as well as that of teacher so that they can see both

> sides of the coin. These practices must be backed up with sustained periodic mentoring by professional development providers. The improvement-of-practice problem for in-service teachers must, at the root, influence teaching philosophies. It is from philosophies that beliefs arise, and beliefs give rise to decisions. Decisions bring about actions, and actions have consequences. Hence, to influence outcomes, professional development providers need to give attention to teaching philosophies. (p. 14)

Wenning (2005) emphasizes the the importance of adequate time for PD activities and also placing teachers as students, as well as teachers in order to experience both situations. Hence, I decided to conduct the six-day PD workshop stretched over a period of three weeks to allow participating teachers enough time to reflect over the new concepts and practice obtained during the PD workshop. I also involved the participants in micro-teaching to place teachers in role of students as well as of the teachers so that they were able to see both sides of the coin as argued by Wenning (2005).

Overall Goal of the PD Workshop:

To improve the science (chemistry) teachers' understanding and ability to implement inquiry-based instruction in their chemistry lessons to help learners to learn science successfully.

General Objective of the PD Workshop:

By the end of six days, science teachers should be able to:

1. Utilize ICT/Internet resources competently to prepare and conduct inquiry-based instruction lessons.
2. Conduct inquiry-based lessons successfully.
3. Teach with and about NOS in their inquiry lesson.
4. Assess/evaluate students' understanding in inquiry lessons.

Method of Training/ Learning:

- Case studies

- Demonstrations
- Experimentation
- Micro-teaching
- Inquiry-based approach
- Discussions
- Reflective writing
- Co-operative learning.

The workshop discussed the eight science practices (NRC, 2012) and the eight tenets of NOS (NGSS, Lead States, 2013). The four chemistry teachers prepared inquiry-based lesson plans with my guidance based on the readings provided in the PD workshops, and carried out peer teaching exercises and then received feedback from fellow participants and me (see Appendix C for the detailed six-day PD program). The micro-teaching lessons were based on chemistry topics covered in the first and second school terms because I wanted the participating teachers to reflect on their previous lessons and then utilize the acquired knowledge to plan new IBI for the current term (third school term). In this way, I could observe the effect of the PD workshop on the science teachers' ability to implement IBI in their classroom. Participants were trained how to teach with and about NOS in the inquiry lessons and we discussed the myth of IBI commonly held by many science teachers (see Appendix C for detailed PD workshop objectives, readings, and activities).

Table 3. Outline of the Professional Development (PD) workshop on Inquiry and NOS

Week	Days	Topics	Learning Activities
1	1 & 2	• Concept of NOS (tenets of NOS) • Concept of Inquiry (three level of inquiry and eight science practices • Myth about inquiry-based instruction	➢ Discussion and reflection about the eight tenets of NOS with explicit examples from chemistry topics ➢ Discussing the relationship between NOS and Inquiry ➢ Discussing different levels of inquiry-based instruction ➢ Discussing how to teach with and about NOS in inquiry-based instruction lesson
2	3 & 4	Preparation of different types of inquiry-based instruction lesson plans (i.e. structured inquiry, guided inquiry and open inquiry lessons)	➢ Prepare sample inquiry lesson plans ➢ Discuss the challenges and opportunities of inquiry-based instruction. ➢ Discuss how to develop and access the eight science practices among learners during inquiry lessons
3	5 & 6	Micro-teaching of Inquiry Lessons	➢ Prepare inquiry lessons ➢ Micro-teaching of inquiry lessons ➢ Give peer feedback on micro-lessons. ➢ Revise and re-teach the improved micro inquiry lessons.

Strengths and limitations of the Explicit-reflective PD workshop on inquiry and NOS. Overall, the explicit-reflective PD workshop on inquiry and NOS was able to improve science teachers' understanding and practice of IBI because I conducted it after interviewing the participants and observing them while teaching. In this way, I was able to prepare the readings and activities related to the context/ challenges the participants were facing in their real classroom. Also, involved the participants in many activities that helped them to own their learning like, discussions of the literature on inquiry and NOS, writing reflective memo, micro-teach IBI lesson, and providing positive criticism to their colleagues' micro-lesson. All these helped teachers to be active learners/ participants in the PD workshop, hence constructing their understanding of IBI and NOS required to teach with and about NOS in IBI lesson. Another strength of PD workshop is that I conducted it for six days stretched over three weeks to allow teachers enough time to reflect on their activities and literature read during the workshop.

I had a lot of readings with advanced scholar academic language that the participants had to read and comprehend in short period. Most of these readings were published by science education researchers in western countries where English is their first language, and the participants are in the country where English is their second language. Hence, if I am to repeat the PD workshop, I would select few readings with simple language that high school teachers can read and comprehend. I would also read these articles and highlight the new technical words in the article so that I provide the glossary for teachers, to help them understand the readings. Also, the seven hours per day were too many for teachers because this involved academic work that needed enough time to reflect/ relax. Hence, if I am to conduct another PD workshop, I would have four hours per day (ten days) stretched over a period of five weeks. I believe this will give the teachers enough time to relax and reflect about the new concept obtained during the workshop accordingly. Thus, teacher may improve their ability to teach with and about NOS in their IBI lessons successfully.

Post-PD interviews, classroom observation, and document analysis (Second phase).

After attending the PD workshop, the participants individually prepared IBI lessons without my guidance and implemented them in their classroom. I then observed how they planned and implemented IBI, and I also interviewed them to establish the effect of the PD workshop on their understanding of IBI. Meanwhile, I also interviewed and observed School B participants (control group) to establish whether there was any other factor affecting their understanding and practice of IBI other than the PD workshop during the study period.

Researcher Positionality Statement

I am a Ugandan and completed my primary, secondary, undergraduate and post-graduate education (master's degree) in Uganda. I hold a Master of Science degree in science education (chemistry), a Post-graduate Diploma in education (chemistry and biology), a Bachelor of Science (Hons) (chemistry, botany, and zoology), and a diploma in science technology (chemistry and biochemistry techniques). I have more than twenty years of experience in the Ugandan education sector where I have worked as teacher educator/trainer, researcher, curriculum developer/evaluator (chemistry curriculum specialist), administrator, and high school classroom teacher (chemistry and biology). I am certified by the Republic of Uganda as a high school chemistry and biology teacher [senior, 1-6 (K8-12)]. I have completed three courses in qualitative research methodology during my doctoral program at Syracuse University (EDU 603: Introduction to Qualitative Research; EDU 810: Advanced Seminar in Qualitative Research Methods I; EDU 815: Advanced Seminar in Qualitative Research Methods II), and also three courses in science education where the NOS and inquiry were discussed and studied in depth (SCE 614: The Nature of Science in Science Education; SCE 737: Methods and Materials in Teaching Physical Science; SCE 789: Seminar in Science Education Research).

I have an interest in chemistry as a discipline because of my background and also because chemistry as a science subject has been a strong focal point in my education and career. It is my belief that if learners understand chemistry, they will be able to understand other science subjects such as biology and physics as well. I decided to explore science teachers' understanding and practice of inquiry because I believe the teacher is the most important facet of the education process. Therefore, any effort to improve the learning process may not be successful unless teachers can have solid knowledge, skills and positive attitudes and implement them in their classrooms.

My background as a chemistry classroom teacher and a teacher trainer had both positive and negative impacts on this study. For example, my classroom experience as a chemistry teacher helped me to observe and understand the processes and lessons during the classroom observations. It also helped me interact with the teachers as an insider and "one of them," which was advantageous in getting them to open with information relevant to this study. On the other hand, my experience in the classroom may also have biased my view of the teachers' practices and caused subjectivity instead of keeping an open, objective learning mind. I tried to minimize any negative impacts by engaging the teachers as sources of information and accorded them due diligence. I also strictly followed the observation protocol to examine how chemistry teachers implement inquiry by engaging learners in the eight science practices (NRC, 2012).

Qualitative Data Analysis

By qualitative data analysis, I mean a process of systematic searching and arranging the interview transcripts, field notes, and other materials to come up with findings (Bogdan & Biklen, 2007; Saldana, 2013, 2016). Taylor and Bogdan (1998) asserted that data analysis is an ongoing process that involves coding data, developing description and themes from data, connecting the related themes, understanding the data in context, and reporting findings. I converted the field notes generated through audio interviews and classroom observations into

Word documents for qualitative data analysis using open coding (Lichtman, 2013; Saldana, 2016). I utilized NVivo™, a powerful software program available for qualitative data analysis. This program was useful for storing and managing complex qualitative data. It was helpful to code my data in the most efficient manner. I coded the text data to identify themes using Saldana's (2016) criteria for coding data, which involves identifying code words from the text data, then grouping similar codes and looking for redundant codes with the intention of reducing the codes to a smaller more manageable number. Using this refined list (see Appendix D), I went back to the data to find if there are any emerging codes, and then reduce codes to common themes supported by evidence.

For instance, in the case of chemistry teachers' understanding of IBI, I developed the rubric based on the themes I discovered through coding my data and utilizing available literature on inquiry like inquiry grid (Llewellyn, 2013) and science practices (NRC, 2012). I grouped the science teachers' understanding of IBI into five themes: meaning of IBI, role of a teacher in an IBI lesson, role of students in an IBI lesson, role of assessment in IBI lessons, and science practices in IBI lessons (see Table 8). I then classified the science teachers' understanding of IBI based on each theme into three levels: insufficient, moderate and sufficient (see Table 8).

For the chemistry teachers' practice of IBI, my analysis of the lesson observation notes was integrated within the notes as observation comments (OC) and theoretical notes (TN). I finally evaluated the nature of IBI implemented using the classroom observation protocol in Appendix C (Cavas et al., 2013), the different settings of inquiry teaching in Table 1 (Cavas et al., 2013), and science practices in Table 2 (NRC, 2012). I finally classified the chemistry teachers' implementation of five IBI categories: no IBI (none), pre-IBI, structured IBI, guided IBI, and open IBI (see Chapter 5 Tables 15 and 16).

When analyzing the chemistry teachers' NOS epistemological views, I developed the following six themes/categories through my data analysis: meaning of science, tentativeness of scientific knowledge, the role of imagination and creativity in science, differences between scientific laws and theories, and the relationship between science, society, and cultural values. I also analyzed the chemistry teachers' responses to the myth of science questionnaire both qualitatively and quantitatively by looking at their scores before (beginning of study in the case of School B) and after (end of study in the case of School B) attending the PD workshop on inquiry and NOS.

I then coded the factors influencing the science teachers' understanding and practices of inquiry with guidance from the semi-structured interview questions (Saldana, 2013, 2016). My data analysis yielded nine factors that I divided into (two) internal factors and (seven) external factors (Chapter 7).

I also wrote reflective, analytical memos during the process of data analysis, reflecting particularly on how I relate personally to my participants in the study, emerging patterns, and emerging and existing themes (Saldana, 2013, 2016). These analytical memos helped me to write my findings after reading and summarizing them. For example, in one of the reflective, analytical memos, I noted one of the School A teacher's comment during the PD workshop, where they claimed that:

> We rejected SESEMAT training because they were not facilitating us for training and also the training did not address the challenges we face in the classroom. But for you, you are facilitating us on Saturday for our transport and you have listened to our challenges. Hence, we are interested in implementing the IBI despite the challenges in our schools (Mr. Agaba, PD workshop)

This memo helped me to realize how some of the internal factors (attitudes and motivation) affect teachers' understanding and practice of IBI in Kampala City Public High Schools.

All in all, I utilized structural, conceptual and theoretical coding to come up with the themes/ categories in my findings (Saldana, 2013, 2016). I have provided the details of how I moved from data to themes/categories and findings in Chapters Five, Six and Seven.

Chapter 4: Schools and Participant Profiles

Introduction

In this chapter, I describe the participating schools (Schools A and B) and participating science teachers' profiles since in a qualitative study the context is very important to help the readers appreciate the findings of the study (Creswell, 2014). I briefly describe the background and contexts of School A and School B, and the background of the eight chemistry teachers who participated in the study.

Profiles of School A and Participants

In this section, I present the brief profile of School A by describing the school context, the school administration, the curriculum and general performance of students in O-level UNEB exams. I also provide the profiles of the four participating in-service chemistry teachers by giving their educational background, qualifications, research interest, teaching subjects, chemistry topics they find easy/ difficult to teach, and years of teaching experience. I conclude the section with the table showing the summary of participating teachers' profiles.

School A profile. School A is a public high school in Kampala City that was started by the Government of the Republic of Uganda in 1984. It is admitting students from all the social economic classes and religious affiliations in Uganda. However, most students come from low-income families in the Kampala city suburbs. The school sits on eight acres of land with adequate classrooms (14 classrooms from senior one to six), laboratories and some few staff houses. The school laboratories (chemistry, biology and physic labs) were constructed in 2006 under the African Development Bank Second Education (ADB II) project by the Ministry of

Education and Sports to improve the teaching and learning of science in high school. However, some of the water taps in the lab were not functional and needed repair when I was there. Also, most of the lab stools had broken and hence were not enough for all students during the practical exercises. The motto of the school is “Determined to excel with trust in God”, the school’s vision is “To provide equitable learning opportunities in order to foster creativity, self-reliance, leadership and moral values to upright students who trust in God”, and the school’s mission is “To enhance practical skills for self-reliance”. In pursuance of the above mission, the school offers the teaching of languages (English, French and Luganda), mathematics, pure sciences (physics, chemistry, home economics and foods and nutrition), biological sciences (biology and agriculture), liberal arts (history, geography, religious education, Islamic studies and political education), vocational arts (fine art and music), commercial subjects (commerce, accounts, economics, and office practice), games and sports, and typing and computer classes. School A currently had a total of 787 students (387 boys and 400 girls) and 66 teachers (31 men and 35 women). All the 66 teachers are graduates, and three teachers hold master’s degrees (one woman and two men). The school is headed by the headmaster who is deputized by two deputies (a female deputy head teacher-in-charge of academic and a male deputy head teacher-in-charge of administration). The head teacher and his two deputies specialized in arts subjects, that is, none of them is a science teacher. Like other schools in Uganda, students in school A performs poorly in science subjects, especially chemistry (see Table 6 below showing the UCE 2014 results by subject). For example, in the UCE 2014 results, the total number of candidates who failed chemistry (F9) is the highest (106 students got F9= 59.2% fail) compared to other compulsory subjects like English (4 failed = 2.23% fail), mathematics (43 failed = 24% fail), physics (79 students failed =44.1 % fail) and biology (08 students failed = 4.49% fail). Hence, students in

School A perform poorly in chemistry (59.2% fail) and physics (44.1% fail) as indicated in the sample of UCE 2014 results below.

Table 4. School A Uganda Certificate of Education (UCE) 2 014 Results by Subjects (UNEB Report-2015)

Subjects/Grades	D1	D2	C3	C4	C5	C6	P7	P8	F9	Total	D1-C6	D1-C6-%	Pass-%	Fail-%
English	1	7	24	51	34	37	11	10	4	179	154	86	97.8	2.2
Literature	0	0	1	1	8	2	6	3	3	24	12	50	87.5	12.5
C.R. E	2	2	15	17	16	13	3	3	1	72	65	90.3	98.6	1.4
History	9	12	26	36	28	29	17	7	15	179	140	78.2	91.6	8.4
Geography	0	0	2	11	21	35	32	23	54	178	69	38.8	69.7	30.3
Mathematics	0	1	2	6	11	26	33	57	43	179	46	25.7	76	24
Agriculture	0	0	7	16	19	16	8	5	1	72	58	80.6	98.6	1.4
Physics	0	0	2	4	11	28	23	32	79	179	45	25.1	55.9	44.1
Chemistry	0	2	2	1	3	7	16	42	106	179	15	8.38	40.8	59.2
Biology	0	1	5	13	34	54	38	25	8	178	107	60.1	95.5	4.5
Fine Art	0	1	11	18	2	1	0	0	0	33	33	100	100	0
Foods and Nutrition	0	2	11	28	19	5	1	0	0	66	65	98.5	100	0
Commerce	1	4	12	7	10	10	4	4	4	56	44	78.6	92.9	7.1
Luganda	6	4	9	5	1	2	3	1	0	31	27	87.1	100	0
Accounts	2	4	4	6	2	1	1	2	0	22	19	86.4	100	0
Computer	0	1	3	3	10	7	8	7	16	55	24	43.6	70.9	29.1
Grand Total	21	41	136	223	229	273	204	221	334	1682	923	65.8	85.9	14.1

School A participant profiles. In this sub-section, I provide the profiles of the four participating in-service chemistry teachers in School A, by giving their educational background, qualifications, research interest, teaching subjects, chemistry topics they find easy/ difficult to teach, and years of teaching experience.

Mr. Byamukama. Mr. Byamukama graduated from Makerere University, Kampala in 2010 with a Bachelor's of Science with Education (BSc/ Edu.), majoring in chemistry and biology. Therefore, he has six years of teaching experience in chemistry and biology at both ordinary and advanced level in high schools. He finds teaching the mole concept and electrolysis difficult because they are abstract, whereas he enjoys teaching structure and bonding because he uses some animations to explain the concepts. He is currently teaching in three other private high schools to supplement his income. He is the current head of chemistry department in school A, and he heads the chemistry department in one of the private schools he teaches in as a part-timer. This situation indicates the serious shortage of science teachers in Kampala city schools. It may imply that many private schools cannot afford to employ a full-time chemistry teacher. This also affects the teachers' efficiency due to the limited time they have to plan their lessons because they have to move from one school to another to look for money to supplement their income.

Mr. Kigozi. Mr. Kigozi obtained a diploma in secondary education (chemistry and biology) from Nkozi Teachers' College in 2000. He later upgraded and graduated with a Bachelors of Education degree (chemistry and biology) from Kyambogo University in 2013. Hence, he has approximately 16 years of high school teaching experience. He has so far taught in seven different high schools in Uganda since 2000. Currently, he is teaching in four other private high schools in addition to school A public school to supplement his income. He finds teaching mixtures easy because students can easily relate the content with their daily life, whereas he finds teaching atomic structure difficult because it is abstract to many students. His research project during the B.ED. was on "Establishing the alcoholic content in the local brew ("waragi") in Uganda." He gained interest in this project because many people have been killed by the local brew in Uganda due to the toxic substances contained in the local brew. His research was supposed to continue and make recommendations to the Ministry of Health in Uganda to address the problem of the quality of the local brew.

Mr. Agaba. Mr. Agaba holds a Master's of Science degree in chemistry (Msc.) from Nairobi University, Kenya, a Bachelor's of Education (B.ED.) from Kyambogo University and a Diploma in Secondary Education (chemistry and biology) from Kyambogo Teachers College (currently, Kyambogo University). His Msc. (chemistry) research project was in medicinal chemistry. He has approximately 11 years of teaching experience in high school (chemistry and biology) at both the lower and upper secondary. He also teaches in two more private high schools where he is head of chemistry department in one of the schools. Also, he is a part-time lecturer of chemistry content and teaching methods courses at Kyambogo University.

Mr. Opolot. Mr. Opolot holds a diploma in secondary education (chemistry and biology) and a Bachelor's of Education (B.ED.) from Kyambogo University. His research project during the B.ED Program was on "Determining the poisonous substance present in cassava varieties in Eastern Uganda." He did this project to address the problem of people and animals dying due to cassava poisoning. He has approximately five years of teaching experience in high schools in Uganda. He finds properties of gasses easy to teach because he can easily demonstrate to students how the gasses react with different substances in the laboratory. He also finds atomic structure easy to teach because of the availability of teaching aids to teach the topic. However, he finds mole concept difficult to teach because it is an abstract topic and lacks teaching aids.

Table 5. Summary of School A Participating Teacher Profiles

Teacher's name (Pseudo- name)	Qualification	Teaching subjects	Teaching experience (years)
1. Mr. Byamukama	B.Sc./ Educ.	Chemistry and Biology	6
2. Mr. Kigozi	1. Dip. Edu 2. B.ED.	Chemistry and Biology	16
3. Mr. Agaba	1. Dip. Edu. 2. B.ED. 3. MSc. (Chemistry)	Chemistry and Biology	11
4. Mr. Opolot	1. Dip. Edu. 2. B.ED.	Chemistry and Biology	5

Profiles of School B and Participants

In this section, I present the brief profile of School B by describing the school context, the school administration, the curriculum and general performance of students in O-level UNEB exams. I also provide the profiles of the four participating in-service chemistry teachers by giving their educational background, research interest, teaching subjects, chemistry topics they find easy/ difficult to teach, their teaching subjects and years of teaching experience. I conclude the section with the table showing the summary of participating teachers' profiles.

School B profile. School B is one of the public high schools in Kampala City that was started by the government of the Republic of Uganda in 1970 as an ordinary level (lower secondary-senior one to four) day school. In 1984, the school upgraded to the advanced level (upper secondary) day mixed school. The school sits on 25 acres of land with a number of classrooms (16 classrooms from senior one to six), laboratories and staff houses. The motto of the school is "*Duc in Altum*," translated into English from its Latin version; it means "Take to the Deep." The direct implication of this motto is that everyone in the school is called upon to strive to the ultimate just as Christ did. The school's mission is "To promote the individual and corporate acquisition of scientific, technical and cultural knowledge, skills and attitudes, and inculcate ethical, moral and spiritual values that enhance patriotism, national unity, and integrated, self-sustaining economy." In pursuance of the above mission the school offers the teaching of languages (English, French and Luganda), mathematics, pure sciences (physics, chemistry home economics and foods and nutrition), biological sciences (biology and agriculture), liberal arts (history, geography, religious education, Islamic studies and political education), vocational arts (fine art, music and technical drawing [TD]), commercial subjects (commerce, accounts, economics, and office practice) , games and sports, and typing and computer classes. School B currently has a total of 824 students (450 boys and 374 girls) and 69 teachers (39 males and 30 females). All the 69 teachers are graduates, and four teachers hold master's degrees (one female and three males). The school is headed by the headmistress who is deputized by two deputies (a male deputy head teacher in charge of academic and a female deputy head teacher in charge of administration). The headmistress and her two deputies specialized in arts subjects, that is, none of them is a science teacher. Like other schools in Uganda, students in school B perform poorly in science subjects, especially chemistry (see Table 7 below showing the UCE results in 2012 by subject). For example, in the UCE results in Table 7 below, the total number of candidates who failed chemistry (F9) is the highest (65 students got F9) compared to other compulsory subjects like English (4 failed), Mathematics (14 failed), Physics (23 students failed) and Biology (28 students failed). Hence, students in School B perform poorly in chemistry, biology, and physics as indicated in the sample of UCE 2012 results below.

Table 6. School B Uganda Certificate of Education (UCE) Results 2012 by Subjects (UNEB Report-2013)

Subjects/Grades	D1	D2	C3	C4	C5	C6	P7	P8	F9	Total	D1-C6	D1-C6-%	Pass-%	Fail-%
English	1	7	36	71	77	44	20	8	4	268	236	88	98.5	1.5
History	9	23	49	54	52	37	23	14	7	268	224	83.6	97.4	2.6
Geography	5	36	65	65	46	26	9	12	4	268	243	90.7	98.5	1.5
Mathematics	6	12	20	30	39	41	54	52	14	268	178	66.4	94.8	5.2
Physics	2	11	15	37	59	50	35	36	23	268	174	64.9	91.4	8.6
Chemistry	6	6	15	13	24	37	42	60	65	268	101	37.7	75.7	24.3
Biology	4	15	9	26	44	64	44	34	28	268	172	64.2	89.6	10.4
Commerce	9	17	35	48	42	26	13	5	13	208	177	85	93.7	6.3
Agriculture	1	11	15	23	22	17	6	1	2	98	89	90.8	98	2
Technical Drawing	4	16	11	4	3	1				39	139	100	100	0
Fine Art	0	3	10	30	8					51	51	100	100	0
Literature	2	1	2	9	8	7	7	0	4	40	29	72.5	90	10
French	4	0	2	1	2	2	0	0	1	12	11	91.7	91.7	8.3
Home Economics	6	16	14	9	4	1	2	1		53	50	94.3	100	0
Computer	1	15	14	14	3	2	2			51	49	96	100	0
C.R. E	0	1	3	14	17	25	17	11	11	99	60	60.6	88.9	11.1
Entrepreneurship	5	8	13	14	15	16	14	4	2	91	71	78	97.8	2.2
Grand Total	65	198	328	462	465	396	288	238	178	2618	2054	78.5	98.2	6.8

School B participant profiles. In this sub-section, I provide the profiles of the four participating in-service chemistry teachers in school B, by giving their educational background, research interest, teaching subjects, chemistry topics they find easy/ difficult to teach, and years of teaching experience.

Mr. Bbosa. Mr. Bbosa obtained a diploma in secondary education (chemistry and biology) in 2002 from Nangogera National Teachers' College (NTC), and a Bachelor of Education (B.ED.) in 2007 from Kyambogo University (public University located in central Uganda). His research project during the B.ED program was" Analysis of medicinal properties of some plant extracts." He is currently pursuing a Master's of Science (Chemistry) degree at Kyambogo University, and he hopes to do his research in organic chemistry. He has 14 years of teaching experience and has been teaching in school B for the last eight years. He teaches in two other private high schools to supplement his income. He enjoys teaching mixtures, whereas he finds the mole concept difficult to teach because it is abstract to many students.

Mr. Ssentumbwe. Mr. Ssentumbwe obtained a diploma in secondary education (chemistry and biology) in 1996 and a Bachelor of Education degree (B.ED.) in 2005 from Kyambogo University. His research project during the B.ED program was about "Preservation of fruits." He has 20 years of high school teaching experience. He has been teaching in school B for only one year and is an old boy (meaning that he attended this school for his secondary education) of School B. He claimed that he does not find any topic in chemistry difficult to teach, except that students in senior one find some chemistry topics difficult to learn. However, on further probing, he admitted that he finds it hard to help students understand the structure and bonding because it is abstract. On the other hand, he enjoys teaching the mole concept unlike most of his colleagues who said that they find teaching the mole concept difficult because it is abstract to most students.

Mr. Muhangi. Mr. Muhangi obtained a Bachelor of Science with Education degree (BSc. /Edu.) in 2005 from Mbarara University of Science and Technology [MUST] (public university located in the western part of Uganda). He majored in chemistry and biology teaching subjects during his Bsc. /Edu. Program and his research project was on "Determining the number of heavy metals in *Amaranthus* plant species in different habitats." He found out that the *Amaranthus* plant species near the road and the refuse areas had a higher concentration of chromium, lead, and copper. He is currently pursuing a Master's of Science (Chemistry) degree at Kyambogo University and hopes to do a research project in environmental chemistry looking at "Effect of oil on water quality in areas where oil mining is taking place in Uganda." He has 11 years of high school teaching experience and is a regional trainer in an in-service science teachers' training program (SESEMAT). He is also currently the head of chemistry department in school B, the coordinator of a cyber school project (a project about ICT integration in teaching-learning science and mathematics in Ugandan high schools), and teaches in three other private schools to supplement his income. He claimed that he finds structure and bonding interesting to teach because it is "mysterious (you cannot visualize it)." He argued that he learned a simple way of demystifying the structure and bonding topic by using computer animations when explaining the concepts to students in the classroom. However, he finds it very difficult to teach the mole concept because most students find the topic too abstract to understand, and hence he tries to use a lot of minds on activities to help the learner understand it during the lesson.

Ms. Akello. Ms. Akello obtained a Bachelor of Science with Education (BSc. / Edu.) in July 2016 from Uganda Martyrs University Nkozi- Kisubi campus (private Catholic university- located in central Uganda) majoring in chemistry and biology teaching subjects. She, therefore, has only three months of teaching experience (0.25 years). She is an old girl of school B, having completed her secondary education at the school, and the only female chemistry teacher in the school. Her research during the BSc. / Edu. Program was on “Determine medicinal properties of some plant extracts.” She enjoys teaching organic chemistry and finds the mole concept difficult to teach because it is abstract to most students.

Table 7. Summary of School B Participating Teachers’ Profiles

Teacher’s name (Pseudo- name)	Qualification	Teaching subjects	Teaching experience (years)
1. Mr. Bbosa	1. Dip. Edu 2. B.ED.	Chemistry and Biology	14
2. Mr.Ssentumbwe	1. Dip. Edu 2. B.ED.	Chemistry and Biology	20
3. Mr. Muhangi	1.Bsc. / Educ.	Chemistry and Biology	11
4. Ms. Akello	1.Bsc. / Educ.	Chemistry and Biology	0.25 (3 months)

Chapter Summary

This chapter gives a brief background of the participating schools and chemistry teachers. Both schools had the basic laboratories to enable science teachers to implement inquiry-based instruction. The schools are among the average schools in Kampala city basing on the performance and the facilities in school A and B. All the chemistry teachers in school A and B were graduates, and one of the teachers (Mr. Agaba) had a Master’s of Science degree. I noted that all teachers except Mr. Ssentumbwe find the mole concept difficult to teach, and also most teachers were teaching in more than one private school to supplement their incomes. This may be affecting their effectiveness and efficiency due to limited time. I decided to conduct the PD Workshop in School A because the two teachers in school B (Mr. Bbosa and Mr. Muhangi) were pursuing a Master's of Science degree (chemistry) at Kyambogo University and hence were not available on Friday and Saturday. I also noted that most teachers except three (Mr. Byamukama, Mr. Muhangi, and Ms. Akello) started as grade V teachers (Dip. Edu.) and they later upgraded to graduate teachers after obtaining the B.ED. Additionally, all participating teachers were chemistry and biology majors; there was no chemistry and physics or chemistry and mathematics majors among the teachers.

Chapter 5: Chemistry Teachers' Understanding and Practice of Inquiry-based Instruction

Introduction

In this chapter, I provide the findings from the qualitative analysis of the interviews and classroom observations of how chemistry teachers in School A (group receiving PD; I will call them the active group) understood and implemented inquiry-based instruction before and after attending the explicit reflective PD on inquiry and NOS. I also provide the findings of how chemistry teachers in School B (control group) understood and implemented inquiry-based instruction at the beginning of the study and towards the end of the study. Hence, I am addressing (a) research question one: How do in-service chemistry teachers understand and implement inquiry-based instruction before attending an explicit reflective PD workshop on inquiry and NOS? and (b) research question two: How do in-service chemistry teachers understand and implement inquiry-based instruction after attending an explicit reflective PD workshop on inquiry and NOS? I conclude the chapter by discussing the effect of the explicit reflective PD workshop (on inquiry and NOS) on chemistry teachers' understanding and practice of inquiry based instruction in Kampala city high schools.

Chemistry Teachers' Understanding of Inquiry-Based Instruction (IBI)

In this section I provide the findings from data analysis of interviews of how the eight participating in-service chemistry teachers in School A (four teachers-active group) and School B (four teachers-control group) understood IBI at the beginning of the study (before attending PD workshop on inquiry and NOS) and at the end of the study (after attending PD workshop on inquiry and NOS in case of School A teachers). To analyze the interview scripts to answer part of research questions one and two, I developed the rubric based on the themes I discovered through coding my data, and utilizing available literature on inquiry, such as the inquiry grid

(Llewellyn, 2013) and science practices (NRC, 2012). I grouped science teachers' understanding of IBI into five themes: meaning of IBI, role of a teacher in IBI lesson, role of students in IBI lesson, role of assessment in IBI lessons, and science practices in IBI lessons (see Table 8). I then classified the science teachers' understanding of IBI based on each theme into three levels: insufficient, moderate and sufficient (see Table 8).

Table 8. Classification of Science Teachers' Understanding of IBI

Levels of Understanding	Insufficient	Moderate	Sufficient
1. Meaning of IBI	➢ Describes just one aspect of IBI ➢ Not aware of any type of IBI	➢ Fairly describes some aspects of IBI ➢ Aware of at least one type of IBI	➢ Describes clearly all the aspects of IBI ➢ Aware of the three main types of IBI
2. Role of a teacher in IBI lesson	➢ Thinks that the main role of teacher is to deliver content ➢ Thinks that the teacher is the center of instruction	➢ Thinks that the teacher's main roles are to explain, demonstrate and motivate learners	➢ Thinks that the teacher is coach, mentor and facilitator of the learning process in IBI lesson
3. Role of students in IBI lesson	➢ Think that students are passive learners, taking notes and observing what teacher is doing	➢ Thinks that students are fairly engaged to small extent ➢ Thinks that students are direction-followers in an experiment	➢ Thinks that students are problem-solvers and researchers ➢ Thinks that students are consistently and effectively engaged in hands-on and minds-on activities

Levels of Understanding	Insufficient	Moderate	Sufficient
4. Role of assessment in IBI lesson	➢ Assessment focuses on formal factual discrete knowledge (assessment of learning)	➢ Assessment should guide instruction ➢ Assessment *for* learning is important rather than assessment *of* learning.	➢ The role of assessment is to challenge evidence and claims by students to encourage curiosity in learners. ➢ Thinks that students have ability to generate questions to be answered
5. Science practices in IBI lessons	➢ Aware of less than three science practices learners develop in IBI lesson	➢ Aware of at least four (50%) science practices learners develop in IBI lesson	➢ Aware of the eight science practices learners develop in IBI lesson

Chemistry teachers' understanding of inquiry-based instruction before attending PD workshop on inquiry and NOS in School A. In this sub section, I provide the findings regarding how the four in-service chemistry teachers in School A (active group) understood IBI at the beginning of the study before attending the PD on inquiry and NOS. I analyze and classify the chemistry teachers' understanding under the five themes and three levels of understanding shown in Table 8. I conclude the sub-section by providing the overall summary in Table 9 to show how the chemistry teachers' levels of IBI understanding under different five themes of IBI.

Meaning of IBI. *IBI as utilizing learners' prior knowledge.* Some participating chemistry teachers in School A described IBI as a type of teaching where a teacher uses the learners' prior knowledge. For instance, Mr. Byamukama, when he was asked to describe IBI during the interviews, argued that,

> Inquiry-based teaching, in my understanding, is where you find that when you are teaching about something, you first get to know the prior knowledge the students have about it. Let's say it is atomic structure, you first try to know if the learners know anything about it or not. Then you first get to know what the learners know about the topic before you talk about it. (Mr. Byamukama)

Mr. Byamukama thinks that when the teacher utilizes the learners' prior knowledge, he is then teaching with IBI. Mr. Byamukama also he was not aware of the main three types of IBI. Hence, in this case Mr. Byamukama had insufficient understanding of the meaning of IBI basing on the classification in Table 8.

*IBI as question and answer teaching technique***.** Some participating teachers in School A described IBI as a question and answer teaching technique, where the teacher asks students questions and students answer the questions. For instance, when I asked Mr. Kigozi to describe IBI, he stated that "IBI is a question and answer process." This implies that Mr. Kigozi thinks that whenever he uses a question and answer technique in his lesson, then is teaching with IBI. In this case, Mr. Kigozi had insuffient understanding of the meaning of IBI.

In the same vein, when I asked Mr. Opolot to describe IBI, he stated that, "IBI is where you try to find out what other people know through question and answer." This implies that Mr. Opolot, like Mr. Kigozi, thinks that whenever a teacher uses question and answer technique, they are using IBI. This is definitely a narrow/incomplete view of IBI. Hence, Mr. Opolot in this case had insufficient understanding of the meaning of inquiry-based instruction.

IBI as hands-on activities. Some chemistry teachers in School A described IBI as hands-on-activities. Here is a short excerpt from the interview to illustrate this:

> Researcher: What about inquiry-based instruction or teaching?
>
> Mr. Agaba: Inquiry- based instruction or teaching? There is teaching and there is giving instruction. Is that something you mean?
>
> Researcher: Yes, the Americans use instruction instead of teaching.
>
> Mr. Agaba**:** Yes, because teachers are called instructors. I think instructors use more experimentations than when you go to teachers. Because when we go to a teacher it is generally anyone who can transfer knowledge in any form. An instructor is using instruction and majorly in a hands-on matter. So, this means that it's more experimental when you are an instructor than when you are a teacher, because a teacher may be anyone and teaching may be in any form whether it is experimental or otherwise.

Mr. Agaba believes for IBI to take place, the teachers should be an instructor where he/she give learners a practical experiment (hands-on activities). Mr. Agaba ignores the fact that learners who are involved in cookbook lab activities are not necessary learning through IBI. Hence, in this case, Mr. Agaba held one of the common myths about IBI, where most teachers think giving students hand-on activities (experiments) means IBI. Also, Mr. Agaba was not aware of any type of IBI. Therefore, in this case, Mr. Agaba had insufficient understanding of the meaning of IBI before attending the PD workshop on inquiry and NOS (at the beginning of the study).

Role of a teacher in IBI lesson. *The teacher as a center of learning*. Most participating chemistry teachers in School A believed that their role in IBI was to direct the learning process by asking students question and giving them the content. This implies that these teachers had a teacher-centered philosophy of teaching, which is contrary to the culture of inquiry, which is based on the constructivism theory of learning. This teacher-centered attitude about IBI may have been developed in these teachers over a long period throughout their elementary, high school and college education. Hence, there is an urgent need for serious PD workshops on IBI to reverse this type of teacher- centered philosophy among the science teachers in Uganda. For instance, here is another short excerpt from an interview with Mr. Byamukama:

> Researcher: Okay, you use it, so please describe in your own words what your role is as a teacher. What do you do first? If for example you are in that classroom and you are using inquiry, what is your role, what will you be doing?
> Mr. Byamukama: Of course, my role is to introduce what am going to talk about, then secondly ask the learners if they know anything about what I am going to talk about, then thirdly depending on the responses the learners have given I then give a comprehensive talk about that. I can say I talk about that given concept.

Mr. Byamukama believes that his role is to give student content in IBI lesson. That is why he puts much emphasis on “talking about content.” This implies that Mr. Byamukama believed that his major role in an IBI lesson is to give and explain the content to learners or to engage in “talking about content.” In this case, Mr. Byamukama had insufficient understanding of his role as the teacher in an IBI lesson before attending the PD workshop on inquiry and NOS.

In the same vein, here is an excerpt from Mr. Kigozi when he was asked to describe his role in an IBI lesson:

> Researcher: Okay, if you are in the classroom and you are teaching inquiry-based instruction, can you describe what you are doing as a teacher? Just mention the things you will be doing as a teacher.
>
> Mr. Kigozi: The teacher’s activities are asking, appreciate, and rephrase the questions, guiding learners with their answers.

Mr. Kigozi believed that his main role was to ask student questions and guiding them with answers. This implies that Mr. Kigozi believed in a teacher-centered type of instruction where the teacher's main role is to give student content to pass exams. Hence, in this case Mr. Kigozi had insufficient understanding of the role of the teacher in an IBI lesson before attending the PD workshop on inquiry and NOS.

Also, Mr. Opolot, like his colleagues, believed that his role in IBI is to design questions for students to answer and to design experiments for students in the practical. This implies that Mr. Opolot, like Mr. Byamukama and Mr. Kigozi, had a teacher-centered philosophy of teaching. Below is an excerpt of what Mr. Opolot said when asked to describe his role in an IBI lesson:

> Researcher: What is your role as a teacher in an inquiry lesson? Let's begin with that.
> Mr. Opolot: In my role as a teacher I would design questions that I would ask the students and as I ask them I would be trying to get what they already know in relationship to what I want them to know. Secondly their answers will guide me to know what knowledge they already have about what I want to teach before I can tell them the exact thing. I will also design some experimental things and give them the procedure on how to do it and as they are doing; they will discover some of the questions that I will inquire.

Mr. Opolot believed that he was supposed to design experiments for students and give them procedures to do the practical. This implies that Mr. Opolot believed in cookbook labs where learners are just following the procedure to confirm what the teacher has told them. In this case, Mr. Opolot believed that the teacher is the center of learning in IBI lesson. Hence, Mr. Opolot had insufficient understanding of the role of the teacher in an IBI lesson before attending the PD workshop on inquiry and NOS.

Generally, the above interview extracts show that Mr. Byamukama, Mr. Kigozi and Mr. Opolot had insufficient understanding of the role of the teacher in an IBI lesson because they believed in a teacher-centered type of instruction which contradicts the culture of inquiry and the constructivism theory of learning.

The teacher as motivator in IBI lesson. Mr. Agaba, unlike his colleagues in School A, believed that his role in an IBI lesson is to motivate students to work on a problem. Below is what Mr. Agaba said when I asked him to describe his role in IBI lesson:

> In this case, what I do is I design an experiment and I formulate the procedure then I give out the apparatus so that they can work. So, from that work they do, they also ask questions related to what they have done. As you ask them questions, I am building the concept, I have not yet told them the final answer but I first give them the activity and the apparatus to carry out the experiment and then it is from that experiment as they are ending then I formulate questions that will lead them to what I want them to know. This is other than going there to tell them the answer and then giving them the questions, that approach makes their knowledge absorption limited. But when they get it from the experiment they realize what they are supposed to learn and get it better. (Mr. Agaba).

Mr. Agaba believed that his role is to give students the practical activity and motivate them to work on their own to find out the answers rather than telling them the answers before they have worked on their own. Mr. Agaba argued that this approach helps students to retain the knowledge they have acquired more than when the teacher just tells them the correct answer before they have tried working on their own. Hence, Mr. Agaba, unlike his colleagues in School A, had a moderate understanding of the role of a teacher in an IBI lesson before attending the PD workshop on inquiry and NOS. This may be due the fact that Mr. Agaba holds a master of science (chemistry) degree and is also a part-time lecturer of chemistry content and method courses at Kyambogo University. Hence, may be had been exposed to more literature on inquiry than his colleagues in School A.

The role of students in IBI lesson. *Students as passive learners.* Most of the participating chemistry teachers in School A believed that students have a passive role in an IBI lesson. This attitude confirmed their teacher-centered philosophy about education they gave when describing their roles in IBI in the above interview. They argued that the students' role in an IBI lesson is to answer the questions given by the teacher and follow the instruction given by the teacher. For instance, Mr. Byamukama, when asked to describe the role of students in an IBI lesson, argued that:

> So, the role of the student is to first answer questions. Then two is to ask, because they must ask. So, they ask questions about what I am introducing and then three to summarize what I have been talking about and then I give them some work and some exercises to do about what we have talked about. (Mr. Byamukama)

Mr. Byamukama believed that the first role of students is to answer questions. Also, he thinks that students can only ask questions about what he has talked about. In other words, he does not consider students to be involved in discussion and generating evidence-based arguments in his IBI lesson. Hence in this case, Mr. Byamukama had insufficient understanding of the role of students in an IBI lesson before he attended the PD workshop on inquiry and NOS.

Likewise, when I asked Mr. Kigozi to describe the role of students in an IBI lesson, he confidently stated, "answering questions." This implies that Mr. Kigozi believed that the main role of students during an IBI lesson is to respond to questions posed by the teacher. Hence, Mr. Kigozi did not expect students to raise their own questions, conduct investigation, present their findings and participate in classroom discussions in an IBI lesson. Therefore, in this case Mr. Kigozi had insufficient understanding of the role of students in an IBI lesson before attending the PD workshop on inquiry and NOS.

In the same vein, Mr. Opolot believed that the main role of students in an IBI lesson was to just answer his questions and to perform the activities as instructed by the teacher. Below demonstrates what Mr. Opolot said when I asked him to describe the role of students in an IBI lesson:

> Researcher: What are your students' roles in that inquiry lesson?
>
> Mr. Opolot: They are supposed to give their thoughts and answer my questions. And secondly in case there is any activity, they must do it as instructed. Lastly they will should get the outcome from me.
>
> Researcher: But that one is not doing. You remember lesson planning, it says teacher's activity, learner's activity so I am interested in what you put in the learners' activity because I have heard you are saying they answer, then do the activity as it is, what else will they be doing?
>
> Mr. Opolot: They can also be asking me questions.

Mr. Opolot did not give any adequate science practices and learners will not be engaged in an IBI lesson. He was instead more interested in students following his instructions during the practical exercise. This implies that Mr. Opolot believed in cookbook lab activities where students just confirm the concepts they have been given by the teacher in their theory lesson. Therefore, in this case Mr. Opolot had insufficient understanding of the role of students in an IBI lesson before attending the PD workshop on inquiry and NOS.

Students as fairly active learners. Mr. Agaba, unlike his colleagues in School A, believed that students are active in an IBI lesson by engaging in hand-on activities presented by the teacher. He argued that students will also ask questions concerning the practical exercise provided by the teacher. He emphasized that, when students engage in experiments, they learn the science concepts better than when the teacher just tell them the scientific facts. Below is what Mr. Agaba said when asked to describe the role of the students in an IBI lesson:

> In this case, what I do is I design an experiment and I formulate the procedure then I give out the apparatus so that they can work. So, from that work they do, they also ask questions related to what they have done. As you ask them questions, I am building the concept, I have not yet told them the final answer, but I first give them the activity and the apparatus to carry out the experiment and then it is from that experiment as they are ending then I formulate questions that will lead them to what I want them to know. This

> is other than going there to tell them the answer and then giving them the questions, that approach makes their knowledge absorption limited. But when they get it from the experiment they realize what they are supposed to learn and get it better. (Mr. Agaba)

Mr. Agaba emphasized the portion where he said "I have not yet told them the final answer, but I first give them the activity and the apparatus to carry out the experiment and then it is from that experiment as they are ending then I formulate questions that will lead them to what I want them to know." This quotation shows that Mr. Agaba believed that students are fairly active in an IBI lesson unlike his colleagues in School A. Hence, Mr. Agaba had a moderate understanding of the role of students in an IBI lesson before attending the PD workshop on inquiry and NOS.

The role of assessment in IBI lesson.

Assessing pre-determined discrete knowledge. Most participating chemistry teachers in School A believed in formal assessment of pre-determined discrete knowledge in IBI lessons. For instance, here is an excerpt from the interview when I asked Mr. Byamukama to explain how he will assess his students in an IBI lesson:

> Researcher: Okay let's go to the assessment. How do we assess the inquiry which is different from the traditional teaching?
>
> Mr. Byamukama: In inquiry assessment, I give the learners the content and they can formulate some questions about what has been taught and then see if the learners are able to generate answers from what has been given to them.

Mr. Byamukama believed that the role of assessment is a traditional type of assessment that just aims to determine how much discrete pre-determined knowledge learners have memorized. Hence in this case, Mr. Byamukama had insufficient understanding of the role of assessment in an IBI lesson.

In the same vein, Mr. Kigozi argued that, "The assessment in IBI is immediate, but the one in traditional teaching is done after some time." In this case, Mr. Kigozi also had insufficient understanding of the role of assessment before attending the PD workshop on inquiry and NOS.

Likewise, Mr. Opolot believed that the role of assessment in an IBI lesson is to determine the level of learners' knowledge and ability to handle the apparatus. Hence, Mr. Opolot believed in formal assessment focusing on basic knowledge instead of assessment for learning. Below is an excerpt from the interview with Mr. Opolot when I asked him to describe how he will assess students in an IBI lesson:

> Researcher: How do you assess learners in that IBI lesson?
>
> Mr. Opolot: You gauge their rate of responding to questions that you are inquiring and then secondly the level of their ability to handle the experiment that you have designed.

Mr. Opolot believed in a traditional type of assessment that does not aim to improve the learning process. Hence in this case, Mr. Opolot had insufficient understanding of the role of assessment in an IBI lesson before attending the PD workshop on inquiry and NOS.

Assessing the learners' progress. Mr. Agaba, unlike his colleagues in School A, believed that the role of assessment in IBI is to help students understand the science concepts. In other words, he believed in assessment *for* learning rather than assessment *of* learning. Below is what Mr. Agaba said when I asked him to describe how he assesses his students in IBI lesson:

> In this case, what I do is I design an experiment and I formulate the procedure then I give out the apparatus so that they can work. So, from that work they do, they also ask questions related to what they have done. As I ask them questions, I am building the concept, I have not yet told them the final answer but I first give them the activity and the apparatus to carry out the experiment and then it is from that experiment as they are ending then I formulate questions that will lead them to what I want them to know. This is other than going there to tell them the answer and then giving them the questions, that approach makes their knowledge absorption limited. But when they get it from the experiment they realize what they are supposed to learn and get it better.

Mr. Agaba emphasized that "As I ask them questions, I am building the concept." This indicated that Mr. Agaba believed in assessment *for* learning more than assessment *of* learning, unlike his colleague in School A. Hence in this case, Mr. Agaba had a moderate understanding of the role of assessment in an IBI lesson before attending the PD workshop on inquiry and NOS.

Science practices in IBI lesson. None of the four participating chemistry teachers in School A could explicitly outline the eight science practices learners develop/engage in in an IBI lesson as outlined in US documents (NRC, 2012). They instead described basic skills like observation, recording results and interpretation. For instance, when I asked Mr. Byamukama to describe the science practices learners develop in an IBI lesson, he said:

> Researcher: What science practices do you engage/develop your students in during the chemistry lesson when using inquiry-based instruction?
>
> Mr. Byamukama: Practical skills, if it is a practical lesson we are aiming at learners getting practical skills.
>
> Researcher: But I am interested in scientific practices.
>
> Mr. Byamukama: For example, in preparation of gases, you can get skilled about to how prepare gases.

I categorized Mr. Byamukama as having insufficient understanding about the science practices his students develop during inquiry-based instruction.

When I asked Mr. Kigozi to outline the science practices students develop in his IBI lessons, he stated, "observation, recording results, interpretation and noting skill." This indicated that Mr. Kigozi had insufficient understanding of the science practices learners develop in IBI as outlined in US documents (NRC, 2012), before attending the PD workshop on inquiry and NOS.

For Mr. Agaba, he believed that the key skills students develop in IBI lessons are: manipulation of apparatus, manipulation of results and making conclusions. Below is an excerpt of an interview with Mr. Agaba and what he said when I asked him to describe the science practices learners develop in IBI lessons:

> Researcher: Okay what key scientific practices do you think these learners undergo in that inquiry classroom. Could you outline them for me?
>
> Mr. Agaba: The skills?
>
> Researcher: Yes, you could call them skills but I am calling them scientific practices that you think the learners are learning in the inquiry.
>
> Mr. Agaba: One is manipulation of the apparatus and with apparatus we are looking at different things. We have the lab apparatus which we use, but in the future, they will be handling other things. There is assembling them, then observation skills, they learn how to observe. They learn how to manipulate the results or use the results, then they know how to draw conclusions.
>
> Researcher: Don't worry, you can talk fast. I am writing in shorthand.
>
> Mr. Agaba: I think those are the major ones. There is manipulation, observations, recording, there is also data recording and interpretation which I have already mentioned. Then they should make conclusions.

It is evident from the above interview extract that even Mr. Agaba had insufficient understanding of science practices learners develop in an IBI lesson as outlined in US documents (NRC, 2012) before attending the PD workshop on inquiry and NOS. He only mentioned one key science practice manipulation of results and making conclusion (Analyzing and interpreting data). He was not aware of the other seven science practices, accordingly.

In the same vein, Mr. Opolot argued that the science practices learners develop in IBI lessons are mainly: handling the apparatus in an experiment, observing what is happening and reporting what they have observed, and time management. Below is an excerpt of what Mr. Opolot said during the interview when I asked him to describe the science practices students develop in IBI lesson:

> Researcher: Then what are the scientific practices you develop/engage learners in your inquiry-based instruction lessons?

Mr. Opolot: Handling of the apparatus in the experiment, observe what is happening and exactly tell me what they have observed, then time management.

Mr. Opolot was not aware of the eight science practices as outlined in US documents (NRC, 2012). Hence in this case, Mr. Opolot had insufficient understanding of the science practices learners develop in an IBI lesson.

Summary. In this section I provide the summary of participating chemistry teachers' understanding based on the five themes of IBI in Table 9. Generally, all the participating chemistry teachers in school had insufficient understanding of IBI in all the five themes except Mr. Agaba, who had a moderate understanding of the role of teacher, student and assessment in an IBI lesson. None of the four teachers were aware of any type of IBI. They understood IBI as question and answer technique, utilizing learners' prior knowledge and hands-on activities. Hence they held the common myth about IBI.

Table 9. Summary of School A Participating Chemistry Teachers' Understanding of IBI Before Attending PD Workshop on Inquiry and NOS

IBI theme	Mr. Byamukama	Mr. Kigozi	Mr. Agaba	Mr. Opolot
Meaning of IBI	"IBI is utilizing learners' prior knowledge" [Insufficient understanding]	"IBI is question and answer techniques" [Insufficient understanding]	"IBI is hands-on-activities" [Insufficient understanding]	"IBI is question and answer technique" [Insufficient understanding]
The role of a teacher in IBI	"Teacher is center of instruction" [Insufficient understanding]	"Teacher is center of instruction" [Insufficient understanding	"Teacher is motivator" [moderate understanding]	"Teacher is center of instruction" [Insufficient understanding
The role of students in IBI lesson.	"Students are passive learners" [Insufficient understanding]	"Students are passive learners" [Insufficient understanding	"Fairly active learners" [Moderate understanding]	"Students are passive learners" [Insufficient understanding
The role of assessment in IBI.	"To determine pre-determined discrete knowledge"	"To determine pre-determined discrete knowledge"	"assessment for learning" [Moderate understanding]	"To determine pre-determined discrete knowledge"

IBI theme	Mr. Byamukama	Mr. Kigozi	Mr. Agaba	Mr. Opolot
	[Insufficient understanding]	[Insufficient understanding]		[Insufficient understanding]
Science practices in IBI.	"not aware of the science practice" [Insufficient understanding	"not aware of the science practice" [Insufficient understanding	"not aware of the science practice" [Insufficient understanding]	"not aware of the science practice" [Insufficient understanding

Chemistry teachers' understanding of IBI at the beginning of the study in School B. In this sub-section, I provide the findings about how the four in-service chemistry teachers in School B (control group) understood IBI at the beginning of the study. I analyze and classify the chemistry teachers' understanding under the five themes and three levels of understanding listed in Table 8. I conclude the sub-section by providing the overall summary in Table 10 to show how the chemistry teachers' levels of IBI understanding are different under the five themes of IBI.

***Meaning of IBI*.**

IBI as question and answer technique. Most participating chemistry teachers in School B described IBI as question and answer technique. They were also not aware of any type of IBI. For instance, when I asked Mr. Bbosa to describe IBI, he stated that "It is a teaching involving question and answer." This implies that Mr. Bbosa had an insufficient understanding of IBI at the beginning of the study.

Also Mr. Muhangi believed that IBI is where the teacher facilitates in a question and answer approach. When I asked Mr. Muhangi to describe IBI, he argued that "here the teacher, the facilitator or instructor interact with the learners in form of question and answers." This implies that Mr. Muhangi believed that IBI is basically the same as question and answer technique. Hence in this case, Mr. Muhangi had insufficient understanding of meaning of IBI at the beginning of the study.

IBI as discovery learning. For Mr. Ssentumbwe, he described IBI as discovery learning. However, Mr.Ssentumbwe was not aware of any type of IBI. When I asked Mr. Ssentumbwe to describe IBI, he argued that “IBI is where you just send the problem and then someone discover it.” This implies that Mr. Ssentumbwe held one of the common myths about IBI where many teachers think that during IBI learners discover their own knowledge (Wilcox, Kruse & Clough, 2015). Hence in this case, Mr. Ssentumbwe had insufficient understanding of the meaning of IBI at the beginning of the study.

IBI as a process of giving knowledge. For Ms. Akello, she believed that IBI is a process of giving knowledge. When I asked Ms. Akello to describe IBI, she argued that “Inquiry-based teaching is a process of giving knowledge to your learners based on the knowledge the teacher obtains from other different scholars.” This implies that Ms. Akello believed that the learners just receive knowledge from the teacher in IBI. Ms. Akello also was not aware of any type of IBI. Hence in this case, Ms. Akello had insufficient understanding of the meaning of IBI at the beginning of the study.

The role of a teacher in an IBI lesson.

The teacher as the center of leaning. Mr. Bbosa and Mr. Ssentumbwe believed that the teacher is the center of learning in an IBI lesson. They argued that they believed in teacher-centered type of instruction. For instance, when I asked Mr. Bbosa about his role in an IBI lesson, he argued that:

> I can ask the students, questions, then I appraise those who have given answers, I correct wrong answers, I pick on even those who have not raised their hands, I motivate those who have answered and encourage others to participate. (Mr. Bbosa)

Mr. Bbosa believed that his main role was to ask students questions and evaluate their answers. This implies that Mr. Bbosa believed in a "teachers as the center of learning" process. Hence in this case, Mr. Bbosa had insufficient understanding of the role of the teacher in IBI at the beginning of the study.

Likewise, when I asked Mr. Ssentumbwe to describe his role in an IBI lesson, he said, "My role as a teacher? I am monitoring what am teaching, then evaluating it." This implies that that Mr. Ssentumbwe believed that his key role is to monitor and evaluate what he is teaching. Mr. Ssentumbwe did not consider himself a mentor, coach and facilitator of learning process in an IBI lesson. Hence in this case, Mr. Ssentumbwe had insufficient understanding of the role of the teacher in an IBI lesson at the beginning of the study.

The teacher as a facilitator of learning process. Mr. Muhangi and Ms. Akello believed that their role in IBI is to facilitate the learning process. For instance, when I asked Mr. Muhangi to describe his role in an IBI lesson, he stated that:

> It is to facilitate the learners, of course to set critical thinking questions which you will ask the learners, you can help learners to be able to make reasonable observations, you can also facilitate learners to make meaningful conclusions from their observations. (Mr. Muhangi)

Mr. Muhangi believed that his role in an IBI lesson is to help students make reasonable observations and conclusions from the experiment. Hence in this case, Mr. Muhangi had moderate understanding of the role of the teacher in IBI lesson at the beginning of the study. This may be because Mr. Muhangi is a SESEMAT national trainer.

Also, Ms. Akello believed that her role in an IBI lesson is to facilitate and motivate learners. For instance, here is an excerpt from an interview when I asked Ms. Akello to describe her role in an IBI lesson:

> Researcher: So now tell me the role of a teacher when you are teaching using inquiry. What is your role as a teacher?
>
> Ms. Akello: I act as a facilitator, I moderate, I supplement. In case what students have given me is not right or it is beyond what I am teaching at that very time I can tell them that we shall meet it in the next part.

Ms. Akello appreciated her role as a facilitator and moderator in an IBI lesson. In this case, Ms. Akello had a moderate understanding of the role of teacher in an IBI lesson at the beginning of the study. This may be because Ms. Akello was a fresh graduate (3 months of teaching experience) and hence still remembered the theory she studied in method courses at the college or had learned different instructional practices.

Role of students in IBI lesson.

Students as passive learners. Mr. Bbosa believed that students are passive learners in an IBI lesson. For instance, when I asked Mr. Bbosa to describe the role of students in an IBI lesson, he said that they "Answer the questions, write down the corrected information, they also ask some questions". This implies that, Mr. Bbosa took students as passive learners whose role was to answer the questions without participating in classroom discussion and presentations. In this case, Mr. Bbosa had insufficient understanding of the role of students in an IBI lesson at the beginning of the study.

Students as discoverer of knowledge. Some participating chemistry teachers in School B believed that the role of students in an IBI lesson is to discover new knowledge. For instance, when I asked Mr. Ssentumbwe to describe the role of students in an IBI lesson, he stated that, "Students' role is they are discovering, they are proving what I have given them, they are exercising their activities that is it". This implies that Mr. Ssentumbwe believed that students discover new knowledge in the IBI lesson. Unfortunately, this is one of the common myths about IBI held by many science teachers. Hence in this case, Mr. Ssentumbwe had insufficient understanding of the role of students in an IBI lesson at the beginning of the study.

Students as active learners / researchers. Some participating chemistry teachers in School B believed that the role of students in IBI is to actively participate in investigation by answering research questions. For instance, when I asked Mr. Muhangi to describe the role of students in an IBI lesson, he argued that:

> The students will answer the questions, they will make observations and record them, they can present their findings if they are in groups, then make also conclusions and deductions from their observations and then they can be able to analyze their data which they have obtained. (Mr. Muhangi)

Mr. Muhangi believed that the students' role in IBI is to actively participate in scientific investigation. Hence in this case, Mr. Muhangi had sufficient understanding of the role of students in an IBI lesson at the beginning of the study.

Additionally, Ms. Akello believed that students participate actively in IBI by asking questions, participate in classroom discussions and demonstration. Here is an interview excerpt from when I asked Ms. Akello to describe the role of students in an IBI:

> Researcher: Okay what about the students, what is their role? What are the students doing in your inquiry class?
>
> Ms. Akello: Most of them ask questions, others give you solutions, others even demonstrate. For instance, one time I was teaching transport in plants then I told them about a closed and open circulatory system. And some of them were demonstrating for closed and open by using this road of Banda and Bweyogerere something like that.

Ms. Akello believed that students are active learners in an IBI lesson. Hence in this case, Ms. Akello like Mr. Muhangi had sufficient understanding of the role of the students in an IBI lesson at the beginning of the study.

Role of assessment in IBI lesson.

Assessing pre-determined factual knowledge. Most participating chemistry teachers in School B believed that the purpose of assessment in IBI is to determine learners' basic knowledge. They believed in summative assessment that is given at the end of the lesson rather than continuous assessment. For instance, when I asked Mr. Bbosa how he assesses his students in IBI, he argued that, "At the end of the lesson, I give an exercise". This implies that Mr. Bbosa believed in summative assessment, which aims to determine students' factual knowledge. Hence in this case Mr. Bbosa had insufficient understanding of the role of assessment in IBI at the beginning of the study.

When I asked Mr. Ssentumbwe to describe how he assesses his learners in an IBI lesson, he stated, "through general exercises". This implies that Mr. Ssentumbwe believes in formal assessment that focuses on factual knowledge. Hence in this case, Mr. Ssentumbwe had insufficient understanding of the role of assessment in an IBI lesson.

In the same vein, when I asked Ms. Akello to describe how she assesses her students in an IBI lesson, she argued that, "I give them tests, exercises. Some can be out of five, others out of nine". This implies that Ms. Akello believed in assessment *of* learning rather than assessment *for* learning, which aims to improve the learning process. Hence in this case, Mr. Akello like Mr. Bbosa and Mr. Ssentumbwe, had insufficient understanding of the role of assessment in an IBI lesson at the beginning of the study.

Assessing learners' progress and learning process. Mr. Muhangi believed in continuous assessment of learners in an IBI lesson to monitor and improve the learners and the entire learning process. Here is an interview excerpt when I asked Mr. Muhangi to describe how he assesses his students in an IBI lesson:

> Researcher: How do you assess and evaluate learners' understanding of concepts when you are using inquiry?
>
> Mr. Muhangi: If the learners can answer the evaluation questions the teacher has set. If they can produce a good conclusion from what is being taught. If they are able to generate a hypothesis from an experiment or a demonstration they are carrying out.

Mr. Muhangi believed in continuous assessment of students' knowledge and skill in an IBI lesson. Hence in this case, Mr. Muhangi, unlike his colleagues in School B, had sufficient understanding of the role of assessment in an IBI lesson at the beginning of study. This may be due the fact that Mr. Muhangi is a national in-service science teachers' trainer under the SESEMAT program and is also a head of the chemistry department in School B. Hence, he might have attended more in-service PD workshops that his colleagues.

Science practices in an IBI lesson. None of the four participating chemistry teachers in School B were able to explicitly outline the eight science practices learners develop/engage in in an IBI lesson as outlined in US documents (NRC, 2012). However, they instead described basic skills like manipulation of apparatus, observation, recording results and interpretation. For example, when I asked Mr. Bbosa to describe the science practices learners develop in an IBI, he stated, "Manipulating apparatus, recording of data, drawing conclusions, following instructions". This implies that Mr. Bbosa had insufficient understating of the science practices learners develop in an IBI lesson at the beginning of study.

Here is an interview excerpt from when I asked Mr. Ssentumbwe to describe the science practices learners develop in an IBI lesson:

Researcher: What are the scientific practices or skills you engage learners when you use inquiry in your chemistry lesson?

> Mr. Ssentumbwe: Possibly observation.
>
> Researcher: Why do you say possibly?
>
> Mr. Ssentumbwe: When carrying out an experiment, one uses observation and conclusion, exploration, recording and interpretation
>
> Researcher: Is that all?
>
> Mr. Ssentumbwe: Yes.

Mr. Ssentubwe had insufficient understanding of science practices learners develop in an IBI lesson at the beginning of study. For example, he used the word “possibly” implying that he was not sure of what he was saying.

Here is an excerpt of an interview from when I asked Mr. Muhangi to describe the science practices learners develop in an IBI lesson:

> Researcher: What are the scientific practices or skills you usually engage learners when they do inquiry lessons?
>
> Mr. Muhangi: I think manipulative skills, you can talk of observation skills, and you can talk of recording skills, I am not sure if it is a skill.
>
> Researcher: Yes, it is because when they are marking practical and you have recorded correctly you are given a mark.
>
> Mr. Muhangi: Then analytical skills and you see if they can make conclusions from the data. Maybe some few topics where they need to draw tables and so on but that is also analyzing data. Majorly those ones.
>
> Researcher: Have you heard of skills like argumentation skills anywhere?
>
> Mr. Muhangi: No, we hardly argue in science. People take them to be true facts. In senior 5 today I gave them areas to research on and then I asked them to present. They reach a point where they are arguing but it is very rare.

Mr. Muhangi was not aware of the key science practice, that is, “generating evidence based arguments.” Hence in this case, Mr. Muhangi had insufficient understanding of the science practices learners develop in an IBI lesson at the beginning of the study.

In the same vein, when I asked Ms. Akello to describe the science practices learners develop in an IBI lesson, she argued that:

> Observation skills, the skill of answering for example when we are carrying out tests and you are giving an observation I think currently UNEB does not encourage the use of present tense. So if you say something like "the solution turns blue," they want you to report like, "the solution turned to blue" in other words use past tense. (Ms. Akello)

Ms. Akello focused on skills that help students to pass exams rather than the science practices as outlined in US document (NRC, 2012). Hence in this case, Ms. Akello, like her colleagues in School B, had insufficient understanding of science practices learners develop in IBI at the beginning of the study.

Summary. In this section, I provide the summary of participating chemistry teachers' understanding based on the five themes of IBI in Table 10. Generally, all the participating chemistry teachers in School B had insufficient understanding of IBI in all the five themes except Mr. Muhangi, who had sufficient understanding of the role of the students and assessment, and moderate understanding of the role of a teacher in an IBI lesson. Also, Ms. Akello had sufficient understanding of the role of students, and moderate understanding of the role of a teacher in an IBI lesson. None of the four teachers were aware of any type of IBI. They understood IBI as question and answer technique, discovery learning and process of giving knowledge. Hence, they held the common myth about IBI.

Table 10. Summary of School B Participating Chemistry Teachers' Understanding of IBI before attending PD Workshop on Inquiry and NOS

IBI theme	Mr. Bbosa	Mr. Ssentumbwe	Mr. Muhangi	Ms. Akello
Meaning of IBI	"IBI is utilizing question and answer technique" [Insufficient understanding]	"IBI is discovery learning" [Insufficient understanding]	"IBI is question and answer technique" [Insufficient understanding]	"IBI is a process of giving knowledge to learners" [Insufficient understanding]
The role of a teacher in IBI	"Teacher is center of instruction" [Insufficient understanding]	"Teacher monitor and evaluate learners" [Insufficient understanding	"Teacher is facilitator of learning process" [moderate understanding]	"Teacher is facilitator of learning process" [moderate understanding]
The role of students in IBI lesson.	"to answer questions" [Insufficient understanding]	"to discover new knowledge" [Insufficient understanding	"active learners/researchers" [sufficient understanding]	"active learners/researchers" [sufficient understanding
The role of assessment in IBI.	"To determine pre-determined discrete knowledge" [Insufficient understanding]	"To determine pre-determined discrete knowledge" [Insufficient understanding]	"Continuous assessment of knowledge and skills" [sufficient understanding]	"To determine pre-determined discrete knowledge" [Insufficient understanding]
Science practices in IBI.	"not aware of the science practice" [Insufficient understanding	"not aware of the science practice" [Insufficient understanding	"not aware of the science practice" [Insufficient understanding]	"not aware of the science practice" [Insufficient understanding

Chemistry Teachers' Implementation of Inquiry-based Instruction (IBI)

In this section, I provide the findings from my data analysis of lesson observation notes on how the eight participating in-service chemistry teachers in School A (four teachers-active group) and School B (four teachers-control group) implemented IBI at the beginning of the study (before attending PD workshop on inquiry and NOS) and at the end of the study (after attending

PD workshop on inquiry and NOS in case of School A teachers). My analysis of the lesson observation notes is integrated within the notes as observation comments (OC) and theoretical notes (TN). I finally evaluate the nature of IBI implemented using the classroom observation protocol in Appendix C (Cavas et al., 2013), different setting of inquiry teaching in Table 1 (Cavas et al., 2013) and science practices in Table 2 (NRC, 2012). I conclude the section by giving the effect of the PD workshop on inquiry and NOS on chemistry teachers' practice of IBI.

Chemistry teachers' implementation of inquiry-based instruction before attending PD workshop on inquiry and NOS in School A. In this sub-section, I provide the findings how the four in-service chemistry teachers in School A (active group) implemented IBI at the beginning of the study before attending the PD on inquiry and NOS. I analyzed and classified the chemistry teachers' implementation with respect to five categories of the level of IBI: no IBI (none), pre-IBI, structured IBI, guided IBI, and open IBI. I finally conclude the sub-section by providing the summary of the nature of IBI implemented by participating chemistry teachers in School A before attending the PD workshop on inquiry and NOS in Table 11.

Mr. Byamukama. Mr. Byamukama generally did not implement inquiry-based instruction in his lesson before attending the explicit reflective PD workshop on inquiry and NOS. He tried to demonstrate an experiment, but was not able to engage learners in the science practices as outlined in US documents (NRC, 2012).

Below is the excerpt from lesson observation notes of Mr. Byamukama on Thursday, October 20, 2016. S.1.B Class, Time: 2:00- 3:20pm, Topic: preparation and properties of oxygen, 56 Students (33 boys & 23 girls)

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

2:00pm

ON: Mr. Byamukama entered the laboratory when the students had already settled in. The class has a total of 56 students, but today 54 students were present (32 boys and 22 girls); hence 2 students were absent.

OC: Mr. Byamukama is the only teacher who had explicitly indicated in his scheme of work and lesson plan "inquiry" as one of the teaching methods he intended to use in the lesson. He is also the only graduate teacher from Makerere University in School A. The other teachers (Mr. Agaba, Mr. Kigozi, and Mr. Opolot) had graduated from Kyambogo University and they also had both Diploma in Education and Bachelors of Education degrees. This was because they had upgraded from being Grade V teachers to graduate teachers. Mr. Agaba had gone further to pursue a Master's Degree (MSc. Chemistry) from Nairobi University in Kenya. Hence, this may be the reason why Mr. Byamukama had a different lesson plan method compared to his colleagues in School A.

2:05pm

ON: Mr. Byamukama informed the students, "We are going to look at preparation and properties of oxygen." He then faced the chalkboard to write the topic of the day. According to the lesson plan of Mr. Byamukama, he had the following objectives: "By the end of lesson, learners should be able to:

1. Prepare oxygen in the laboratory.
2. State the chemical and physical properties of oxygen
3. Test for oxygen."

2:10pm

ON: Mr. Byamukama faced the chalkboard and started sketching the apparatus for preparation of oxygen from hydrogen peroxide and manganese (IV) oxide. He labeled the apparatus as students copied the sketch in their notebooks.

2:15pm

ON: Mr. Byamukama assembled the apparatus for the preparation of oxygen on the working table in front of the students. He then added the required chemical to demonstrate how oxygen is prepared in the laboratory. The students watched the demonstration attentively.

2:20pm

ON: Mr. Byamukama explained the procedure for the preparation of oxygen gas in the laboratory. He told students, "Oxygen is commonly prepared in the laboratory by the reaction between peroxide and manganese (IV) oxide. At room temperature, hydrogen peroxide decomposes (breaks down) very slowly.

Hydrogen peroxide $\longrightarrow$ water +oxygen

Under this circumstance, it would take a long time to collect even one gas jar of oxygen. So, manganese is added to speed up the decomposition reaction. Substances like manganese (IV) oxide that work to speed up chemical reactions are called catalysts." The students listened attentively as Mr. Byamukama explained how oxygen is prepared. After the verbal explanation, Mr. Byamukama faced the chalkboard and started writing down the explanation on the chalkboard. The students started copying the notes in their notebooks as Mr. Byamukama wrote on the chalkboard.

OC: Generally, Mr. Byamukama seemed interested in covering the content he had prepared. That is why he did not involve the students in any inquiry-based learning as he had indicated he would in his lesson plan.

2:50pm

ON: Mr. Byamukama asked the students to describe the color of oxygen they had just observed and explain how oxygen can be tested. One of the students said that oxygen is colorless and another student said, “We can test oxygen using a glowing splint. We light the splint and then blow it out. Then put the glowing splint in a jar of oxygen. If the jar has oxygen, the glowing splint will light again because oxygen supports burning.” Mr. Byamukama informed the class that the student’s explanation was correct. He told the students to write down their colleague’s explanation in their notebooks.

OC: It seems that this student had read ahead of the teacher about how to test for oxygen because the student was very confident and articulate. However, most the students had not captured his explanation very well and so did not write down anything as instructed by their teacher.

3:00pm

ON: Mr. Byamukama informed the students, “Many metals react with oxygen, but they do not all react at the same speed. By reacting different metals directly with oxygen and carefully observing the speed and vigor of the reaction, we can establish a reaction series for metals.” Mr. Byamukama then demonstrated how different metals react with oxygen by burning sodium, magnesium and iron in air. He asked students to observe carefully and record the appearance of the product and effect of solution in universe indicator. He drew the following table on the chalkboard to guide the students in recording their observations.

Metal burning in oxygen	Appearance and name of product	Effect of solution on universal indicator
Sodium		
Magnesium		
Iron		

ON: After the experiments, Mr. Byamukama told students, "All metals react with oxygen to give the respective metal oxides. When a metal combines with oxygen this is called oxidation. The metal has been oxidized. For example, magnesium is oxidized to form magnesium oxide. Metal oxides if soluble in water, give alkaline solutions. Most metallic oxides are called bases and soluble bases such as sodium oxide are called alkalis. We will study the properties of metal oxides in subsequent lessons." He then faced the chalkboard and wrote the explanation and the equation of reaction between oxygen and magnesium.

Magnesium + Oxygen $\longrightarrow$ Magnesium oxide

The students started to write down the notes as Mr. Byamukama proceeded to write on the chalkboard.

OC: Here Mr. Byamukama had the opportunity to give students some guided inquiry activities by letting them burn the metals themselves and test the solutions of products with universal indicator. Unfortunately, he did not give the students a chance to do this. He went on to demonstrate and explain what happens indicating that he was interested in finishing the content.

TN: Mr. Byamukama did not practice inquiry-based instruction in his lesson at all. He just used the lecture method to cover the content. Although he tried to demonstrate the experiments, he did not use students' prior knowledge and social scientific issues in his lesson.

Mr. Kigozi. Mr. Kigozi generally did not implement any type of inquiry based instruction in his lesson before attending the explicit reflective workshop on inquiry and NOS. He taught using a traditional lecture method where learners were just given content for passing exams. Below is the excerpt from lesson observation notes of Mr. Kigozi on Tuesday, October 18, 2016.

S.1.A Class, Time: 9:20- 10:40 am, Topic: Separation of solid/solid mixtures, Students (15 boys & 26 girls).

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

9:20am

ON: At exactly 9:20am Mr. Kigozi entered the classroom and greeted the students. The students responded to the greeting. Mr. Kigozi informed students, "Today, we are going to discuss how to separate solid/ solid mixture." He then wrote the topic on the chalkboard. He told students, "If the solid mixture contains iron, the iron can be removed using a magnet. This technique is used to separate scrap from other metals." He then faced the chalkboard and wrote, "How to separate iron."

OC: Mr. Kigozi did not utilize the learners' prior knowledge to predict how much they knew about separating of mixtures before informing them of the facts that he wrote on the chalkboard. Hence Mr. Kigozi was essentially conducting the lecture approach to teach about mixtures. Moreover, he had indicated in his lesson plan that he would use guided discussion method to teach the topic. The chemistry teaching syllabus suggests the following teaching and learning strategy: “Carry out experiments in groups to separate mixtures.” Mr. Kigozi did not, therefore, follow the suggested teaching strategy in the teaching syllabus to teach this topic.

ON: Mr. Kigozi continued to give other examples of solid/solid mixtures like sand and sugar. He explained to students, “We can separate sand from sugar by dissolving the mixture in water. Here sugar would dissolve, but sand would not. One would then separate sand from the sugar by filtration, then later evaporate to dryness the sugar solution to get pure sugar crystals.”

OC: Mr. Kigozi did not utilize the learners’ experience to find out how much they knew about filtration and evaporation. This could have resulted into brainstorming for the best method to separate sugar from sand. He could have given the students the activity to think of the best procedure to utilize in separating sugar from sand. He seemed to be solely interested in covering the content in the syllabus. Hence, he did not use inquiry-based instruction at all, as he had described in the interview. He did not even allow the students to ask questions during the lesson. He seemed interested in finishing the specified content he had prepared.

10:10am

ON: Mr. Kigozi wrote the notes on the chalkboard after his explanation. The learners started writing notes in their books without having any opportunity to ask questions. When Mr. Kigozi finished writing on the chalkboard, he then asked students if they had any questions. No student raised a question.

OC: There was no demonstration or any ICT integration in the lesson. It was purely a teacher-centered lecture approach of teaching.

10:35am

ON: Mr. Kigozi concluded the lesson by giving students an exercise about how to describe the different methods of separating mixtures in their daily life.

TN: Generally, Mr. Kigozi did not attempt to use inquiry-based instruction in teaching this topic. Per the MoES chemistry teaching syllabus (2008), students are expected to:

> 1. Brainstorm and conduct a guided discovery discussion on the different types of mixtures.
> 2. Carry out experiments in groups to separate mixtures.
> 3. Carry out experiments to demonstrate the criteria of purity.
>
> (p. 5)

The general objective of this topic is: ‘The learner should be able to list the different types of mixtures and separate them.’ (p. 5)

However, from the lesson observation, Mr. Kigozi did not address the objectives of the syllabus and did not apply the suggested teaching and learning techniques as well. He instead utilized the lecture method to teach this topic.

Mr. Agaba. Mr. Agaba, like his colleagues in School A, did not implement any inquiry-based instruction in his lesson before attending the explicit reflective PD workshop on inquiry and NOS. He instead just gave learners the content using the traditional question and answer technique.

Below is the excerpt from lesson observation notes of Mr. Agaba on Wednesday, October 19, 2016. S.3.A Class, Time: 2:00- 3:20pm, Topic: Nitrogen and its compounds, 47 Students (20 boys and 27 girls)

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

2:00pm

ON: Mr. Agaba entered the classroom and greeted the students at exactly 2:00pm. He told students, “Today, we are going to discuss nitrogen and its compounds.” He then faced the chalkboard and wrote the topic on the chalkboard. In his lesson plan, he had the following objectives: “By the end of the lesson, learners should be able to:

1. Describe the preparation of nitrogen from the atmosphere and sodium nitrate.
2. State the properties and test for nitrogen.”

OC: According to the lesson plan objectives, the lesson focused on basic knowledge/facts. There did not appear to be a higher-level objective.

2:10pm

ON: Mr. Agaba wrote the sub-topic on the chalkboard: “Preparation and properties of nitrogen.” He then started to draw the apparatus used to prepare nitrogen from the air in the laboratory. The students started to copy the apparatus in their notebooks quietly. Mr. Agaba explained the role of different substances like copper turnings, concentrated potassium hydroxide, lime water and magnesium ribbon. The students continued to write down the notes as the teacher explained the content.

OC: The teacher was giving content to students without involving them in the lesson.

TN: According to the MoES chemistry teaching syllabus (2008), the teachers are supposed to utilize the following teaching and learning strategies when teaching this topic.

- Conduct an experiment to prepare nitrogen in the laboratory.
- Carry out an experiment to demonstrate the properties of nitrogen.
- Assign learners group work on making presentation on the industrial preparation of nitrogen.
- Brain storm on the uses of nitrogen (p. 38)

The teacher did not utilize any of the above strategies when teaching this topic. He instead seemed interested in covering the content according to his lesson plan.

2:50pm

ON: Mr. Agaba asked the students to state the test for nitrogen and its properties. There was no response from the students. He then turned to the chalkboard and outlined the properties of nitrogen as:

Nitrogen gas

- ➢ It is a colorless gas with no smell
- ➢ Is neutral
- ➢ Has no effect on lime water
- ➢ Does not burn
- ➢ Does not support combustion

He told students that the above properties indicate that there is no simple chemical test for nitrogen. The students wrote down the above properties in their notebooks.

3:10pm

ON: Mr. Agaba concluded the lesson by giving the students an assignment to read ahead about "reaction of nitrogen and oxygen with metals." He also told them that he would teach about ammonia the following week.

OC: This lesson was basically a teacher-centered lesson, where Mr. Agaba seemed most concerned about covering the content he had prepared. He did not engage the students in any inquiry-based instruction activities. There was also no relating the chemistry content with the social scientific issues.

TN: Mr. Agaba did not appear to have any idea of how to teach with and about NOS in his chemistry lesson because he simply presented content throughout the lesson. In addition, I did not observe any effort by Mr. Agaba to engage learners in any of the eight science practices outlined in US document (NRC, 2012). Hence, I conclude that there was no inquiry-based instruction in this lesson.

Mr. Opolot. Mr. Opolot, unlike his colleagues in School A, tried to implement structured inquiry in his lesson, although he lacked the competencies to engage learners in the science practices as outlined in US document (NRC, 2012). This may have been caused by his inadequate understanding of the eight science practices that learners should develop in an inquiry-based instruction lesson.

Below is the excerpt from lesson observation notes of Mr. Opolot on Thursday, October 20, 2016, S.2.A Class, Time :7:40 – 9:20 am, Topic: Acids, bases and indicators, 60 Students (35 girls, 25 boys)

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

7:40 am

ON: Mr. Opolot entered the chemistry lab at exactly 7:40am and the lab contained about 30 students (half of the class). Some students continued to enter the chemistry lab as the teacher was writing the topic of the day on the chalkboard.

OC: It seems most students could not make it at 7:40am due to transport problems, since most of the students are day students and there is always a lot of traffic in Kampala city.

7:50 am

ON: By this time most of the students have entered the lab and the total number of students is 52 (30 girls and 22 boys), implying that eight students had not yet arrived. The teacher informed the students, "Today we are going to look at acids, bases and indicators." He then faced the chalkboard and read the topic he had written on the chalkboard.

Mr. Opolot's lesson plan had the following objectives:

By the end of the lesson, learners should be able to:

1. Define an acid, base and indicator.
2. Prepare and use plant extracts as acid- base indicators.
3. Use universal indicator to determine the PH of solutions.

He had also indicated the following methods of teaching:

"Demonstration, Question and answer."

OC: Even though Mr. Opolot said during the interview that he always uses inquiry-based instruction, he had not indicated inquiry as one of the methods to use in teaching this chemistry topic. He instead indicated “question and answer”, which may imply that Mr. Opolot thinks that “question and answer” approach is the same as inquiry-based instruction.

8:00am

ON: Mr. Opolot instructed students to divide themselves into four groups based on the four working tables in the chemistry laboratory. Each group had 13 students due to the large number of students in S.2.A.

He then asked them, “What do you understand by the terms acid, base and indicator?”

Different students attempted to define the terms acid, base and indicator as Mr. Opolot wrote their attempts on the chalkboard. He later wrote the definition of acid, base and indicator on the chalkboard. The students noted the correct definition of acid, base and indicator in their notebooks.

OC: Mr. Opolot tried to provoke the students’ thinking by utilizing their prior knowledge about the acids, bases and indicators. Hence, the teacher asked students to explain before the teacher’s explanation, and students explained.

8:20am

ON: Mr. Opolot distributed to each group the following apparatus to use in preparing the plant extracts.

1. Pestle and mortar
2. Beaker and test tubes

3. Flower petals
4. Ethanol

He then asked students to follow the following procedure to prepare the plant extracts.

1. Put the petals of one flower in a mortar, then add a small amount of ethanol.
2. Crush the petals in the mortar using the pestle and then decant the liquid into the beaker or test tube
3. Repeat steps 1-2 for the other petals.

The students started working in their groups following the above instructions using the three types of flower petals provided by the teacher. They prepared the three types of extractions from the petals provided.

OC: In this case, Mr. Opolot was involving students in structured inquiry because he gave them a step-by-step procedure of how to prepare the plant extracts. He could have given students opportunity the to design for themselves the steps on how to prepare the extracts using the available apparatus and chemicals. This could have been a good guided inquiry-based learning lesson. However, Mr. Opolot taught differently than his colleagues in School A who were using a lecture method; he tried to involve students in some activities.

8:50am

ON: Mr. Opolot gave each group hydrochloric acid and sodium hydrochloric solutions. He told them to test the acid and base using the plant extracts. He gave them the table below to indicate the results.

Plants	Color of extract in Hydrochloric acid (acid)	Color of extract in Sodium hydroxide (base)
Hibiscus flower	red	Yellow
Red flower	red	Blue

The students continued working by testing the three plant extracts and tabulated their results.

9:10am

ON: The students recorded their results in each group. Mr. Opolot asked students to test lemon juice and soap solution provided with the plant extract and record their results.

He concluded the lesson by asking the students to answer the following questions:

1. What color does your chosen extract turn in acid and base solutions?
2. Which of the solutions were acid?
3. Which solution was base?
4. Explain your answers.

Students worked in groups to answer the above questions. The teacher collected the students' results for marking.

OC: Mr. Opolot did not give students opportunity to present their results to the whole class. This could have given students the opportunity to generate arguments based on evidence. Hence, developing their science practices of "Obtaining, evaluating and communicating information."

Nonetheless, I think students had engaged in the following science practices in Mr. Opolot's lesson:

1. Analyzing and interpreting data
2. Constructing explanation and designing solution.

Overall, Mr. Opolot tried to implement structured inquiry-based instruction in his lesson.

Table 11. Summary of the nature of IBI implemented by participating chemistry teachers in School A before attending the PD workshop on inquiry and NOS.

Teacher Name	Mr. Byamukama	Mr. Kigozi	Mr. Agaba	Mr. Opolot
Nature of IBI implemented	None	None	None	Structured IBI

Chemistry teachers' implementation of inquiry-based instruction at the beginning of study in School B. In this sub-section, I provide the findings of how the four in-service chemistry teachers in School B (control group) implemented IBI at the beginning of the study. I analyzed and classified the chemistry teachers' implementation with respect to five categories of IBI: no IBI (none), pre-IBI, structured IBI, guided IBI, and open IBI. I finally conclude the sub-section by providing the summary of the nature of IBI implemented by participating chemistry teachers in School B at the beginning of the study in Table 12.

Mr. Bbosa. Mr. Bbosa generally did not implement any inquiry-based instruction in his chemistry lessons that I observed at the beginning of the study, although during the interview he claimed that sometimes he teaches using inquiry-based instruction. This implies that, much as Mr. Bbosa might have some idea about inquiry-based instruction, he finds it difficult to implement it in the classroom due to some of the factors that I discuss in Chapter Seven.

Below is the excerpt from lesson observation notes of Mr. Bbosa on Tuesday, October 26, 2016, S. 2. East Class, Time: 11:00 am – 12:20 pm, 52 Students (27 girls and 25 boys), Topic: Neutralization reaction of acids and bases.

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

11:00 am

ON: Mr. Bbosa entered the classroom at about 11:02 am and greeted the students. The S.2.East class had 52 students (27 girls and 25 boys). After greeting the students, Mr. Bbosa faced the chalkboard and wrote the topic of the day, “Neutralization reaction of acids and bases.” He then faced the class and asked, “What do you understand by the term, neutralization reaction?” One of the students put up her hand and was picked by Mr. Bbosa to answer the question. She said, “Neutralization reaction is where the acids and bases react together completely resulting into a neutral solution of pH of 7.” Mr. Bbosa wrote the student’s answer on the chalkboard and asked the students whether they agreed with the definition given by their colleague. All the students shouted, “Yes!”

OC: Mr. Bbosa tried to use students’ prior knowledge to introduce the topic.

11:20 am

ON: Mr. Bbosa faced the chalkboard and started writing notes about neutralization reaction. After writing the notes, he faced the class and explained, “Acids and bases react together completely to form neutral solutions of pH 7 by combination of the hydrogen ions in the acid and the hydroxyl ions in an alkali or the oxide ions in a base. These reactions are characteristics of acids and bases. They are called neutralization reactions. Four different kinds of neutralization reaction are now considered.

i. The reaction of acids with metal oxides (insoluble bases)

Acid + metal oxide $\longrightarrow$ salt + water e.g. Hydrochloric acid + magnesium oxide $\rightarrow$ Magnesium Chloride + Water

ii. The reaction of acids with metal hydroxides

Acid + Metal hydroxide (alkali) $\rightarrow$ Salt + Water

e.g. Hydrochloric acid + Sodium hydroxide $\rightarrow$ Sodium hydroxide + water

iii. The reaction of acids with metals

Acid + Metal $\rightarrow$ Salt + Hydrogen

e.g. Sulphuric acid + Magnesium $\rightarrow$ Magnesium Sulphate + Hydrogen

iv. The reaction of acids with metal carbonates

Acid + Metal carbonates $\rightarrow$ Salt + Water + Carbon dioxide

e.g. Sulphuric acid +Copper (ll) carbonate $\rightarrow$ Copper (ll) sulphate + Water+ Carbon dioxide."

OC: Mr. Bbosa explained as students listened. This implies the teacher-centered type of instruction. He did not have any questions and demonstrations to engage students in the thinking process.

11:50 am

ON: Mr. Bbosa asked the students, "What are the applications of acid-base neutralization?" Two male students and one female student raised their hands to answer. Mr. Bbosa picked the female student to answer. The female student responded, "Acid-base neutralization reactions are useful in stomach processes." Mr. Bbosa asked the student to elaborate further. The student explained, “When we get heart burn, we normally swallow magnesium tablets to neutralize the acid which burns our heart.” Mr. Bbosa then explained to students the importance of neutralization reaction in agriculture where the pH of soil is neutralized by use of lime and also in oral hygiene where we neutralize the acid in the mouth by using toothpaste to stop tooth decay due to the acid caused by bacteria reaction with sugar. The students listened attentively and noted down the teacher’s explanation in their notebooks.

12:10 pm

ON: Mr. Bbosa concluded the lesson by giving the students this exercise: “Write separate equations to show the reactions of Sulphuric acid with magnesium carbonate and calcium carbonate.” The students attempted the exercise and collected the books to be marked by the teacher. He informed students that in the following lesson they would go to the laboratory to observe the above reactions they had studied that day.

OC: Generally, Mr. Bbosa conducted a teacher-centered type of lesson where the students were not engaged in any science practice. Hence, this lesson did not utilize any type of inquiry-based instruction.

TN: Mr. Bbosa did not engage students in any investigation and therefore, students were not able to practice the science practices like:

- Asking questions
- Planning and carrying out investigation
- Analyzing and interpreting data
- Engaging in arguments for evidence

- Obtaining, evaluating and communicating information

Hence, Mr. Bbosa did not practice inquiry-based instruction in his lesson accordingly.

Mr. Ssentumbwe. Mr. Ssentumbwe, like Mr. Bbosa, did not implement any nature of inquiry-based instruction in his chemistry lesson. However, Mr. Ssentumbwe tried to utilize students' prior knowledge during the exploration phase of the lesson, but did not adequately give students the opportunity to explore their ideas and there was no clear engagement of students in the eight science practices outlined in US documents (NRC, 2012).

Below is the excerpt from lesson observation notes of Mr. Ssentumbwe on Monday, October 25, 2016, S. 1. East Class, Time: 4:00 – 5:20 pm, Topic: Rusting, 53 Students (28 girls & 25 boys)

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

4:02 pm

ON: To introduce the lesson, Mr. Ssentumbwe assessed the students' prior knowledge about rusting. He asked the following questions, "What do you know about rusting? What do you think causes rusting? How can we prevent rusting?" He waited for about five seconds for the students to think. After this wait, he picked one female student who had raised her hand to respond to the questions. The student said, "Rusting is when a metal turns brown and it is caused by too much water being exposed to the metal." Some students disagreed with their colleague, but Mr. Ssentumbwe noted down the student's response on the chalkboard. Another student was picked and said, "Rusting is a destruction process that occurs in iron and steel." The teacher noted the second student's answer on the chalkboard and most students seemed to agree with the second response.

OC: The teacher tried to prompt the students' prior knowledge before giving them the facts. However, due to the large class (about 50 students), the teacher was not able to give each student an opportunity to share his or her ideas. He could have divided them into groups to brainstorm and share their ideas about rusting.

4:20 pm

ON: After a few minutes of brainstorming about the meaning and causes of rusting, Mr. Ssentumbwe faced the chalkboard and started writing "Rust is hydrated iron (lll) oxide. It is a soft, crumbly solid and hence weakens the structure of iron and steel. During rusting, iron reacts oxygen to form brown iron (lll) oxide.

Iron + Oxygen $\longrightarrow$ Iron (lll) oxide

At the same time, the iron (lll) oxide reacts with water to form brown hydrated iron (ll) oxide or rust.

Iron (lll) oxide + Water $\longrightarrow$ Hydrated iron (lll) oxide

$Fe_2O_{3\,(s)} + xH_2O_{\,(l)} \longrightarrow Fe_2O_3 + xH_2O_{\,(l)}$

Note: The *x* in the equation indicates that the number of water molecules in the hydrated iron (lll) oxide can vary." The teacher gave this explanation as the students were busy writing notes in their notebooks.

OC: The teacher did not have any real objects like rusted iron nails to demonstrate the concept of rusting. The students were being taught rusting as an abstract concept without relating it to reality. This type of instruction demotivates students from studying chemistry, perhaps leaving them to think that it is too abstract to understand.

4:50 pm

ON: The teacher asked students to identify the causes of rusting from the explanation he had given. One of the students said, “I think rusting is caused by both water and oxygen.” The rest of the students agreed with the student. The teacher informed the students, “Substances like rust that have water as part of their structure are described as hydrated and we call them hydrates. Also, rusting costs millions of shillings each year because of the cost of the measures taken to protect objects from rusting and to replace rusted objects.”

Mr. Ssentumbwe then posed another question to students. “How can we stop or prevent rusting?” Students raised their hands and Mr. Ssentumbwe picked them to respond to the question. The students gave the following methods to stop rusting:

- Painting
- Oiling
- Alloying
- Galvanizing

Mr. Ssentumbwe explained each of the above methods and wrote notes on the chalkboard for students to copy.

5:10 pm

ON: Mr. Ssentumbwe concluded the lesson by giving the students the following exercise:

1. What is the chemical name and chemical formula for rusting?
2. Which two substances in the environment cause rusting?
3. Galvanizing is one way to protect iron from rusting. What metal is used in galvanizing?
4. When the galvanized layer is scratched off and the iron is exposed to water and air, it still does not rust. Why is this?

He told the students to finish the exercise outside the classroom and hand in their books to the class monitor who would deliver them to the teacher for marking.

OC: The questions in the exercise were thought provoking. However, during the instruction, Mr. Ssentumbwe did not give ample time to the students to think and brainstorm. Hence, he did not help the students to learn by inquiry. The teacher demonstrated most of the time. This topic was very appropriate for students to have a guided inquiry-based instruction where the teacher and students discuss and create scientific questions together with students then attempt to answer. The teaching aids required were easily obtainable – for example, rusty nails and water. Students could have been provided with nails to put under different conditions to explore the causes of rusting for themselves by testing their hypotheses about the scientific question. This could have helped students engage in science practices like designing investigation, interpreting and analyzing data.

Mr. Muhangi. Despite Mr. Muhangi being a regional SESEMAT in-service science teachers' trainer, he did not implement any inquiry-based instruction in the chemistry lesson I observed at the beginning of the study. Mr. Muhangi used the traditional lecture method with some question and answer technique. Since Mr. Muhangi is the head of department in School B, this may imply that he is not able to advise his colleagues to use inquiry-based instruction because he rarely utilizes it. When I looked at the scheme of work of all the teachers in School B, they had indicated demonstration, discussion and question and answer as teaching methods to be used in their lessons. None of the four teachers had inquiry as one of teaching method to use despite the fact that during the interview they claimed to use inquiry-based instruction in their lessons.

Below is the excerpt from lesson observation notes of Mr. Muhangi on Thursday October 20, 2016. S.3. East class, Time: 11:00 am – 12:20 pm, Topic: Electrochemical cells, 54 Students (34 boys & 20 girls)

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

11:00 am

ON: Mr. Muhangi entered the class at 11:02 am and greeted the students. The class had 54 students (34 boys and 20 girls). He told the students, “Today we are going to look at electrochemical cells.” Then he faced the chalkboard and wrote the topic on the chalkboard. The students copied the topic in their notebooks. Mr. Muhangi had indicated in his lesson plan the following objectives for the lesson.

“By the end of the lesson, learners should be able to:

1. Explain an electrochemical cell in terms of electrons transfer processes.
2. Explain the construction and working of a zinc-copper cell.”

He had also indicated in the lesson plan that he was going to use, “brainstorming, and question and answer approach methods” in teaching this topic.

OC: Mr. Muhangi did not consider guided inquiry as one of the methods to teach this topic. The MoES chemistry teaching syllabus (2008) suggests: “Conduct experiments to demonstrate electron flow using the primary cell, as one of the teaching and learning strategies” (p. 34), however, Mr. Muhangi did not decide to utilize such a good approach, which is articulated in the syllabus.

11:10 am

ON: Mr. Muhangi asked the students what they understood by “electrochemical cells”. The students raised up their hands and he picked some students who attempted to describe what they understood by electrochemical cell. After some brainstorming, he then wrote the definition of “electrochemical cell” on the chalkboard. He also displayed the chart illustrating the labeled diagram of a zinc-copper cell. He then instructed students to start drawing the diagram in their notebooks.

OC: Mr. Muhangi could have utilized students’ prior knowledge more to allow them to relate the diagrams with their practical experiences of electrochemical cells. He did not have real objects like samples of dry cells to use as examples. He did not also utilize ICT/YouTube images to help students observe some animation of electrochemical cells. All these could have helped students to conceptualize the abstract concepts of electron transfer processes.

11:40am

ON: Mr. Muhangi explained how the zinc-copper cells work as students continued copying the labeled diagram of the zinc-copper cell in their notebooks. He told students,

"At the zinc electrode:

- Zinc atoms pass into solution as zinc ions
- A net negative charge form at the zinc electrode
- The electrons eventually dissolve.

At the copper electrode:

- Copper ions draw electrons from the electrode forming copper atoms.
- Current positive charge forms an electrode.
- Copper is deposited in the electrode."

The students wrote down the notes as the teacher explained what happens at the zinc and copper electrodes.

OC: This was basically a lecture. Students were busy copying the notes/content in their notebooks and Mr. Muhangi seemed to be more concerned about finishing the content he had planned before the lesson ends. He did not give the students opportunity to ask/discuss the social-scientific issues related to the primary cells.

12:10 pm

ON: After explaining how the zinc-copper primary cell works, Mr. Muhangi asked students whether they had any questions. Students were still busy writing the notes in their notebooks and did not ask any questions.

Mr. Muhangi gave students an assignment to investigate “What happens when charging and discharging the battery”.

OC: This topic was to help students read ahead and do some research. However, the students were so passive during the lesson that I wondered about their capability to do this assignment outside the classroom.

TN: Generally, Mr. Muhangi taught this topic using a traditional lecture approach. He did not involve students in any science practice (NRC, 2012) and he did not:

1. Supply students with any scientific question to answer.
2. Involve students in any investigation.
3. Provide students with guidelines to relate the science content to social scientific issues.

Hence, I concluded that there was completely no inquiry-based instruction in this lesson.

Ms. Akello. Ms. Akello is a fresh graduate from a private university (Uganda Martyrs University Nkozi) and so I thought she may have a more modern teaching approach conforming to the 21St century, but I was surprised to find out that she used the traditional approach of teaching like other teachers in School B at the beginning of the study. She, however, tried to implement pre-inquiry-based instruction in her lesson, nonetheless, the students were not given the opportunity to engage in science practices as outlined in US documents (NRC, 2012).

Below is the excerpt from lesson observation notes of Ms. Akello on Wednesday October 19, 2016. S.2. West Class, Time: 11:00 am – 12:20 pm, Topic: Strength of acids and bases, 54 Students (30 girls & 24 boys).

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

11:00 am

ON: Ms. Akello entered the classroom at about 11:03 am and greeted the students of S.2.West. The students were 54 (30 girls and 24 boys). Ms. Akello wrote the topic of the day on the chalkboard and she verbally stated, “Today, we will be looking at strength of acids and bases.” The students also wrote the topic in their books. Ms. Akello told the students, “Some acids are stronger than other acids and this is also true for bases.” She then asked the students, “What does the term strength mean?” About 4 students (1 girl and 3 boys) raised their hands to answer the teacher’s question. Ms. Akello picked a girl who answered, “Strength in form of acids means an acid can release more hydroxyl ions when dissolving in water, that is, the acid almost splits up completely when it dissolves in water.” Ms. Akello nodded her head in appreciation of the student’s response. She then informed the class that the same explanation was true for strong bases because they also almost split completely when they are dissolved in water, for example, sodium hydroxide.

11:20 am

ON: She then faced the chalkboard and wrote the meaning of strong acids and bases. She gave an example of ethanoic acid as a weak acid and ammonia as a weak base. The students wrote in their notebooks what the teacher wrote on the chalkboard.

11:40 am

ON: Ms. Akello asked students the meaning of universal indicators. There was no response from students for almost 1 minute. Ms. Akello then explained, “A universal indicator is a commercially produced indicator that exhibits a range of colors depending on the strength of the acid or the base. These colors are linked to a number of scales called pH scale. Substances which are neither acidic nor alkaline are said to be neutral and have a pH of 7."

The students listened attentively to the explanation. Ms. Akello faced the chalkboard and sketched the pH scale from 1 – 14 showing the different colors of the universal indicator. The students started drawing the pH scale in their notebooks.

OC: Basically, Ms. Akello was the center of instruction although she tried to use a question and answer approach at certain moments. Hence students' learning focused solely on the mastery of facts. Students were consistently passive as learners (taking notes). The teacher's questions did not lead students to discuss. Therefore, no guided inquiry-based instruction practice was used.

12: 10 pm

ON: Ms. Akello concluded the lesson by giving students the following exercise:

"For the following sentences indicate if they are true or false. If they are false, explain why they are false.

I. Universal indicator turns red in a strong acid.
II. An acid with a pH of 3 is a weak acid.
III. A solution with a pH of 7 is an acid.
IV. A solution of a base with a pH of 9 is a weak base
V. A solution with pH 1 is a strong acid."

Students started copying the exercise in their notebooks as well as giving the answers. The teacher collected the exercise for marking at the end of the lesson.

OC: Ms. Akello's exercise was strong because it tried to test students' understanding of the concept of strength of acids and bases. It also tested how the universal indicator can be used to determine the strength of acids and bases. However, during instruction the teacher did not assess students' prior knowledge. Also, the lesson did not engage learners in activities of investigation that could have helped them develop the adequate understanding of the strength of acid and base concepts to answer the questions in the above exercise.

TN: Generally, Ms. Akello did not engage students in any science practices. For example, in this lesson, the teacher did not:

- Provide students with any scientific practices.
- Help students to develop any hypotheses.

Hence, there was no type of inquiry-based instruction attempted by Ms. Akello.

Table 12. The summary of the nature of IBI implemented by participating chemistry teachers in School B at the beginning of the study

Name of a Teacher	Mr. Bbosa	Mr.Ssentumbwe	Mr. Muhangi	Mr. Akello
Nature of IBI implemented	None	None	None	None

Chemistry teachers' understanding of inquiry-based instruction after attending PD workshop on inquiry and NOS in School A. I organized a six-day explicitly reflective PD training workshop for the four participants in School A (Active group) on inquiry and NOS understanding guided by the gaps in knowledge obtained from the first phase of interviews and classroom observation above. The workshop took six days because the chemistry teachers were involved in both minds-on and hands-on activities in these six days from 8.00am to 5.30 pm (7 active hours) to enable them to appreciate the concept of inquiry and NOS. The workshop discussed the eight science practices (NRC, 2012) and the eight tenets of NOS (NGSS, Lead States, 2013). The four chemistry teachers prepared inquiry-based lesson plans with my guidance basing on the readings provided in the PD workshops, and carried out peer teaching exercises and then received the feedback from fellow participants and me (see Table 3 in Chapter 3 for the outline of the PD Workshop and Appendix-C for the detailed six-day PD program). The workshop took place within the school for three weeks (on Fridays and Saturdays). Friday was selected because these teachers had no classes, and hence it was possible for the chemistry teachers to be available for the professional development workshop within the school. After attending the PD workshop, I interviewed each of them to establish the effect of the PD workshop on their understanding of IBI. The participants also individually prepared and implemented IBI lessons without my guidance. I then observed at least two of their IBI lessons to establish the effect of PD workshop on their practice of IBI as well. I present the classroom observation notes in the next section.

Generally, all the four chemistry teachers in School A improved their understanding of inquiry-based instruction after attending the explicit reflective PD workshop on inquiry and NOS. They also became aware of the eight science practices learners engage/develop during inquiry-based instruction. They could clearly explain the role of the teacher and students during the inquiry-based instruction lesson. Below is what some teachers said during the post PD workshop interviews:

Mr. Byamukama argued that “In a typical inquiry lesson, learners take center stage by formulating their own investigation about a given scientific concept, making their own analyses and conclusions." In this case, Mr. Byamukama improved from his insufficient early understanding of the role of students as passive learners (see Table 9 above) to the role of students as active learners in the IBI lesson. He could appreciate the role of students as problem solver and researchers after attending the PD workshop. The challenge was now to put this gained knowledge into practice during the IBI lesson as I describe in the next section on chemistry teachers' implementation of IBI after attending the PD workshop on inquiry and NOS.

Mr. Kigozi stated that," In a typical inquiry lesson students explore and find out what is needed on any question and formulate evidence-based scientific arguments." In this case, Mr. Kigozi improved his understanding of IBI by appreciating that students are active learners in IBI and also become aware of one of the key science practice learners develop in IBI, "formulating evidence-based scientific argument." In the previous interview before attending the PD workshop on inquiry and NOS, Mr. Kigozi was not aware of any science practice learners develop in IBI lessons. Hence, the PD workshop helped Mr. Kigozi to obtain sufficient understanding of IBI.

Mr. Agaba noted that, "In inquiry-based instruction, students think and question. They are allowed to come up with questions to investigate. The students design, solve problems and collaborate." In this case, Mr. Agaba also improved his understanding of IBI by acknowledging that students are active learners in IBI lessons who think and question during the IBI lessons. Previously, Mr. Agaba had insufficient understating of the role of student in IBI lesson where he believed that students are passive learners in the IBI lesson. Hence, the PD workshop on inquiry improved Mr. Agaba understanding of IBI. However, the challenge is to implement this understanding in the classroom.

Mr. Opolot mentioned that,” In a typical inquiry lesson, the teachers is a facilitator of learning process, whereas students are consistently and effectively active as learners. The teacher consistently and effectively engages students in open-ended questions, discussions, investigation and / or reflections.” In this case, Mr. Opolot, like his colleagues in School A, improved his understanding of IBI after attending PD workshop on inquiry and NOS by appreciating that his role in IBI is to facilitate the teaching-learning process. Previously, Mr. Opolot believed that the teacher is the center of instruction in IBI lesson. Therefore, the PD workshop helped to improve Mr. Opolot’s understanding of IBI from sufficient. However, the challenge is to transform this understanding into classroom practice.

The above interview quotations of the four participating chemistry teachers provide evidence that the PD workshop improved the chemistry teachers understanding of IBI. Science teachers’ understanding of IBI is one of the important factor influencing their classroom practice (NRC, 2000). For example, John Dewey (1904) noted with great concern that there was inadequate consideration of a proper relationship between theory and practice as far as the preparation of teachers was concerned. He expressed his concern that too much time and effort were being spent on methods and far too little expended on theory that might guide practice in a more enlighten fashion. Therefore I conducted the PD workshop on inquiry and NOS so that the participating teachers could have sufficient theory guiding IBI before attempting to implement the IBI in their classroom to address the concerns that Dewey raised more than 100 years ago concerning teacher preparation. Also, Wenning (2005) argued that:

> Professional development probably will always be less effective than teacher preparation unless it identifies, confronts, and resolves the problems associated with expository teaching. Professional development activities must be of high saliency and prolonged if expected practices are to become the “coin of the realm.” Activities should include

> placing teachers in the role of students as well as that of teacher so that they can see both sides of the coin. These practices must be backed up with sustained periodic mentoring by professional development providers. The improvement-of-practice problem for in-service teachers must, at the root, influence teaching philosophies. It is from philosophies that beliefs arise, and beliefs give rise to decisions. Decisions bring about actions, and actions have consequences. Hence, to influence outcomes, professional development providers need to give attention to teaching philosophies. (p. 14)

Wenning (2005), like Dewey (1904), emphasized the importance of teachers' teaching philosophies to address the theory-practice problem as far as IBI is concerned. He emphasized that, "It is from philosophies that beliefs arise, and beliefs give rise to decisions. Decisions bring about actions, and actions have consequences" (p. 14). Therefore, improving science teachers' understanding of IBI is important step in helping teachers implement IBI in their classroom. However, science teachers understanding IBI does not automatically mean that they will implement authentic IBI due to the factors discussed in Chapter 7. There is also a possibility that these teachers may just memorize (cognitive domain) the concept of IBI without appreciating the role practice of IBI (affective and psychomotor domain). I checked this possibility by observing these teachers while implementing IBI in their classrooms (see lesson observation notes in next section). All in all, the teachers could appreciate that in inquiry-based instruction the learner is the center of the learning process and they dropped the myth of inquiry attitudes they had before attending the PD workshop.

Chemistry teachers' understanding of inquiry-based instruction at the end of study in School B. Generally, teachers in School B maintained their understanding of inquiry-based instruction towards the end of the study. They were still not able to outline the eight science practices learners develop/engage in inquiry-based instruction. They also retained their myth of inquiry-based instruction they had during the beginning of study. Below are what teachers in School B said during the interviews at the end of the study:

Mr. Bbosa argued that, “The role of teacher in inquiry-based instruction is to ask questions, while the role of students is to answer questions and carryout activities given by the teacher.”

Mr. Ssentumbwe stated that, “Inquiry-based instruction involves students discovering their knowledge guided by the teacher.” In this case Mr. Ssentumbwe still held the myth of inquiry where teachers think that learners discover their own knowledge during inquiry-based instruction.

Mr. Muhangi noted that, “Inquiry-based instruction is where the instructors give a set of questions or steps which the learners follow to perform a task”. Mr. Muhangi held a teacher-centered attitude of inquiry-based instruction from the above quotation.

Ms. Akello mentioned that, “In a typical inquiry-based instruction the role of the teacher is to direct students in carrying out the practical, while the role of students is to participate in the experiment.” Ms. Akello like Mr. Muhangi believes in teacher-centered type of instruction.

All in all, the four teachers in School B did not change their understanding of inquiry-based instruction at the end of study. They were not able to clearly describe the role of the teacher and students during inquiry-based instruction, except Mr. Muhangi who previously had a moderate understanding of the role of teacher, students and assessment in IBI lesson, although Mr. Muhangi still maintained his insufficient understanding of meaning of IBI because was not able to describe the different types of IBI by the end of the study. In addition, none of the teachers could outline the eight science practices the learners develop/engage during inquiry-based instruction.

Chemistry teachers' implementation of inquiry-based instruction after attending PD workshop on inquiry and NOS in School A. After attending the six-day PD workshop on inquiry and NOS, the participants individually prepared the IBI lesson without my guidance during the following weeks and implemented them in their classroom. I observed at least two lessons for each participant and then selected one that the participant and I felt was the best prepared and implemented IBI. It was not possible to observe the participants more than three times because of the commencement of year-end exams. Additionally, the moment the practical exams started, the laboratories were out of bounds to prepare for candidates' exams. Hence, the participating teachers were not able to prepare the required IBI for me to observe them. Despite the few number of lessons I observed, the participating chemistry teachers improved their ability to implement IBI after attending the PD workshop on inquiry and NOS as is demonstrated in some lesson observation notes excerpts below.

Mr. Byamukama. Mr. Byamukama tried to implement a guided inquiry lesson, unlike his previous lesson where he used a teacher-centered instruction with question and answer techniques. Below is the excerpt from lesson observation of Mr. Byamukama on Tuesday, November 1, 2016, S.1.B Class, Time: 2:00pm – 3:20pm, Topic: Classification of oxides, 53 Students (31 boys & 22 girls)

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

2:20 pm

ON: The S.1.B class had a total of 53 students (31 boys and 22 girls) in attendance.

OC: The total number of students in this class is 56 per the teacher's lesson plan. Hence 3 students were absent. This is quite a large class for the teacher to manage inquiry-based instruction. The lesson started 20 minutes late because students were trying to settle as they looked for stools to sit on in the chemistry laboratory. Some students went to pick stools from the physics laboratory to have somewhere to sit.

2:22 pm

ON: Mr. Byamukama began the lesson by asking the students, "Who remembers how oxygen reacts with metals like sodium, magnesium, etc.?' One of the students answered by saying, "Sodium burns with oxygen to form a yellow substance." Mr. Byamukama then informed students that, "today we are going to look at classification of oxides," and he wrote the topic on the chalkboard. He then asked students to mention the types of oxides they know. The students raised up their hands and started to mention the types of oxides while Mr. Byamukama recorded their answers on the chalkboard as follows:

- Neutral oxides
- Acidic oxides
- Basic oxides
- Amphoteric oxides
- Mixed oxides

ON: According to the lesson plan of Mr. Byamukama, the learning objectives of this lesson were: "By the end of this lesson, learners should be able to:

- Distinguish the different colors of oxides formed by heating metal carbonates and metal nitrates like zinc carbonate, calcium carbonate, magnesium carbonate and lead (II) nitrate, respectively.
- React the formed oxides with water and test the resultant solution with litmus paper to establish the class of oxide formed.
- Name the other classes of oxides."

OC: Mr. Byamukama appeared to want students to develop the following science practices:

- Asking questions
- Planning and carrying out investigations.
- Constructing explanations.
- Obtaining, evaluating and communicating information.

2:30 pm

ON: Mr. Byamukama asked students to mention ways through which oxides are formed. The students raised their hands and he picked them to give the answer. Mr. Byamukama noted on the chalkboard the students' responses.

1. Action of heat in making hydroxides
2. Action of heat on carbonates
3. By heating elements in oxygen
4. By heating metal nitrates

Mr. Byamukama informed students, "We are going to carry out an experiment about the effect of heat on metal carbonates to see how oxides can be formed." He instructed students to divide themselves into 4 groups due to limited apparatus. Each group had about 13 students.

OC: The students were crowded in each group, so some students were not actively participating in the investigation. This is one of the factors affecting science teachers' implementation of inquiry. Both large classes and limited apparatus influences the practice of chemistry teachers' practice of inquiry-based instruction in Kampala city public schools.

2:35pm

ON: The teacher distributed the apparatus and chemicals to each group (test tubes, litmus paper, salts- zinc carbonate, calcium carbonate, magnesium carbonate, lead (II) carbonate.) Then the teacher told students in each group to have a secretary to write down their findings. He told them to investigate the given metal carbonates, then design their own procedure and come up with their conclusions.

OC: In this case, Mr. Byamukama was implementing guided inquiry where he guided students to plan their own investigation procedures.

2:40 pm

ON: The teacher moved from group to group monitoring and guiding students. Students started heating the metal carbonates and were recording the initial and final color in their respective groups. After heating the carbonates, they were putting the heated carbonates in test tubes and added water. Then they tested whether the solution was alkaline, neutral or acidic using the litmus paper. As some students were doing the practical, other students were making a lot of noise and the teacher had to tell them to keep quiet. The class was becoming uncontrollable for the teacher.

OC: The senior one students were too active for their teacher to control. Also, due to the absence of the laboratory technician, the teacher found it difficult to monitor and manage the 50+ students alone. This may be the reason why some teachers do not want to teach using inquiry-based instruction because students may not easily be controlled in the laboratory with only one teacher (especially the young and very active form 1 classes.) Hence, if the science teachers are to be motivated to teach using inquiry-based instruction, the school must recruit a laboratory assistant to help some teachers to prepare and manage practical lessons and very large classes, or classes need to be divided into manageable shifts in case of practical lessons.

2:50 pm

ON: Mr. Byamukama advised students to note the type of gas that comes out at the top of the test tube by inserting the litmus paper on top of the test tube when heating the carbonates. The students continued working in their groups, as the teacher moved around to monitor what they were doing.

3:00 pm

ON: The teacher told the students to answer the following questions basing on their findings.
“Name two examples of:

a) Acidic oxides
b) Basic oxides
c) Neutral oxides
d) Amphoteric oxides
e) Mixed oxides”

OC: Here the students were supposed to make claims basing on the evidence they obtained from the experiments. However, the teacher did not bring out the issue of argumentation very well in his class. It appeared that Mr. Byamukama had not yet conceptualized the argumentative concepts.

3:10 pm

ON: The teacher told the students to present their findings to the whole class. Each group was given three minutes to share their findings.

OC: Here the students were practicing how to design explanation and proving arguments using evidence, which is a very important science practice.

ON: The teacher also told each student to write a reflective memo about what they had learned from their investigations and individually hand in their work at the end of the lesson. The teacher collected students’ work at the end of the lesson for evaluation.

TN: Generally, the teacher tried to develop science practices and conducted the guided IBI through the following activities.

- The teacher and the students together created scientific questions that students attempted to answer.
- The teacher guided students to think about the relevant literature they needed to develop their investigations.
- The teacher provided the students with hypotheses that they tested through investigations.
- The teacher guided students to plan investigation procedures.

- The teacher guided students on the variables to be controlled in an investigation.
- The teacher guided students on how to collect data to answer a science question.
- The teacher guided students to develop conclusions using scientific evidence.
- The teacher guided students to use experiment data to explain patterns leading to conclusions.

The teacher did not consider the social scientific issues in this lesson.

Overall, the teacher had a successful guided inquiry-based instruction lesson where the following scientific practices were developed by the students.

1. Asking questions
2. Planning and carrying out investigations
3. Engaging in argument from evidence
4. Constructing explanations
5. Obtaining, evaluating and communicating information.

Mr. Kigozi. Mr. Kigozi tried to implement a structured inquiry-based instruction in his lesson even though there was no experiment given to students. During the lesson, he engaged learners in science practices like asking questions, generating arguments using evidence, and communicating their arguments. He generally improved his competency to implement inquiry-based instruction compared to his previous lesson before attending the PD workshop.

Below is the excerpt from lesson observation of Mr. Kigozi on Tuesday, November 1, 2016. S. 1. A Class, Time: 9:20am – 10:40 am, Topic: Air, 40 Students (15 boys & 25 girls).

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes).

9:20 am

ON: Mr. Kigozi entered the classroom and greeted the students. The class consisted of 40 students (15 boys and 25 girls) of senior 1.A. He distributed plain paper to the students to be used in writing the response from the classroom discussion. He told students, “Today, we are going to look at air.” He then asked students, “What do you know about air?” All the students raised their hands. He then asked students to write down what they know about air. The students wrote down what they knew about air for one minute. Mr. Kigozi asked students to share what they had written about air. One of the female students stated that, “Air is a mixture of gases.” He asked them also to write down the components of air on the paper provided. After two minutes, the teacher asked the students to share in groups (six students each group) what they had written about the components of air. The students were engaged in the discussion of components of air for about three minutes.

ON: After the three minutes, Mr. Kigozi picked one group to come up in front of the class to share with the whole class about the components of air. The group came in front of the class and wrote on the chalkboard the components of air as follows:

- Carbon dioxide
- Nitrogen
- Rare gases
- Dust
- Bacteria

OC: The teacher supplied the questions for students to answer most of the time. Hence, he was basically utilizing structured inquiry. However, the teacher allowed the students to discuss and share their findings through discussion. Hence, all students were active during the lesson.

TN: The teacher tried to teach from known to unknown by using the learners' prior knowledge. This was important as a means of scaffolding in an inquiry-based instruction lesson.

10:00 am

ON: Mr. Kigozi asked the students to explain what happens when a person uses body perfume. What makes other people able to smell the body perfume? He asked students to write down the percentages of air components and to share their findings in their groups.

OC: The teacher encouraged the students to think and discuss throughout the lesson.

ON: The teacher picked one group of students (six students) to come up and share their findings (percentages of air components) on the chalkboard. The group came in front of the class and wrote this on the chalkboard:

> "Oxygen - 21%
>
> Rare gases – 0.9%
>
> Carbon dioxide – 0.03%
>
> Nitrogen – 78%"

ON: The teacher said that they had used their elementary school knowledge to come up with the above percentages. Other students in class challenged their colleagues, claiming that the percentages they had given were incorrect. The learners were engaged in a debate about the true air components and their percentages.

OC: Here the teacher helped the learners to engage in argument based on evidence, which is a very important scientific practice.

ON: After debating for some time about the true components of air, the teacher gave the students the correct components of air and their percentages by writing them on the chalkboard.

10:10 am

ON: The teacher then instructed the students to write down the uses of the components of air and share their views in their groups. He allocated each group one component of air to present its uses to the whole class.

OC: The teacher used learners' prior knowledge to build their understanding of the uses of oxygen. This is in line with inquiry-based instruction and a constructivist learning approach.

10:24 am

ON: He also informed them that oxygen is used in breathing in hospitals, and it is also used by mountain climbers and deep sea divers. He asked students to think about where oxygen is used in welding (e.g., oxyacetylene flame used for welding). He also asked students to provide any additional uses of oxygen for the whole class. One student said, "It is used in rusting." The teacher told the class, "Rusting is not useful in our daily life."

10:35 am.

ON: The teacher concluded the lesson by asking the learners of groups that had not presented to collect their papers on which they had recorded the uses of carbon dioxide, nitrogen, etc. He later gave the students the exercise to discuss after the lesson.

1. "List down the components of air and their percentages.
2. Explain how oxygen can be used in hospitals.
3. Explain how carbon dioxide can be used in soft drinks."

OC: The teacher engaged the learners throughout the lesson and used social scientific issues in the lesson to help students relate the chemical content with their daily life. Even though this was not a practical lesson (i.e., the lesson did not have a lab), the teacher tried to utilize inquiry-based instruction in the lesson. This helped learners construct their own understanding of the components of air. The teacher mainly used structured inquiry in this lesson. Compared to the previous lesson before he attended the PD workshop, Mr. Kigozi had improved greatly.

Mr. Agaba. Mr. Agaba improved his ability to implement inquiry-based instruction. He was able to implement fairly successful guided inquiry-based instruction in his chemistry lesson after attending the PD workshop on inquiry and NOS.

Below is the excerpt from lesson observation notes of Mr. Agaba on Wednesday, November 9, 2016, S.3.A Class, Time: 2:00pm – 3:20pm, Topic: Properties of Ammonia gas, 43 Students (26 girls & 17 boys).

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

2:00 pm

ON: Students entered the laboratory at exactly 2:00 pm and took their seats. The class had 43 students (26 girls and 17 boys). Mr. Agaba greeted the students and then started writing the following instructions on the chalkboard.

> "You are provided with substances A and B. Identify the substance that produces ammonium gas and test for the properties of ammonia."

When I examined the lesson plan for Mr. Agaba, I noticed that he had outlined the following objectives of the lesson.

"By the end of the lesson, learners should be able to:

1. Identify the salt that produce ammonium gas.
2. Test for ammonium gas using litmus paper, concentrated HCl and smell.
3. Explain the effect of ammonium on litmus paper and concentrated HCl.

Methods: Guided inquiry and experimentation.

Science practices:

- Planning and carrying out investigation
- Engaging in argument from evidence
- Constructing explanation
- Analyzing and interpreting data"

OC: Mr. Agaba had internalized the concepts of science practices from the PD workshop on inquiry and NOS. He was able to explicitly indicate the science practices he intended to develop in the students. This was different from his previous lesson plans before he had attended the PD workshop. Therefore, it seems that the PD workshop helped Mr. Agaba to conceptualize the science practices.

2:05 pm

ON: Students started to write the instructions on the chalkboard in their notebooks. Meanwhile, Mr. Agaba instructed the students to divide themselves into four groups. This was because the chemistry laboratory had four working tables. Each group had about 11 students.

2:10 pm

ON: Mr. Agaba started to review the previous lesson by asking students questions. He asked them, “Where do we get ammonia from?” Students responded to the teacher’s question.

2:30 pm

ON: Students were instructed to follow the instructions on the chalkboard and start working in their respective groups. Mr. Agaba told students to design their own procedure and table of results. They were also supposed to identify the salt that produces ammonia between substance A and B.

OC: This was an exploration phase where students had to think of the appropriate problem and the way to present their results. Students in this case were engaging in science practices of planning and carrying out investigations. Hence, Mr. Agaba was involving students in a guided inquiry-based instruction.

ON: I moved around the four groups and noticed that in all groups about four students in each group were actively involved in the experiment. The rest of the students were just observing what their colleagues were doing.

OC: These large classes may be one the factors negatively affecting science teachers' practices of inquiry-based instruction in Uganda.

2:35 pm

ON: One of the groups had this type of table of results:

Substance	Test	Observation with litmus paper	Observation with HCl
A	Heat		
	Add sodium hydroxide		
B	Heat		
	Add sodium hydroxide		

2:50pm

ON: Students were instructed by the teacher to present their results to the whole class starting with group 1, then group 2, group 3, and finally group 4. Students presented their findings to the whole class as the teacher attentively listened to their results. After all students, had presented their results, Mr. Agaba asked them to chemically explain their observations. For example, he asked them to explain why they get white fumes when ammonia reacts with Hydrochloric acid (HCl), and why substance A produces ammonia and substance B does not.

One of the students said, "When ammonium salt, like ammonium chloride, is heated it gives out HCl and ammonium gas. That is why we get ammonia gas from substance A, but not from substance B."

ON: One of the students asked, “Why the gas does not change the dry litmus, but turns the wet litmus paper from red to blue? “Another student answered, “Ammonium gas dissolves in water to produce ammonium hydroxide, which is alkaline.”

The teacher asked students to think of instances where ammonium is applied in their daily life.

OC: The teacher could engage learners in the following science practices in this lesson:

1. Asking questions
2. Planning and carrying out investigations
3. Analyzing and interpreting data
4. Constructing explanation and designing solutions
5. Engaging in arguments from evidence
6. Obtaining, evaluating and communicating information

TN: Generally, the teacher used guided inquiry-based instruction throughout his lesson when he

- Guided students to think about relevant literature to develop their investigations.
- Guided students to plan investigation procedures
- Guided students on how to collect data to answer scientific questions
- Guided students to consider social scientific issues related to their lives.

OC: Therefore, Mr. Agaba had improved on the way he implemented inquiry-based instruction after attending the PD workshop, especially as far as engaging students in science practices in the chemistry practical.

Mr. Opolot. Mr. Opolot improved his ability to implement inquiry-based instruction after attending the explicit reflective PD workshop on inquiry and NOS. He was able to implement the guided inquiry-based instruction chemistry lesson fairly well.

Below is the excerpt from lesson observation notes of Mr. Opolot on Thursday. November 10, 2016, S.2.A Class, Time: 7:40 – 9:40 am, Topic: Salts, 60 Students (35 girls & 25 boys).

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

7:40am

ON: Students entered the laboratory and got stools to sit on. According to the lesson plan, the class consists of 60 students (35girls and 25 boys). The teacher told students to sit in four groups, (each group had about 15 students.) These groups were based on the four working tables in the chemistry laboratory.

7:50am

ON: Since there was no laboratory assistant, the teacher started distributing the apparatus to the four groups. Then the teacher greeted the students and told them, "The last time we met on Monday, we continued with our topic of acids and bases. We have finished learning the acids and the bases."

OC: By this time, the lab had 42 students present – 18 students had not yet arrived.

ON: The teacher asked the students the meaning of the word "acid". Students raised their hands and the teacher picked one student who said, "Acids are compounds that dissolves in water to form salts and hydrogen ions." Another student said, "Acids dissolve in water to form acids."

Then the teacher corrected the students by stating that: “Acids are substances that dissolve in water to produce hydrogen ions as the only positively charged ions.”

The teacher then asked the students, “What are the types of acids?” One student answered, “We have two types of acids, the strong acids and the weak acids.” The teacher asked the students to explain the difference between strong acids and weak acids. The students gave their views about the strong acids and the weak acids. The teacher noted down on the chalkboard the students’ explanations. After gathering the students’ views, the teacher gave an explanation of the difference between weak and strong acids.

OC: Mr. Opolot used the learners’ prior knowledge in the lesson during the exploration phase of the lesson.

ON: Mr. Opolot then asked the students, “What is a base?” One of the students answered, “A base is a substance which dissolves in water to form acidic properties.” Her fellow students shouted, ‘No! No! No!’ Another student answered, ‘A base is a compound that reacts with acid to form water and salt only.’ The teacher told students, “It seems you don’t revise your notes.” By this time, most students were opening their notebooks to look for the correct definition of a base.

OC: It appears most students do not review their notes after the lesson. Hence, they had come for the practical lesson without the basic understanding of acid and base concepts. This could result into a cookbook lab where students do not understand what they are learning. I was pleased that the teacher first engaged them theoretically before giving them the practical exercises.

8:30 am

ON: The teacher told one of the group members to come for test tubes. The teacher then asked the students to explain the difference between normal salts and acidic salts. The students attempted to explain and the teacher noted down their views on the chalkboard. Afterwards, the teacher explained to the students the difference between the normal salts and acidic salts. The teacher demonstrated how magnesium nitrate salt is formed from acid (nitric acid) and magnesium metal. The students were able to observe the function of magnesium nitrate salt practically in the laboratory. The teacher explained how other salts can be formed.

9:04 am

ON: The teacher told students, "Today you are supposed to identify the salts that are soluble and those that are insoluble in water." He told them to:

1. Design their own procedure.
2. Observe.
3. Explain what they observe.
4. Present to the classroom their explanation and conclusion.
5. Prepare a question that they will ask the groups that will be presenting.

OC: In this case, the teacher was able to conduct a guided inquiry-based instruction compared to the previous lesson that was basically structured inquiry. Hence students were able to engage in the following science practices.

1. Asking questions
2. Planning and carrying out investigations
3. Engaging in arguments from evidence
4. Constructing explanation

5. Obtaining, evaluating and communicating information

9:10 am

ON: Students started working in their groups. However, due to the large number of students in each group (more than 10 students), some students were passive during the investigations.

ON: As I moved around the groups, I observed that students had designed tables of results like this one below.

Name of salt	Solubility	Color of solution
A		
B		
C		
D		

9:36 am:

ON: The teacher asked students to present their procedure, observations, explanations and conclusion to the whole class. Students came in front of the class one group at a time, to present their findings from their investigations.

OC: This appeared to help students to develop confidence to present in the whole class, although some students seemed nervous because they were not used to this type of instruction. I think Mr. Opolot has fairly mastered inquiry-based instruction after attending the PD workshop on inquiry and NOS. This lesson is better than the previous lesson I observed on November 3, 2016.

9:50 am:

ON: After the students, had finished presenting, the teacher collected the students' reports for assessment and he also gave them feedback afterwards.

TN: Mr. Opolot was able to engage students in guided inquiry in this lesson where he performed the following tasks:

1. Discussed and created scientific questions together with the students.
2. Guided students to think about the relevant literature before the practical
3. Guided students to plan investigation procedure.
4. Guided students to identify variables during investigations.
5. Guided students on how to collect data to answer a scientific question.
6. Guided students to develop conclusions to scientific questions.

However, he did not provide students with socio-scientific issues related to the chemistry content they learned.

Table 13. Summary of the nature of IBI implemented by participating chemistry teachers in School A after attending the PD workshop on inquiry and NOS

Name of a Teacher	Mr. Byamukama	Mr. Kigozi	Mr. Agaba	Mr. Opolot
Nature of IBI implemented	Guided	Structured	Guided	Guided

Chemistry teachers' implementation of inquiry-based instruction at the end of study in School B. I continued to observe the chemistry teachers in School B up to the end of the study. In this section, I present findings from at least one excerpt from lesson observation notes for the four participating teachers in School B. None of the four participating teachers in School B improved their practice of inquiry-based instruction at the end of the study as is demonstrated in the lesson observation notes below.

Mr. Bbosa. Below is the excerpt from lesson observation notes of Mr. Bbosa on Tuesday November 15, 2016, S.2 East Class, Time: 11:00 am – 12:20 pm, Topic: Preparation of salts, 52 Students (27 girls & 25 boys), in School B towards the end of the school term (study).

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

11:00 am

ON: At exactly 11:02 am, Mr. Bbosa entered the laboratory where the students had already settled. S.2. East contained 52 students (27 girls and 25 boys) and hence the laboratory was packed without even adequate space for easy movement. Mr. Bbosa informed the students, "Today we are going to prepare soluble salts." He reminded students, "Remember that we looked at neutralization reactions sometime back and we saw that the acid can react with the base to form salt and water." He instructed students to form four groups basing on the four working tables in the laboratory (each group had about 13 students).

OC: The laboratory looked small for the S.2 students. I think the ideal number of students would be 26. Therefore, to conduct a proper practical, the class needed two shifts. (52/2=26).

11:10 am

ON: Mr. Bbosa informed students, "The metal, insoluble base or carbonate neutralizes the acid. The equations for the reactions are:

- Acid + metal $\rightarrow$ salt +hydrogen
- Acid + base $\rightarrow$ salt + water
- Acid + carbonate $\rightarrow$ salt + water + carbon dioxide

In all three reactions, the acid is neutralized to form a salt and other products (hydrogen, water and carbon dioxide)." He then informed students, "We are today going to prepare some soluble salts in this laboratory." He faced the chalkboard and wrote the general method of preparation of soluble salts.

"General method of preparation of salts:

1. Add the solid to the acid, a small amount at a time. In case of a metal oxide, warm the acid and add solid until no more dissolves. For metals and metal carbonates, do not warm the acid. Stop adding solid once fizzing stops.
2. Check the solution with a universal indicator. Stop adding solid if the indicator turns green (pH 7, neutral). Otherwise, repeat 1 and 2 until it turns green.
3. Filter the solution to remove excess solid.
4. Evaporate the solution until crystals start to form.
5. Set the solution aside to cool and crystalize. The crystals can be separated from the remaining solution by filtration or decanting."

The students copied the above method in their notebooks. Mr. Bbosa called the group leaders to pick the chemicals and apparatus for preparing the soluble salts (prepare Copper (ll) sulphate from Sulphuric acid and Copper (ll) oxide).

11:30 am

ON: Students started working in groups following the method given by the teacher. Due to the large number of students in each group (13 students), I observed some students just observing their friends working. The students prepared Copper (ll) sulphate and zinc nitrate salts following the procedure provided by the teacher. Mr. Bbosa asked the students to:

1. Name the salt formed in each case.
2. Describe what crystals of the salt look like.
3. Write the equation for the reaction in each case.

Students worked in their respective groups to answer the above questions, however, students noted the answers in their own notebooks individually for the teacher to grade.

OC: Although the teacher was able to give the students a practical, this was like a cookbook lab, where the students were not given opportunity to design their investigation. Hence, the instruction was not a true inquiry-based instruction. However, the students were fairly engaged in a few science practices, like engaging in some argument using evidence. Overall, the lesson was based on teacher-centered instruction.

Mr. Ssentumbwe. Below is the excerpt from lesson observation notes of Mr. Ssentumbwe on Monday November 14, S.1.East Class, Time: 2016. 4:00 – 5:20 pm, Topic: Reaction of non-metals with oxygen, 47 students (24 girls & 23 boys), in School B toward the end of the school term.

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

4:00 pm

ON: At exactly 4:00 pm, Mr. Ssentumbwe entered the S.1.East classroom and greeted the students. The class consisted of 47 students (24 girls and 23 boys). Mr. Ssentumbwe then faced the chalkboard and wrote the topic for the day, “Reaction of non-metals with oxygen.” He then faced the class and informed the students that, “Last time we looked at how oxygen reacts with metals. Today, we are going to look at how oxygen reacts with non-metals.” The students listened attentively as Mr. Ssentumbwe introduced the topic of the day.

OC: Mr. Ssentumbwe did not review the previous lesson thoroughly to help students relate the previous lesson to the current lesson.

4:10 pm

ON: Mr. Ssentumbwe went on to inform the students, “We have seen how metals react with oxygen to give metal oxides by a process called oxidation. The soluble metal oxides give alkaline solutions. Here, we will today look at the types of oxides formed by some non-metals when burnt in oxygen.” He then told students, “For example, Sulphur burns with a deep blue flame to produce a white fuming gas, Sulphur dioxide. Sulphur dioxide gas readily dissolves in water to give an acidic solution. The Sulphur has been oxidized.

$$\text{Sulphur} + \text{oxygen} \longrightarrow \text{Sulphur dioxide}$$

He explained the above content as he wrote the notes on the chalkboard. Meanwhile, the students were busy copying the notes as they listened to the teacher’s explanation.

OC: Mr. Ssentumbwe seemed mostly interested in covering the content he had prepared. He did not appear concerned whether the students were following or not. He did not prepare any demonstration to illustrate the concepts he was talking about.

4:40 pm

ON: Mr. Ssentumbwe asked the students, “What happens when carbon and phosphorous are burnt in oxygen?” One of the male students responded to the question by saying, “When carbon is heated in oxygen, it forms carbon dioxide gas." Another female student raised her hand and she was picked by Mr. Ssentumbwe. She then answered, "When we burn phosphorus in oxygen we produce phosphorus oxide." Mr. Ssentumbwe asked both the male and female students to come in front and write the equations for the reactions of carbon and phosphorus with oxygen respectively. The male student came in front of the class and wrote the following word equation:

"Carbon + Oxygen $\longrightarrow$ Carbon dioxide"

The female student came up and wrote the following word equation:

"Phosphorus + oxygen $\longrightarrow$ Phosphorus (lV) oxide"

Then Mr. Ssentumbwe explained to the whole class, "Carbon glows red-hot in oxygen, to give a colorless gas carbon dioxide. This, too, dissolves in water to give an acidic solution. Meanwhile, phosphorus burns with a bright white flame and produces a white solid oxide, Phosphorus (IV) oxide. Phosphorus (IV) oxide dissolves in water to give an acidic solution."

After the explanations, Mr. Ssentumbwe faced the chalkboard and wrote down the above explanation. The students started noting down in their notebooks the teacher's notes he was writing on the chalkboard.

OC: Students seemed most interested in copying down the notes. They did not ask the teacher any questions. Generally, the learners were passive in the lesson.

5:10 pm

ON: Mr. Ssentumbwe concluded the lesson by giving the students the following exercise:

"Question 1. In contrast to metals, non-metals burn to give oxides which are acidic when dissolved in water. Give two differences between magnesium oxide and Sulphur oxide.

Question 2. Are the following statements true or false? If the statement is false, write it again to make it a true statement.

a) Sulphur reacts with oxygen to give a solid called Sulphur dioxide.

b) Sulphur dioxide gas is an acid."

Students copied the exercise in their notebooks and started working out the answers. After finishing the exercise, the teacher collected the books for marking.

OC: Mr. Ssentumbwe tried to engage the students in the question and answer approach, however he did not adequately engage the learners in the science practices like: asking questions, planning and carrying out investigations, analyzing and interpreting data, and so on. Hence, he did not use inquiry-based instruction. The lesson was generally teacher-centered, although at some point he involved students in answering the questions on the chalkboard. He did not engage students in any serious brainstorming. He also did not demonstrate how these non-metals burn with oxygen to allow students to observe what exactly happens.

Mr. Muhangi. Below is the excerpt from lesson observation notes of Mr. Muhangi on Thursday November 17, 2016, S.3. East Class, Time: 11:00 am – 12:20 pm, Topic: Reaction rates, 48 students (30 boys & 18 girls), In School B towards the end of the school term.

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

11:00am

ON: Mr. Muhangi entered the laboratory at 11:00 am and greeted the students. Some students entered the laboratory when Mr. Muhangi was already there. He cautioned them to always keep time. The class had 48 students (30 boys and 18 girls).

OC: It appears that the school had sent some students home, for school fees as the school term was coming to an end.

ON: Mr. Muhangi informed the class, “Today, we are going to look at reaction rates.” He then faced the chalkboard and wrote the topic of the day. Students also copied the topic in their notebooks. According to Mr. Muhangi’s lesson plan, he had the following lesson objectives.

> “By the end of the lesson, learners should be able to:

1. Define rates of reaction.
2. Describe some methods used to measure rates of reaction.
3. Explain the effect of the different factors on reaction rates.”

He had also planned to use question and answer, and guided discovery methods in his lesson plan. He then asked students to explain what they understood by “rate of reaction”.

OC: Mr. Muhangi had low-level objectives that focused basically on knowledge and comprehension without high level objectives such as application, analysis, thesis and evaluation. He also did not seem to consider the use of either structured inquiry or guided inquiry when teaching this topic. I suspect that he thinks that inquiry-based instruction is the same as question and answer approach. That is why he is confident that when he uses question and answer in his lesson that he is implementing inquiry-based instruction. This type of misconstruing of inquiry may be one of the factors influencing science teachers' practices of inquiry-based instruction in Kampala city public schools.

11:20 am

ON: Students attempted to define the meaning of rate of reaction as Mr. Muhangi noted their answers on the chalkboard. After about four students' attempts to describe the rate of reaction, Mr. Muhangi wrote on the chalkboard the correct definition of rate of reaction. The students also noted this down in their notebooks.

11:30am

ON: Mr. Muhangi asked students to outline the methods used to measure the rate of reaction by suggesting a particular reaction they knew. One of the students put up his hand and was picked by Mr. Muhangi. The student explained, "We can measure the rate of chemical reaction by measuring the amount of the product formed per unit time. For example, during the production of ammonia, we can measure the amount of ammonia gas produced from the reaction between nitrogen and hydrogen." Mr. Muhangi seemed impressed by the student's answer because the student had used his previous knowledge from nitrogen and its compounds topic to relate to the rate of reaction.

OC: It seemed that this student was a very serious student. He was the only one who had put up his hand and he was able to give a well-researched answer. Unfortunately, the potential of such students is not activated when science teachers use a traditional lecture method to teach science.

ON: Mr. Muhangi instructed the students to write the example given by their colleague in their notebooks. Some students started noting down the example, while others were just looking on which seemed to imply that they had not captured what their colleague had explained. Mr. Muhangi later wrote on the chalkboard the methods used to measure the rates of reaction. All the students noted down what the teacher had written on the chalkboard.

- Rate of production of gas
- Changing mass of a reaction
- Change of intensity of color.
- Formation or disappearance of products

11:50 am

ON: Mr. Muhangi asked the students what they thought affected the rate of reaction. Students put up their hands and started mentioning different factors. Among the factors were:

- Concentration of a solution
- Surface area of a solution
- Catalyst of a solution

12:10 pm

ON: Mr. Muhangi concluded the lesson by giving the students the assignment to investigate "The effect of different factors in reaction rates by giving several examples." He then asked the students whether they had any questions. There were no questions from the students.

OC: This topic could have been very good for the teacher to utilize either guided or open inquiry. However, Mr. Muhangi decided to use just a question and answer approach to teach it. Hence, he did not utilize any inquiry-based instruction. He did not even carry out any demonstration, which could have helped students to think about the content in relation to their daily life.

The Uganda teaching syllabus suggests that the teacher should "conduct experiments to demonstrate how different variables influence the rate of reaction." (p. 36) However, Mr. Muhangi did not utilize any experiment to teach this topic. He seemed to believe that the question and answer approach was enough to help students understand the concepts that would enable them pass the national exams. This examination oriented type of teaching may be a serious factor influencing science teachers' practice of inquiry-based instruction in Uganda.

Ms. Akello. Below is the excerpt from lesson observation notes of Ms. Akello on Wednesday November 16, 2016. S.2.West Class, Time: 11:00 am – 12:20 pm, Topic: Salta, 46 Students (26 girls & 20 boys), in School B towards the end of the school term.

(ON: Observation Notes, OC: Observer Comments, TN: Theoretical Notes)

11:02 am

ON: At exactly 11:02 am, Ms. Akello entered the laboratory. She found that all of the 46 students were already in the laboratory (26 girls and 20 boys).

OC: It seems some students were absent because of a school fees problem since the school normally sends students away for school fees before the beginning of the end of term exams. This affects the teaching and learning process tremendously since the students who are absent miss the essential practical lessons that are only conducted once by the teacher.

11:08 am

ON: Ms. Akello told students, "Today, we are going to study salts." She then faced the chalkboard and wrote on the chalkboard the lesson of the day. In her lesson plan she indicated the following objectives.

"By the end of the lesson, learners should be able to:

1. Define salts
2. Identify soluble and insoluble salts
3. Select an appropriate method for the preparation of a particular salt."

She also indicated that she would use question and answer, and guided discovery methods.

OC: It seems that most of the teachers equate question and answer technique to mean inquiry. Almost all of the teachers in School B claimed during the interview that they always use inquiry-based instruction, but to my surprise, all of them indicated question and answer as the main method in their lesson plans.

11:20 am

ON: Ms. Akello asked the students whether they had ever seen or used any salt. All of the students answered, "Yes!" She then asked them, "What is a salt and what type of salts have you seen or used?" Six students raised their hands (3 boys and 3 girls). Ms. Akello picked one girl and she answered, "Salts are substances formed when an acid reacts with a base. I have used sodium chloride as a table salt which we put in our sauce to give it good taste." Ms. Akello listened attentively and wrote the student's response on the chalkboard. She then asked the students whether they agreed with the definition given by their colleague. All of the students said, "Yes." She then told them to write down the explanation and example provided in their notebooks. The students noted the explanation and example in their notebooks.

11:20 am

ON: Ms. Akello picked four sample types of salts. She assembled four test tubes labeled 1, 2, 3, 4 and inserted the four salts, each one in a test tube. She then told the students to observe carefully what will happen when she adds water in test tube 1. When she added water to test tube 1, the salt started dissolving and later disappeared. She told student to record what they had seen and explain why. One of the students raised his hand and was picked by the teacher to explain. He said, “The salt in test tube 1 has disappeared and hence it is soluble in water.” Ms. Akello asked the students whether they agreed with their colleague’s observation and explanation, and the students said. “Yes.”

OC: Ms. Akello’s demonstration was fairly good, but I wish she had given the students an opportunity to inquire for themselves which salt was soluble and which salt was insoluble.

11:50 am

ON: Ms. Akello proceeded by adding water to the rest of the salts in test tubes 2, 3 and 4, respectively. She told the students to write their observations and conclusion for each. After adding the water in all the salts, she gave students about six minutes to write their observations and conclusions. She asked them to identify which of the salts are soluble and which are insoluble in water. The students worked individually. They wrote their observations and conclusions in their exercise books.

12: 10 pm

ON: The teacher concluded the lesson by asking the students to read about the methods used in preparation of salts. She then collected the students’ books for marking.

OC: Although Ms. Akello conducted the demonstration about solubility of salts, the demonstration did not engage the students in appropriate science practices like creating scientific questions and arguments basing on evidence. Hence, this looked like a cookbook laboratory demonstration that did not have the basis of inquiry-based instruction. In other words, the teacher did not:

- Guide students to think about relevant literature and other results they need to develop from their investigation.
- Guide students on how to collect data to answer a scientific question.
- Guide students to use experiment data to explain patterns leading to conclusions
- Guide students in relating their ideas to social scientific issues.

Hence, Ms. Akello's instruction may be classified as a pre-inquiry lesson.

Table 14. The summary of the nature of IBI implemented by participating chemistry teachers in School B at the end of the study

Name of a Teacher	Mr. Bbosa	Mr.Ssentumbwe	Mr. Muhangi	Mr. Akello
Nature of IBI implemented	None	None	None	Pre-IBI

Section summary. The participating chemistry teachers in School A improved their practice of IBI after attending the PD workshop as indicated in Table 15 below; this can be seen by comparing the nature of IBI implemented before and after attending PD workshop on inquiry and NOS. However, the participating chemistry teachers in School B did not improve their practice of IBI at the end of the study as is shown in Table 16 below; this can be seen by comparing their nature of IBI implement at the beginning and end of study.

Table 15. Comparing the Nature of IBI Implemented in the Lesson by Participating Chemistry Teachers in School A before and after attending the PD Workshop on Inquiry and NOS

Name of the teacher	Nature of IBI implemented in Leeson before attending PD workshop.	Nature of IBI implemented in Leeson after attending PD workshop.
Mr. Byamukama	None	Guided IBI
Mr. Kigozi	None	Structured IBI
Mr. Agaba	None	Guided IBI
Mr. Opolot	Structured IBI	Guided IBI

Table 16. Comparing the Nature of IBI Implemented in the Lesson by Participating Chemistry Teachers in School B at the beginning and end of the study

Name of the teacher	Nature of IBI implemented in Leeson at the beginning of study,	Nature of IBI implemented in Leeson at the end of the study.
Mr. Bbosa	None	None
Mr. Ssentumbwe	None	None
Mr. Muhangi	None	None
Ms. Akello	None	Pre-IBI

Chapter Summary

Generally, all the eight participating in-service chemistry teachers in School A and B had insufficient understandings of the meaning of IBI at the beginning of the study as indicated in the interviews and summaries in Tables 9 and 10 above. Most of the teachers had a common myth about inquiry and equated inquiry-based instruction to mean question and answer technique, utilizing learners' prior knowledge, and hands on activities. However, Mr. Agaba (School A) unlike his colleagues, had moderate understanding of the role of the teacher, role of the student, and assessment in IBI at the beginning of the study. Also, Mr. Muhangi (School B) had sufficient understanding of the role of students and assessment in IBI, and moderate understanding of the role of teacher in IBI lesson at the beginning of the study. Whereas Ms. Akello (School B) had a sufficient understanding of the role of students and a moderate understanding of the role of a teacher in an IBI lesson. However, Mr. Agaba, Ms. Akello and Mr. Muhangi, like their colleagues, were not aware of any type of IBI and the eight science practices learners develop in IBI lessons as outlined in US documents (NRC, 2012).

In addition, all the participating teachers, except Mr. Opolot, were implementing a traditional lecture method in their lesson with some bit of demonstrations that they thought were inquiry-based instruction lessons at the beginning of the study. Mr. Opolot tried to implement structured IBI, unlike his colleagues, in one of the lesson observed in the beginning of the study. This may imply that Mr. Opolot tried to read about IBI after I interviewed him so that by the time I observed his lesson, he might have had improved his understating of IBI.

Chemistry teachers in School A improved their understanding and practice of inquiry-based instruction after attending the PD workshop on inquiry and NOS as seen from the above interviews and classroom observation notes. Most of School A teachers successfully implemented guided inquiry instruction despite the large classroom size (more than 50 students in the classroom). They were able to also explicitly engage learners in science practices as outlined in US documents (NRC, 2012) during the IBI lessons. The chemistry teachers in School B were not able to implement any type of inquiry towards the end of the study, except Ms. Akello, who tried the pre-inquiry based instruction.

Overall, the explicit reflective PD workshop on inquiry and NOS seems to have improved the chemistry teachers' understanding and practice of inquiry-based instruction. However, some teachers had a challenge of teaching with and about NOS in inquiry lessons and also bringing out the social-scientific issues.

Chapter 6: Relationship between Chemistry Teachers' NOS Epistemological Views and the Nature of Inquiry-Based Instruction Implemented in their Classroom

Introduction

In this chapter, I describe the NOS epistemological views of each of the eight teachers I interviewed in this study. I present the participating chemistry teachers' NOS epistemological views under the following five themes derived from coding the interviews with these chemistry teachers: Meaning of science; Tentativeness of scientific knowledge; Role of imagination and creativity in science; Differences between scientific theories and laws; and Relationship between science, society, and cultural values. I categorize participating teachers NOS epistemological views as either informed, naïve/ positivist, or mixed/contradictory about the contemporary views of NOS (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2001: Lederman, 2004, 2015) (see Table 17 below). I also present participating chemistry teachers' responses to the Myth of Science questionnaire before attending the PD workshop/beginning of the study and after attending the PD workshop/end of study in Tables 18 and 20. I conclude the chapter by discussing the relationship between NOS epistemological view and the inquiry-based instruction implemented in the classroom by the participating chemistry teachers in Schools A and B. I hence answer research question number three: To what extent does the NOS view of these chemistry teachers relate to the nature of inquiry implemented in their classrooms? I use the findings of Chapter 5 regarding the nature of inquiry implemented in their classrooms (Tables 15 and 16), and relating these to their NOS epistemological views to answer research question three.

Table 17. Categories of NOS epistemological views of Participating Chemistry teachers about the contemporary views of NOS (Lederman, 2004, 2015; Lederman, et al., 2001)

NOS aspect/Categories	Informed view [Contemporary view of NOS]	Naïve/ positivist view	Contradictory/ Mixed views
Meaning of science.	➢ Scientific knowledge is based on and derived from observation of natural world. ➢ Scientific knowledge is theory-laden and subjective	➢ Scientific knowledge is only obtained through experimentation and following a scientific method	➢ Science is product of scientific method and other methods
Tentativeness of scientific knowledge.	Scientific knowledge is subject to change with new observations and interpretations of existing observation.	Scientific knowledge is absolute truth, hence will not change.	Some scientific knowledge is tentative, whereas another is absolute truth.
Role of imagination and creativity in science	Scientific knowledge is partially based on human imagination and creativity. Data do not interpret themselves: scientists use their creative metaphors and imagination to make sense of the empirical world and to develop future research questions	Scientific knowledge is generated through step by step scientific method without creativity and imagination.	Some scientific knowledge is based on scientific method, whereas others is based on creativity /imagination.
Differences between scientific Laws and theories.	Laws describe patterns or regularities in data while theories are inferred explanation for natural phenomenon and mechanism for	Scientific Laws are proved, whereas theories are still under investigation.	Some scientific laws and theories are proved, whereas other are still under investigation.

NOS aspect/Categories	Informed view [Contemporary view of NOS]	Naïve/ positivist view	Contradictory/ Mixed views
	relationships among natural phenomenon.		
Relationship between science, society and cultural values.	Science is human endeavor and, as such, is influenced by the society and culture in which it is practiced. The values and expectations of the culture determine what and how science is conducted, interpreted, and accepted.	Scientists are objective human beings who are not influenced by their society and culture when conducting scientific investigation.	Some scientific knowledge is not influenced by social and cultural factors (objective knowledge) whereas others are influenced by social and cultural factors (subjective knowledge)

NOS Epistemological Views of Participating Chemistry Teachers in School A before Attending the Explicitly Reflective PD Workshop on Inquiry and NOS

In this section, I present the NOS epistemological views of the four participating chemistry teachers in School A before attending the explicit reflective PD workshop on inquiry and NOS (beginning of the study) under five themes. I also present their responses to the five assertions in the Myth of Science questionnaire before and after attending the PD workshop on inquiry and NOS. I conclude the section by presenting the summary of School A participating chemistry teachers' NOS epistemological views in Table 19.

Meaning of science. In this section, I discuss how I categorized each of the four participating teachers from School A according to their NOS views on the meaning of science.

Mr. Byamukama. Mr. Byamukama had a positivist view about science before attending the explicit reflective PD workshop on inquiry and NOS. He believed that science is different from other subjects because it is practical. For example, he argued that "For science, what you teach theoretically, you can also do practically." In this case, Mr. Byamukama believed that all scientific knowledge is generated through experimentation. He was not aware that science is theory-laden and that scientists use multiple methods of investigations. For example, a lot of scientific knowledge in Astronomy and Geology (Earth Sciences) have been generated without experimentation. Also in case of biology, nobody has conducted the experiments to test evolution.

Mr. Kigozi. Mr. Kigozi believed that science is the study that involves experiments to obtain knowledge. In this case, Mr. Kigozi had a naïve view of the nature of science. For example, during the interviews, he argued that "Science is the study of the knowledge gotten from experimentation on facts about something." Mr. Kigozi also asserted that the main difference between science and other subjects, like history and economics, is that science is not about fiction. Mr. Kigozi believed that all scientific knowledge is practical and experimental. He ignored the fact that science contains a lot of abstract theoretical knowledge where we may not do direct experiments, like evolution and astronomy.

Mr. Agaba. Mr. Agaba believed that science was the application of laws to understand how things work. He had a fairly informed view in this case. Below is what Mr. Agaba said during the interview:

> Researcher: So, if somebody called you and asked you what science is, what would you tell that person? Just a normal person is asking you what science is.
>
> Mr. Agaba: Science is the application of laws to understand how things work. We apply things to discover and know how many things work.
>
> Researcher: What makes science different from other things like history, geography?

> Mr. Agaba: Most of the things in science are empirical. If we are to go deeper and analyze whatever we talk about, it is testable, it can be related, and it can be seen. Most of the things in science are.

Mr. Agaba, in this case, had fairly informed view of NOS because according to the contemporary view of NOS, scientific knowledge is empirically based (Lederman, 2004, 2015; Lederman, et al., 2001). However, it is not true that all scientific knowledge is testable, for example, a lot of scientific knowledge in Astronomy cannot be tested practically.

Mr. Opolot. Mr. Opolot believed that science is the art of doing and discovering new things. He believed that science is different from other subjects because it is specific. In this case, Opolot had a naïve and positivistic view of NOS. Below is what exactly Opolot said during the interview:

> Researcher: If someone found you on the way and asked you what science is; how would you explain to that person?
>
> Mr. Opolot: I would tell that person that science is the art of doing and discovering new things.
>
> Researcher: What makes science or scientific disciplines different from other subjects like history and geography? What is the major difference?
>
> Mr. Opolot: I think that with us scientists we are more specific in the practices that we teach. The moment you go outside the fact you are wrong. Other subjects compromise this.

Mr. Opolot believed that science is about facts and hence absolute truth. This implied that Mr. Opolot is likely to emphasize the discrete fact when teaching chemistry content than the method and values of scientific knowledge. According to the contemporary views of NOS, scientific knowledge is tentative but durable ((Lederman, 2004, 2015; Lederman, et al., 2001). Hence, Mr. Opolot had naïve/ positivist views about the NOS.

The tentativeness of scientific knowledge. All the four participating chemistry teachers in School A believed that scientific knowledge would change with time due to new discoveries. Below is what each teacher said when asked whether the scientific knowledge produced by scientists may change or not with time:

"Scientific knowledge changes because knowledge keeps on changing." (Mr. Byamukama)

"Scientific knowledge would change in future because of the new additions resulting from research." (Mr. Kigozi)

"Scientific knowledge changes depending on new discoveries.'" (Mr. Agaba)

"Scientific knowledge could change since it depends on discovery." (Mr. Opolot)

It is evident from the above quotations that in this case, all the four participating chemistry teachers in School A had an informed NOS epistemological view concerning the tentativeness of scientific knowledge before attending the explicit reflective PD workshop on inquiry and NOS.

The role of imagination and creativity in science. In this section, I discuss how I categorized each of the four participating teachers from School A according to their NOS views on the role of imagination and creativity in science.

Mr. Byamukama. Mr. Byamukama believed that some scientists use scientific methods, whereas others utilize creativity when conducting a scientific investigation. In this case, Mr. Byamukama had mixed views about NOS. Below is what he said during the interview:

Researcher: So scientists try to find answers by doing investigations or experiments?

Mr. Byamukama: Yes

Researcher: Do you think that scientists use their imagination and creativity when they do these investigations, or they follow a scientific method?

Mr. Byamukama: I can say that some follow the scientific method and others use their creative thinking.

Researcher: What determines this? What is the determinant for some to use the scientific method and others not to?

Mr. Byamukama: I think that when someone is doing something as a trial, they use a scientific method to come up with a certain result. But you can repeat something using your invention and theory and get something different or something which has not been talked about.

Researcher: So, in which part of the investigation, for example, planning, experimentation, making an observation, analysis of data, interpretation, reporting results, which part do you think creativity and imagination are normally used among these in scientific investigation? Is it on a planning level, is it the method level, or is it during observation? Do you apply creativity when you observe or do you apply creativity when you are analyzing data or interpretation, or in reporting?

Mr. Byamukama: The priority is in experimenting.

Researcher: It is in experimentation?

Mr. Byamukama: Yes, in most cases, and then maybe when you are analyzing.

Researcher: So, you might use a lot of imagination?

Mr. Byamukama: Yes, to bring out something that matches.

Mr. Byamukama argued that scientists use a lot of creativity in experimenting. He claimed that in the other parts of Investigation (planning, observation, and analysis of data) and interpretation and recording results, scientists usually apply the scientific method. Since Byamukama believes in scientific methods to a great extent, it implies that he holds a positivistic/ mixed view of NOS in this case.

Mr. Kigozi. Kigozi strongly believed that imagination and creativity are very useful in science. He argued that “The best scientist is that one who talks the scientific language and has creativity." In this case, Kigozi had an informed view of NOS accordingly. Below is what Kigozi said during the interview:

> Researcher: Scientists try to find out the answers to their questions by doing experiments or investigations like you said. Do you think that scientists use their imagination and creativity when they do these investigations or do they follow the scientific method?
>
> Mr. Kigozi: Experiments are based on theories that have been proved. So, through these experiments, they can think and imagine.
>
> Researcher: What about a scientific method? Do you mean that a scientific method is not used? Is it possible to have creativity and at the same time follow the step by step scientific method as we see it in the textbooks? Because as they say, science follows the scientific method. Is it possible to have both?
>
> Mr. Kigozi: The best scientist is the one who talks the scientific language and has creativity.

From the above interview, it is evident that as much as Mr. Kigozi believes that imagination and creativity are very important in science. He also thinks there is no room for creativity in secondary school science practical lessons. This could be one of the factors that limits Mr. Kigozi from allowing his students to be creative in chemistry practical lessons. Hence, he may continue with cookbook lab practical lessons, accordingly.

Mr. Agaba. Mr. Agaba believed that scientists use both creativity/imagination and the scientific method when they are conducting the scientific investigations. In this case, Mr. Agaba had a fairly informed view of NOS. Below is what Mr. Agaba said during the interview:

> Researcher: Scientists find answers to their questions by doing investigations and experiments. Do you think these scientists use imagination and creativity when they are doing these experiments? Is there imagination and creativity or there is the scientific method?
>
> Mr. Agaba: It is a combination because we imagine then after you do the experiment to see whether what you are imagining is possible. So, I think it is a combination of the two.
>
> Researcher: What about creativity? Is there creativity?
>
> Mr. Agaba: Yes. If you are not creative, you cannot do science.

> Researcher: But is it possible to be creative and at the same time follow the scientific method?
>
> Mr. Agaba: Yes
>
> Researcher: I thought the scientific method is systematic.
>
> Mr. Agaba: No. By the way, when we talk about scientific methods, that's why we say that we follow it and don't become creative by modifying some of the methods then you may not come up with anything. Because when you follow only that, then you are not creating something new. So, as you do something, then you also say, "Suppose I did this," then you formulate your hypothesis and work out and see what it will come to. Otherwise, when you follow only what somebody else did, are you doing anything new?

Per the above interview, Mr. Agaba indeed showed that he is fairly informed about NOS. This may be due to his experience when he was doing research in the MSc. (chemistry) program.

Mr. Opolot. Mr. Opolot believed that current scientists mainly follow the scientific method, unlike in the past where scientists used creativity/ imagination. In this case, Mr. Opolot had a naïve view of NOS because creativity and imagination are vital in scientific investigation to date. Below is what Mr. Opolot said during the interview:

> Researcher: So, scientists try to answer questions by doing experiments and investigation. Do you think these scientists use their imagination and creativity or do they follow the scientific method?
>
> Mr. Opolot: Nowadays they follow the scientific method, but I think in those days those people used to imagine.
>
> Researcher: So, do scientists these days use that systematic step by step procedure?
>
> Mr. Opolot: Yes.
>
> Researcher: So, all scientific investigations and planning require the systematic methods. Is there any part where you can have a lot of creativity and imagination?
>
> Mr. Opolot: We can use it, but we have to find it out using the scientific method exactly. You imagine something, and after the imagination, you can try to find out scientifically if what you are trying to imagine exists in that form.

Mr. Opolot believed that the current scientists utilize scientific method more than creativity/imagination. According to the contemporary view of NOS, scientific knowledge is partially based on human imagination and creativity (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, Mr. Opolot had naïve NOS epistemological views as far as the role of imagination and creativity in science

Differences between scientific theory and law. All the four participating chemistry teachers in School A believed that scientific laws are proven, whereas the scientific theories are still under investigation. Below is what each teacher said when asked to explain the main difference between the scientific theories and laws:

> "To me, a law has been agreed upon by various scientists, so it's proved, and then a theory is still subject to research. These are ideas gathered by a few people who are still talking about some idea. It is not yet subject on a global level by all scientists to agree with that." (Mr. Byamukama)
>
> "A scientific theory is under investigation whereas a scientific law has been proved." (Mr. Kigozi)
>
> "A scientific law is something that has been investigated, and there is some concrete evidence. But a theory contains so many things. I think a law is stronger because a law comes from theory. You first develop a theory then from there you come up with law." (Mr. Agaba)
>
> "There is a difference. A law is something that has been proven beyond doubt, but a theory is still under investigation. You find some factors differing in what the theory is talking about especially when people have discovered other things." (Mr. Opolot)

In this case, all the four chemistry teachers in School A had a naïve view of the nature of science as far as the difference between scientific laws and theories is concerned before attending the explicitly reflective PD workshop on inquiry and NOS. Per the contemporary view of NOS, scientific laws and theories serve different purposes (Lederman, 2004, 2015).

The relationship between science, society, and cultural values. In this section, I discuss how I categorized each of the four participating teachers from School A according to their NOS views on the relationship between science, society, and cultural values.

Mr. Byamukama. Mr. Byamukama believed that science influences culture to a certain extent. However, he also argued that we have universal science. Hence, Mr. Byamukama's NOS views, in this case, were contradictory and mixed:

> Researcher: Is there a relationship between science, society, and cultural values or is a science just a universal body which is not influenced by any culture?
>
> Mr. Byamukama: They are related. Science influences culture, but culture does not influence science.
>
> Researcher: So, that means we do not have a universal science.
>
> Mr. Byamukama: No, we do not have a universal science, to me.
>
> Researcher: Yes, I am getting your opinion, do not worry. I am not interested in textbook knowledge; I am interested in what you think.
>
> Mr. Byamukama: By not having a universal science, most of these things are predictable. For example, when we go to different countries, their science is based on their culture. What people can get in their cultural level is the beginning of the development of their science.

Mr. Byamukama views were contradictory and mixed because he believed in universal science and at the same time he argued the society/culture influence science. According to the contemporary view of NOS, science is human endeavor and, as such, is influenced by the science and culture in which is practiced. The values and explanation of the culture determine what and how science is conducted, interpreted, and accepted (Lederman, 2004, 2015; Lederman, et al., 2001).

Mr. Kigozi. Mr. Kigozi believed that there is a relationship between science and culture. However, when probed further, he argued that we have universal science. Therefore, Mr. Kigozi had mixed views about NOS in this case. Below is what Kigozi said during the interview:

> Researcher: Is there a relationship between science, society and cultural values, or is science objective and in other words not influenced by culture?
>
> Mr. Kigozi: I would say they are so related.

Researcher: Is there African science like you talked about African chemistry? Because when you say African chemistry it means there is a relationship between chemistry and culture, or do we have universal chemistry and universal science?

Mr. Kigozi: The depths of chemistry are also like some magic in African things. You say I can do this, so some people say that is magic and somewhere things can happen without other things. Then they say, how come the thing can change from colorless to pink? So, people think that this is African chemistry. So, some scientific things are like myths. For example, when you are doing research for the students, of course, there is some explanation when hydrogen makes a pop sound. When I go back to African chemistry some things can happen without you seeing. It's just a matter of me getting a burning stick and putting it in hydrogen, and it makes a popping sound.

Researcher: So, what is your conclusion?

Mr. Kigozi: My conclusion is that science has almost a direction it follows with culture.

Researcher: Do you think what we follow as science is just Western culture? Is it a culture of Europeans?

Mr. Kigozi: Because science is universal, if I talk about oxygen, the whole world will agree that oxygen supports burning.

Researcher: But nobody has ever seen oxygen, so how are we sure that what these people tell us is oxygen? Because have you read about the phlogiston theory. At around 1800 A.D (about 200 years ago), scientists thought that combustion involves the release from a fuel of mysterious material called phlogiston. It is Joseph Priestley (1733-1804 A.D) who carried experiments and confirmed that phlogiston does not exist. Hence, oxygen is dephlogisticated air.

Mr. Kigozi: The confirmatory tests for oxygen are there, and that is oxygen.

Researcher: But we might find that it is another element that causes that to burn. Assuming we go to Mars and the same situation happens then, we know it is not oxygen.

Mr. Kigozi: Yes, I think that is where the facts come in.

Researcher: There is what we call, what we see and then the explanation. What declares this explanation as exactly what we see or could it be different?

Mr. Kigozi: What we see may not be the explanation because if I look at ethanol, it is colorless.

Mr. Kigozi like Mr. Byamukama had mixed view of NOS about the relationship between science, society, and culture on science because he believed in existence of universal science which is objective and also argued that society influence some science. According to the contemporary view of NOS, science is human endeavor and, as such, is influenced by the science and culture in which is practiced. The values and explanation of the culture determine what and how science is conducted, interpreted, and accepted (Lederman, 2004, 2015; Lederman, et al., 2001).

Mr. Agaba. Mr. Agaba believed that culture influences science and science affects culture. He went on to give examples in society related to science. In this case, Mr. Agaba had an informed view of the NOS. Below is what he said during the interview:

> Researcher: Is there a relationship between science, society and cultural values? Do you think culture influences science?
>
> Mr. Agaba: Yes.
>
> Researcher: How?
>
> Mr. Agaba: When we talk about culture and science, I see one affecting the other. Science can affect culture and culture can affect science. Because what is culture, culture is what people believe in and I think that what people believe in comes from within the people, and within the people comes the chemistry. This is because the way we behave when we look at the way human beings behave and you relate to the way we do things. Like look at the atom and the way it loses electrons; the way they are bonded, you will find that even marriage itself can be explained using science. So, marriage is part of the culture, then the atoms and the way they lose electrons and gain, etc. man is attracted to a woman, which is all that happens in science. So, meaning that science and culture are much related and therefore even science can affect culture.

Mr. Agaba believed science, society/ culture influence each other. According to the contemporary view of NOS, science is human endeavor and, as such, is influenced by the science and culture in which is practiced. The values and explanation of the culture determine what and how science is conducted, interpreted, and accepted (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, in this case, Mr. Agaba had informed view of the NOS.

Mr. Opolot. Mr. Opolot believed that culture influences science. However, when I probed further, he gave an example of the Maasai's (one of the tribes in Kenya) traditional knowledge as an example of the influence of culture on science. Then later he changed his views and said that culture does not influence the Western world of science accordingly. In this case, Mr. Opolot had contradictory and mixed views about the influence of culture on scientific knowledge. He believed that culture does not influence Western science. Below is what Mr. Opolot said during the interview:

> Researcher: So, is there a relationship between science, society and cultural values? Does culture influence science? Or does science influence culture?
>
> Mr. Opolot: Culture influences science.
>
> Researcher: How?
>
> Mr. Opolot: Like if you look at Kenya and the Maasai culture, they were born herbalists. So culturally all they do deals with disease treatment with herbs, etc.
>
> Researcher: But is the Maasai's knowledge considered to be science?
>
> Mr. Opolot: It is science if they can get medicine and give it and someone gets cured.
>
> Researcher: But you said science is about facts, but someone can challenge the Maasai knowledge that it is not universally accepted. It can be considered superstition. Don't you think so?
>
> Mr. Opolot: For sure it is not yet proven, and yes, to some extent it can be considered superstition.
>
> Researcher: Here when I say science I mean this knowledge which has been qualified, which the whole world has accepted. Do you think that knowledge is neutral and objective or has it been influenced by culture?
>
> Mr. Opolot: It is objective.
>
> Researcher: Isn't there an influence of culture there or society?
>
> Mr. Opolot: It is not there because if you bring culture, they will ask you to prove and yet cultural ways of proving things do not apply. Culture majorly deals with things in a natural setting.

Mr. Opolot had contradictory views of NOS because he believed that some science is influenced by culture whereas the western science is free from cultural influence. According to the contemporary view of NOS, science is human endeavor and, as such, is influenced by the science and culture in which is practiced. The values and explanation of the culture determine what and how science is conducted, interpreted, and accepted (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, Mr. Opolot NOS views were contradictory/mixed as far as the relationship between science, society, and culture.

Chemistry teachers' responses to the Myth of Science questionnaire before and after attending the explicit reflection PD workshop on inquiry and NOS in School A. Here I present the responses by participating chemistry teachers on the five NOS statements contained in the Myth of Science questionnaire. I categorized a science teacher who disagreed (D) with all the statements as having informed NOS epistemological views (scores 100%). On the other hand, I categorized a science teacher who agreed (A) with all the statements as having a naïve view of NOS.

Table 18. Response to the Myth of Science Questionnaire at Pre-PD and Post PD of the Study

Teacher	Mr. Byamukama		Mr. Kigozi		Mr. Agaba		Mr. Opolot	
Question	Pre-PD	Post PD	Pre-PD	Post PD	Pre-PD	Post PD	Pre-PD	Post PD
1 Hypotheses are developed to become theory.	D	D	A	D	D	D	A	D
2 Scientific theories can be developed to become laws.	A	A	A	A	A	A	A	A
3 Scientific knowledge cannot be changed.	D	D	D	D	D	D	D	D
4 Accumulation of evidence makes scientific	A	D	A	U	A	A	A	D

Teacher	Mr. Byamukama	Mr. Kigozi	Mr. Agaba	Mr. Opolot
knowledge more stable.				
5 Scientific models (e.g., atomic model) expresses a copy of reality.	A U	D D	A A	U U

Note. A = Agree, D = Disagree and U = Uncertain

From Table 18, it is evident that all the four participating chemistry teachers in School A had a naïve view of NOS as far as the *relationship between the scientific laws and theories* is concerned. This is because all of them agreed that scientific theories could be developed to become laws. This finding agrees with what the teachers said during the interviews, where they claimed that "the scientific laws are proven, whereas the theories are still under investigation." This naïve view was maintained by the participating chemistry teachers even after attending the explicitly reflective PD workshop on inquiry and NOS. However, the participating chemistry teachers in School A had an informed view of NOS before and after attending the explicitly reflective PD workshop on inquiry and NOS as far as *tentativeness of scientific knowledge* was concerned. All the four teachers disagreed (D) with the statement that, "scientific knowledge cannot be changed" (see Table 18). This agreed with their responses in the oral interviews.

Section Summary

The four participating chemistry teachers in School A had a naïve view of NOS before and after attending the explicit reflective PD workshop on inquiry and NOS as far as the difference between scientific laws and theories was concerned (see Tables 18 and 19). However, all the four participating chemistry teachers had informed views of NOS as far as the tentativeness of scientific knowledge is concerned (see Tables 18 and 19). They had mixed, contradictory and positivist views of NOS on the rest of NOS aspects. They also scored less than 50% on the Myth of Science questionnaire because they agreed with most of the NOS statements in the questionnaire before attending the explicit reflective PD workshop on inquiry and NOS. Mr. Byamukama, Mr. Kigozi, and Mr. Opolot improved their scores on the Myth of Science questionnaire from 40% to 60% after attending the explicit reflective PD workshop on inquiry and NOS.

Table 19: Summary of NOS Epistemological Views of the Four Participating Chemistry Teachers in School A Before Attending the Explicit Reflective PD Workshop On Inquiry and NOS (Beginning of the Study) Under Five Themes

Name of the Teacher	*Mr. Byamukama*	*Mr. Kigozi*	*Mr. Agaba*	*Mr. Opolot*
Meaning of science	"For science what you teach theoretically you can also do practically." *[Positivist view]*	"Science is the study of the knowledge got from experimentation on facts about something." *[naive view]*	"Science was the application of laws to understand how things work." [*fairly informed view]*	"Science is the art of doing and discovering new things." [*naïve and positivistic view]*
Tentativeness of scientific knowledge	"Scientific knowledge changes because knowledge keeps on changing." *[Informed view]*	"Scientific knowledge would change in future because of the new additions resulting from research." *[Informed view]*	"Scientific knowledge changes depending on new discoveries." *[Informed view]*	"Scientific knowledge could change since it depends on discovery." *[Informed view]*
Role of imagination and creativity in science	"Some scientists use scientific methods, whereas others utilize creativity when conducting a	"The best scientist is that one who talks the scientific language and has creativity."	"Scientists use both creativity/imagination and scientific method when they are conducting the scientific investigations."	"The current scientists mainly follow the scientific method, unlike in the past where scientists

Name of the Teacher	*Mr. Byamukama*	*Mr. Kigozi*	*Mr. Agaba*	*Mr. Opolot*
	scientific investigation." *[Mixed views]*	[*Informed view]*	[*fairly informed view]*	used creativity/ imagination." *[naive view]*
Differences between scientific theories and laws	*"*Law has been agreed upon by various scientists, so it's proved, and then a theory is still subject to research." *[naive view]*	*"*A scientific theory is under investigation whereas a scientific law has been proved." *[naive view]*	*"*A scientific law is something that has been investigated, and there is some concrete evidence. But a theory contains so many things." *[naive view]*	*"*A scientific law is a law that has been proved beyond reasonable doubt, whereas a theory is still under investigation." *[naive view]*
Relationship between science, society and cultural values	*"*Science influences culture to a certain extent." "We have a universal science." *[contradictory and mixed*]	*"*There is a relationship between science and culture." "Science has almost a direction it follows with culture." "We have a universal science." *[Mixed views]*	*"*Culture influences science and also science affect culture." *[Informed view]*	*"*Believed that culture influences science." *"*Culture does not influence the Western world science." *[contradictory and mixed*]

NOS Epistemological views of Participating Chemistry Teachers in School B before Attending the Explicitly Reflective PD Workshop on Inquiry and NOS

In this section, I present the NOS epistemological views of the four participating chemistry teachers in School B at the beginning of the study under five themes. I also present their responses to the five assertions in the Myth of Science questionnaire at the beginning and end of the study. I conclude the section by presenting the summary of School B participating chemistry teachers' NOS epistemological views in Table 20.

The meaning of science. In this section, I discuss how I categorized each of the four participating teachers from School B according to their NOS views on the meaning of science.

Mr. Bbosa. Mr. Bbosa believed that science is the study of nature and that science is mainly different from other subjects because science is practical, unlike other subjects, such as geography, which are not entirely practical. Mr. Bbosa believed that science is also different because we use all our senses, unlike other subjects which are not the same. Below is what Mr. Bbosa said during the interview:

> Researcher: So, if a person met you on the way and asked you what science is, how would you respond?
>
> Mr. Bbosa: I would tell him or her that it is the study of nature.
>
> Researcher: So, what makes science different from other subjects like history?
>
> Mr. Bbosa: Science is practical, and much of it is practical.
>
> Researcher: But I think subjects like geography are also practical?
>
> Mr. Bbosa: Geography has parts that have some science in it, that is why it is close, but not all of it is practical.

From the above interview extract, this shows that Mr. Bbosa's NOS epistemological views of the meaning of science are positivistic in nature. He thinks that science is special from other subjects because we use all our senses compared to other subjects. This implies that Bbosa holds a positivistic view of NOS, which is typical of many science teachers in Uganda.

Mr. Ssentumbwe. Mr. Ssentumbwe believed that science is the study of nature and science is different from other subjects like history because it is practical and deals with real findings. When I challenged Mr. Ssentumbwe that other subjects like fine arts are also practical, he defended his view by arguing that people in the arts do not come up with conclusions hence it cannot be the same. Mr. Ssentumbwe had a positivistic and naïve epistemological view about science. Below is the interview extract with Mr. Ssentumbwe:

Researcher: Okay, if a person found you on the way and asked you what is science, in your words what would you say?

Mr. Ssentumbwe: It is the study of nature.

Researcher: Okay, what makes science different from other subjects like history?

Mr. Ssentumbwe: Of course, science is practical.

Researcher: Or maybe history is science?

Mr. Ssentumbwe: Science deals with real findings.

Researcher: What do you mean by practical?

Mr. Ssentumbwe: Practical are the ones people can touch on.

Researcher: But geography, I thought that they go to look at towns?

Mr. Ssentumbwe: That is art, but what have you done and what have you found. So, do you mean you can go to the field and get something and mix it with something and then have findings?

Researcher: What do you mean by practical? I thought if a person does something, do you mean that astronomy is not science because also their people look at stars?

Mr. Ssentumbwe: You just go to the stars.

Researcher: No, you don't go there. All these, Galileo's didn't go there, they just looked at the stars and formulated theories, so don't we consider them a science?

Mr. Ssentumbwe: That is why I said science is individual and the definition is broad.

Mr. Ssentumbwe believed science is special and different from other arts because it is practical but other subjects are more theoretical. According to the contemporary view of NOS, scientific knowledge is theory-laden and subjective (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, Mr. Ssentumbwe had positivist/ naïve views of NOS in this case.

Mr. Muhangi. Mr. Muhangi believed that science was about the matter and its components due to the bias he has in chemistry as a science. He also believed that science was different from other arts subjects because it is a practical subject that requires manipulation and even development skills. In this, Mr. Muhangi had a fairly informed view of NOS. Below is what Muhangi said in the interview.

> Mr. Muhangi: Science talks about the behavior of matter because I have a bias in chemistry and its components.
>
> Researcher: What makes science different from other subjects like history, geography, and psychology?
>
> Mr. Muhangi: It is a practical subject which requires manipulative and analytical skills.

Mr. Muhangi believed that science is practical and involves experimentation. According the contemporary views of NOS, scientific knowledge is based on and/ or derived from observation of natural world. (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, in this case, Mr. Muhangi had fairly informed views of NOS.

Ms. Akello. Ms. Akello believed that science is the study of nature. She also believed that in science we study what we see, unlike other subjects that are not science. Ms. Akello argued that subjects like arts could also be regarded as science to some extent since we can see what we are doing. In this case, Akello had mixed views about NOS. Here is what she said during the interview:

> Ms. Akello: In my words, I would say science is the study of nature, simply nature that is the living things and the non-living things. That's nature.
>
> Researcher: Why do you think science is different from history?
>
> Ms. Akello: What I know from science is that in science, you study something you see that very time. From experience, if you are studying about plants, you can pick a plant, and you study it at that very time. But in history, you have to imagine it's more like imagination. It happened because there was something available.
>
> Researcher: What if there were some branches like geology when they talked about the earth and how it is all round, over a million years. Is it easy to see those?
>
> Ms. Akello: It's not easy to see, but there are things that show evidence.

Researcher: What about art, why aren't we able to prove it is science?

Ms. Akello: Art, can be science because it can show evidence.

Researcher: So that means that subjects we consider not to be science also have science.

Ms. Akello: Art has science.

Ms. Akello believed that there is no big difference between science and arts because arts also contain some science. However, she also believed that in science we study what we can see. Hence, in this case, Ms. Akello had mixed views about NOS.

The tentativeness of scientific knowledge. In this section, I discuss how I categorized each of the four participating teachers from School B according to their NOS views on the tentativeness of scientific knowledge.

Mr. Bbosa. Mr. Bbosa believed that scientific knowledge might change in the future. However, Bbosa could not explain his claim that this scientific knowledge may change in the future. Below is what Mr. Bbosa said during the interview:

> Researcher: Scientists produce scientific knowledge. Do you think this knowledge may change in future?
>
> Mr. Bbosa: It may change.
>
> Researcher: What could make it change? What I mean is, we have the knowledge which we are teaching the learners in textbooks. Is this knowledge truth or tentative?
>
> Mr. Bbosa: When we look at our knowledge, we see that it is passed on to the learner until the learner goes into his or her application. Like when we are analyzing some of what we call qualitative analysis and the presence of ions in certain components. The learner will move with that knowledge, and when he or she is analyzing foods or other things, this knowledge would help him or her.

From the above interview, Mr. Bbosa did not give reasons why he thinks that scientific knowledge is tentative. Hence, in this case, Mr. Bbosa had a fairly informed view of NOS.

Mr. Ssentumbwe. Mr. Ssentumbwe believed that scientific knowledge always changes. However, he was not able to give instances where scientific knowledge changed in chemistry. In this case, Mr. Ssentumbwe had a fairly informed epistemological view of NOS despite his failure to provide any example from his teaching subject. This implies that he may not be able to teach with and about NOS in his lessons. Below is what Mr. Ssentumbwe said in the interview:

> Researcher: Scientists produce scientific knowledge. Do you think that this knowledge may change in future?
>
> Mr. Ssentumbwe: It always changes
>
> Researcher: Do you have an example you can give me where scientific knowledge changed?
>
> Mr. Ssentumbwe: In the field of what?
>
> Researcher: You can choose any even if it is in the field of biology but provided it is science. You can tell me that for example in this area people used to think this but due to technology then … even if you have an example in astronomy as long as it is science.
>
> Mr. Ssentumbwe: There, I don't have.

Mr. Ssentumbwe believed that scientific knowledge may change, however, was not able to explain the instances how scientific knowledge changes. According the contemporary view of NOS, scientific explanations are likely to change with the addition of new evidence or reinterpretation of prior evidence (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, in this case. Mr. Ssentumbwe had fairly informed view of NOS.

Mr. Muhangi. Mr. Muhangi believed that scientific knowledge would change in time due to the changes observed in technology. In this case, Muhangi had an informed epistemological view of NOS.

> Researcher: Science produces scientific knowledge. Do you think this knowledge may change in future or is it the absolute truth?

> Mr. Muhangi: I think this knowledge may change. As we advance in technology and research, the knowledge will change.

Ms. Akello. Ms. Akello believed that scientific knowledge might change with time due to the new developments in research. She gave the example of evolutions where at first Lamarck thought that the long necks of giraffes were due to their stretching to eat the leaves on the tall trees, which was later proved to be a false theory because the giraffe's long neck is natural and not caused by nurture (environment). In this case, Akello had an informed epistemological view of NOS. Below is what Ms. Akello said during the interviews:

> Researcher: Do you think that the current scientific knowledge may change or is science an absolute truth? Give an example to support your answer.
>
> Ms. Akello: No, at times this is why people keep on doing research. According to the Limburg, for him, he says the reasons why giraffes developed water storage is because they kept on eating and feeding on trees. They developed longer necks and yet it was not natural so when they researched further other scientists discovered it wasn't that.

Ms. Akello gave a good example to explain how scientific knowledge may change. According to the contemporary view of NOS, scientific knowledge is subject to change with new observations and with the reinterpretation of existing observation ((Lederman, 2004, 2015*;* Lederman, et al., 2001). Hence, the example of the change in the explanation of the causes of the long neck of giraffes by Ms. Akello indicated that she had informed view of NOS as far as tentative of scientific knowledge was concerned

The role of imagination and creativity in science. In this section, I discuss how I categorized each of the four participating teachers from School B according to their NOS views on the role of imagination and creativity in science.

Mr. Bbosa. Mr. Bbosa believed that scientists use both imagination and creativity during a scientific investigation. He emphasized the fact that scientists usually utilize creativity and imagination during the planning phase. However, during the observation phase, there is no need to be creative. Hence, Bbosa believed that observation is objective. This view is contrary to the contemporary view of NOS, which argues that scientific observation is theory led (Lederman, 2004, 2015; Lederman, et al., 2001). Therefore, in this case, Mr. Bbosa had positivist views of NOS. Here is what Bbosa said during the interview:

> Researcher: Do you think that when these scientists carry out these experiments, they use imagination/creativity or do they use the scientific method?
>
> Mr. Bbosa: They use both imagination and creativity, as well as the scientific method.
>
> Researcher: In which phase, do you think scientists apply imagination/creativity? Is it during the investigation, planning, making observations, analysis, etc.?
>
> Mr. Bbosa: In the planning phase one can use imagination/creativity, but during the observation phase, one doesn't need to imagine.

Mr. Bbosa believed in objective observation during an investigation. According to the contemporary view of NOS, scientific knowledge is created from human imagination and logical reasoning (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, Mr. Bbosa had positivist view of NOS bout the role of creativity and imagination.

Mr. Ssentumbwe. Mr. Ssentumbwe believed that scientists always followed a scientific method in their investigation without applying any creativity or imagination due to limited time and funds available for research. In this case, Mr. Ssentumbwe had a naïve view of NOS. Below is what he said during the interview:

> Researcher: Okay, scientists try to find answers to their questions by doing investigations. Do you think that scientists use their imagination and creativity or do they follow a scientific method?
>
> Mr. Ssentumbwe: They follow what is in the scientific method in the literature.
>
> Researcher: Why do you think that they follow the scientific method? Why do you think there isn't any creativity?
>
> Mr. Ssentumbwe: Due to limited time for research and funds for research.

Mr. Ssentumbwe had a common misconception by many science teachers who think that the scientific method is the only method used during scientific investigation. He did not appreciate the role of creativity and imagination in scientific investigation. According to the contemporary view of NOS, scientific knowledge is partially based on human imagination and creativity (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, in this case, Mr. Ssentumbwe had naïve view about NOS.

Mr. Muhangi. Mr. Muhangi believed that scientists follow a scientific method during scientific investigations. However, at the same time, he argued that scientists also utilize imagination and creativity when planning their investigation. He said that the scientific method is mainly followed during experimentation, making observations and analyzing results. Hence, in this case, Mr. Muhangi's epistemological views of NOS were mixed as far as the roles of creativity and imagination in science were concerned. Here is what Mr. Muhangi said during the interview about the role of creativity and imagination in science:

> Researcher: Scientists try to find answers to their questions by doing investigations and experiments as you said. Do you think these scientists use imagination and creativity or do they follow a scientific method?
> Mr. Muhangi: I think they follow a scientific method.
> Researcher: So, there is nothing like creativity and imagination?
> Mr. Muhangi: Of course, it is imagination and creativity that you can follow the scientific method that gives you the result.
> Researcher: So, in which part of the experiment or investigation is imagination/ creativity is used?
> Mr. Muhangi: The planning part of it.
> Researcher: And where is scientific method always used?
> Mr. Muhangi: Experimentation and then making observations and analysis.

Mr. Muhangi had mixed with about the role of creativity and imagination in scientific investigation because he also believed in scientific method. Hence he did not take a stand about the clear role of creativity and imagination in scientific investigation

Ms. Akello. Ms. Akello believed that scientists apply both the scientific method and creativity when conducting a scientific investigation. When probed further, she again said that scientists mainly use the scientific method. This implied that she had a naïve NOS view in this case since she believed that the scientific method is a reality. Here is what Akello said during the interview:

> Researcher: Okay. Scientists carry out investigations through experiments. Do you think the scientists use creativity and imagination or do they follow a scientific method?
>
> Ms. Akello: They follow scientific methods.
>
> Researcher: So, is there no opportunity to use creativity and imagination?
>
> Ms. Akello: They use creativity also.
>
> Researcher: When?
>
> Ms. Akello: For instance, creativity involves thinking.
>
> Researcher: Creativity involves not doing things in a systematic way. Like when they talk about creative dance, it has no pattern, but there is a dance which is structured, and when you look at it, it is structured, and you can even follow and even duplicate. With a creative dancer, you can't even copy his/her dance.
>
> Ms. Akello: I thought thinking brings creativity.
>
> Researcher: That is what I am saying. What do you think? Now with thinking, there is critical thinking, divergent thinking, thinking has very many forms, but here I am talking about scientific method vis-a-vis creativity. Because like you see the taxi drivers when they are driving from here to town they follow the line even in the traffic jam. But haven't you ever seen a taxi driver passing on the wrong side? That is what they mean by the creativity that creativity tries to violate the real norm. So, what do you think?
>
> Ms. Akello: They follow a scientific method.
>
> Researcher: So, there is no creativity?
>
> Ms. Akello: There is no creativity, but I think there are some things in which they use creativity.
>
> Researcher: Can you give me an example of cases or scientists you think did not follow the scientific method? Okay, you can think about it, but when you come across it, you can tell me. But do you have an idea about where creativity could be used? For example, you have the planning, experimenting, making observations, data analysis, and interpretation and reporting among these steps of investigation, where do you think there is flexibility because creativity also means flexibility. Where do you think, scientists can divert?

> Ms. Akello: Maybe in experimenting because, in observation, you observe what you see and what you record, but I think in experimenting one can divert.

Ms. Akello was not sure whether scientists apply creativity and imagination when conducting scientific investigation. When I probed further, she finally accepted that scientists use scientific method during the scientific investigation. Hence, in this case, Ms. Akello had naïve view of NOS.

Differences between scientific theory and law. All the four participating chemistry teachers in School B believed that scientific laws are proven, whereas the scientific theories are still under investigation, and that the scientific laws come from theories. Below is what each teacher said when asked to explain the main difference between the scientific theories and laws:

> "I think the law comes from theory. That is the difference." (Mr. Bbosa)
>
> **"**But the law is just stating; then the theory is describing. The law is a summary of a theory to me." (Mr. Ssentumbwe)
>
> **"**I think a law is proved and a theory is something like a hypothesis." (Mr. Muhangi)
>
> **"**A scientific law is like a statement which must not be changed, and it is stated by a certain scientist, and a theory is something that is not confirmed. Like atomic theory, it is not factual. I think it has some questions; I think that someone else with time will come and expound on that theory. A theory is something which can be argued but a law is something which other people have tried to do and argue about it, and they carry out experiments and find that that law is true, so they don't argue about it." (Ms. Akello)

In this case, all the four participating chemistry teachers in School B had a naïve view of the relationship between law and theory. Per the contemporary view of NOS, scientific laws describe relationships observed or perceived of a natural phenomenon, while theories are inferred explanation for the natural phenomenon (Lederman, 2004, 2015*;* Lederman, et al., 2001). Hence, scientific laws are not superior to scientific theories, but they serve different purposes in science (Lederman, 2004, 2015*;* Lederman, et al., 2001).

The relationship between science, society and cultural values (subjectivity in science). In this section, I discuss how I categorized each of the four participating teachers from School B according to their NOS views on the relationship between science, society, and cultural values.

Mr. Bbosa. Mr. Bbosa believed that there is science attached to a culture like medicine. However, Mr. Bbosa also believed that there was universal science that is not influenced by culture/society. In this case, Bbosa had mixed/ contradictory views about the influence of society/cultural values on scientific knowledge:

> Researcher: Is there a relationship between science, society and cultural values or do we have universal science?
>
> Mr. Bbosa: Yes, there is some science attached to a culture like medicine. People use local medicine to treat illnesses.
>
> Researcher: But that is considered traditional medicine and it is not identified as scientific knowledge. Is it not like physics or chemistry?
>
> Mr. Bbosa: When you look at it critically, it is science. We, as scientists, use plants to get medicine.
>
> Researcher: But when you use these plants they tell you to give their scientific names. Does this mean that their scientific names are different from their common names?
>
> Mr. Bbosa: Yes, you have that name as the name of the plant, but have you gone ahead to see what that plant is used for? Some plants are food, and at the same time, they are medicinal. So, people have used the traditional knowledge, and there are things that they have based on to pick out some plants to work as a medicine. When you come into the field of science, you may analyze plants, and when you look at the components of those plants, you will discover that those plants which are used as medicine contain elements which may not be harmful to people's bodies. When such plants are taken/consumed, they kill the germs in the human body.
>
> Researcher: So, what do you conclude? Does that mean that different parts of the world have different science and there is no universal science?
>
> Mr. Bbosa: They have a universal science.
>
> Researcher: So that means we have different sciences in different communities?

Mr. Bbosa: Those communities where the Europeans took their science use a universal version and where it has not reached it is not there, we find African chemistry.

Researcher: Now explain to me about this African chemistry. That is what I am interested in?

Mr. Bbosa: African chemistry can mix things and get different things. What I am telling you is where people cannot access drugs, people use their traditional ways to treat diseases. There are people who know that when you get a wound, you get a certain herb and put it on that wound. These people came with their hydrogen peroxide and spirit, when you get it, you put it there.

Researcher: For example, when you see the black Jack, somebody will say that when you put it on the wound, it will get cured. This might agree with the universal theory because it contains iodine which is also found in the iodine in the hospital it's just the concentration which is different, and it will kill the bacteria. But there is a situation, and in physics, it is clearer because in physics people talk about ghosts, but in western science, people are talking about waves, like when a person is here, and he is talking to a person in London, and there is no wire in between, and they are using a mobile phone. Another person will say that this is a ghost, another one will say that these are waves.

Mr. Bbosa: But anyway, what I am trying to say is that there are some communities which are ahead of others with research and you may hear where there is no room for research or discovery, which is brought by Europeans. Science is different you will go to certain countries where people are either venturing into too much of research, others are venturing into medicine. You see there is something that was started and people are also given a direction by which they are supposed to move. This science which is here like this teaches chemistry which was taught in the 19th century, and it is the same chemistry we are teaching now. So, what I am trying to tell you is that there are so many things which have not been discovered in our community, but when you go abroad, there are many things. If it is a teacher, for example, he will only sit down and find the possible ways of doing these things in different ways, and they are very theoretical. Science is a science, aims are allocated, and research is done to discover these things.

From the above interview excerpt, Mr. Bbosa thinks that culture influences science. He also argues that the current science we are teaching in school, as much as it is a European version, it is universal in nature because it has been accepted by the world.

Mr. Ssentumbwe. According to Mr. Ssentumbwe, science and culture move hand in hand. He also argued that when we teach chemistry content, we can relate it to the local culture. For example, separation of the mixture is taught in chemistry, but it is also applied at home. In this case, Mr. Ssentumbwe had a fairly informed view about NOS. However, it was not possible to establish whether he could teach with and about NOS when teaching this topic of chemistry. Below is what Mr. Ssentumbwe said in the interview:

> Researcher: So, is there a relationship between science, society, and cultural values?
>
> Mr. Ssentumbwe: Science and culture move hand in hand.
>
> Researcher: So, the science we study is related to Western culture?
>
> Mr. Ssentumbwe: Even to our local culture here.
>
> Researcher: Are you sure?
>
> Mr. Ssentumbwe: Yes, because we normally teach for example separation of mixtures and at home, we do that also.
>
> Researcher: But do you have a textbook here that gives you an example of the Ugandan method of separation?
>
> Mr. Ssentumbwe: Our local methods of separation? No.
>
> Researcher: Then what we have in the textbook is not related to Ugandan culture.
>
> Mr. Ssentumbwe: What I was saying is that science and culture are the same.
>
> Researcher: Then science is the same as history.
>
> Mr. Ssentumbwe: What we are teaching here, much as it is in books, we have them at home. Look at distillation; local people distil their "waragi," the local brew, the crude ethanol and they can purify it.

Mr. Ssentumbwe fairy explained how society and culture influence science. According to the contemporary view of NOS, science is human endeavor and, as such, is influenced by the science and culture in which is practiced. The values and explanation of the culture determine what and how science is conducted, interpreted, and accepted (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, in this case, Mr. Ssentumbwe had a fairly informed view of NOS.

Mr. Muhangi. Mr. Muhangi believed that there is no relationship between science, society and cultural values. He had the view that science is objective and cultural values do not influence it. As such, he thinks that scientific knowledge is absolute truth in nature. In this case, Mr. Muhangi had a positivistic view of nature of science. Below is what Mr. Muhangi said in the interview:

> Researcher: Is there a relationship between science, society and cultural values?
>
> Mr. Muhangi: I don't see it.
>
> Researcher: In other words, do you think we have a universal science? Do we have something in science which is detached from culture?
>
> Mr. Muhangi: Yes. The science is not embedded in culture.

Mr. Muhangi believed that scientific knowledge is not influenced by society/culture, and hence is objective. According to the contemporary view of NOS, science is human endeavor and, as such, is influenced by the science and culture in which is practiced. The values and explanation of the culture determine what and how science is conducted, interpreted, and accepted (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, in this case, Mr. Muhangi had a positivist view of NOS.

Ms. Akello. Ms. Akello believed that there is a relationship between traditional knowledge and science. She argued that the researchers in the Western world of science always use the African indigenous knowledge to come up with the modern scientific knowledge. In this case, Ms. Akello had mixed and complex views of NOS. Here is what Akello said during the interview:

> Researcher: Is there a relationship between science, society and cultural values? Or do we have a universal science that is not attached to any culture?
>
> Ms. Akello: There is a lot of science related to culture, for instance, those witch doctors perform a lot of science.
>
> Researcher: Is that science?
>
> Ms. Akello: Sir that is what I was arguing about. Those people perform science, but they can't explain the principle because I knew someone who had a broken hand so she went to the local doctor and he got some sticks and fixed them there with some herbs, and after

> some time the lady was healed. But then I think that these people can't explain the science. The same thing they say about ghosts, but then do you know when you are speaking on the phone you are speaking to a ghost because this is someone you are not seeing. So also witch doctors do things, but they can't explain the science. There is a lot of science there, but because it is primitive.
> Researcher: So, the science in the schools we are teaching is Western science?
> Ms. Akello: Exactly. You see those people are so bright that they come to Africa and realize that how come these people can speak to dead people, what is the science there? What herbs do they use? So, when they discover the herbs, they go and modify them, they write about them and do a lot of research about them. There is a lot of science with those people.
>
> Researcher: Very interesting; you should do a master's and even a Ph.D. in that area so that you can help and give some explanations.

Ms. Akello had very interesting complex and mixed views about the NOS. She argued that witch doctors have science, but it is primitive. At the same time, she believed that western science contains some African indigenous science. Her explanation indicated that she is not sure how society and culture influence science. According to the contemporary view of NOS, science is human endeavor and, as such, is influenced by the science and culture in which is practiced. The values and explanation of the culture determine what and how science is conducted, interpreted, and accepted (Lederman, 2004, 2015; Lederman, et al., 2001). Hence, Ms. NOS views are neither informed nor positivist/naïve, but complex/mixed.

Chemistry teachers' responses to the Myth of Science questionnaire before and after attending the explicit reflection PD workshop on inquiry and NOS in School B. Here I present the responses by participating chemistry teachers on the five NOS statements contained in the Myth of Science questionnaire. I categorized a science teacher who disagreed (D) with all the statements as having informed NOS epistemological views (scores 100%). On the other hand, I categorized a science teacher who agreed (A) with all the statements as having a naïve view of NOS.

Table 20: Response to the Myth of Science Question at the Beginning and the End of the Study

Name of Teacher	Mr. Bbosa		Mr. Ssentumbwe		Mr. Muhangi		Ms. Akello	
Question	Start of study	End of study	Start of study	End of study	Start of study	End of study	Start of study	End of study
1 Hypotheses are developed to become theory	U	A	D	D	D	D	D	A
2 Scientific theories can be developed to become laws	D	A	A	A	A	A	A	A
3 Scientific knowledge cannot be changed	A	D	D	D	D	D	D	D
4 Accumulation of evidence makes scientific knowledge more stable.	A	A	A	A	A	A	A	A
5 Scientific models (e.g. atomic model) expresses a copy of reality	A	A	A	A	A	A	A	A

Note. A = Agree, D = Disagree and U = Uncertain

Section Summary

The four participating chemistry teachers in School B had a naïve view as far as the difference between scientific laws and theories was concerned at the beginning and end of the study (see Tables 20 and 21). However, all the four participating chemistry teachers had informed/fairly informed views of NOS as far as the tentativeness of scientific knowledge is concerned (see Table 21). They had mixed, contradictory and positivist views of NOS on the rest of the NOS aspects. They also scored less than 50% on the Myth of Science questionnaire because they agreed with most of the NOS statements in the questionnaire at the beginning and end of the study. This implied that School B teachers' NOS epistemological views did not improve throughout the study unlike their colleagues in School A who had some improvement after attending the explicitly reflective workshop on inquiry and NOS.

Table 21: Summary of NOS Epistemological Views of the Four Participating Chemistry Teachers in School B Before at the Beginning and end of the Study under Five Themes

Name of the Teacher	Mr. Bbosa	Mr. Ssentumbwe	Mr. Muhangi	Ms. Akello
The meaning of science	"Science is the study of nature, and also science is mainly different from other subjects because science is practical." [Positivist view]	"Science is the study of nature and science is different from other subjects like History because it is practical and deals with real findings." *[Naïve and Positivist view]*	"Science talks about the behavior of matter." "Science is a practical subject that requires manipulation and even development skills." *[fairly informed view]*	"Science is the study of nature." "In science, we study what we see, unlike other subjects which are not science." *[Mixed views]*
Tentativeness of scientific knowledge	"Scientific knowledge	"Scientific knowledge	"Scientific knowledge will change in time	"Scientific knowledge might change

Name of the Teacher	Mr. Bbosa	Mr. Ssentumbwe	Mr. Muhangi	Ms. Akello
	might change in future." *[Fairly Informed view]*	always changes." *[Fairly Informed view]*	due to the changes observed in technology." *[Informed view]*	with time due to the new developments in research." *[Informed view]*
Role of imagination and creativity in science	"Scientists use imagination /creativity in the planning phase, but during the observation phase, one does not need to imagine." *[Positivist views]*	"Scientists always follows a scientific method in their investigation without applying any creativity or imagination due to limited time and funds available for research." *[naive view]*	*"Scientists use* scientific method during experimentation, making observation and analysis of results." "Scientists also utilize imagination and creativity when planning their investigation." *[Mixed views]*	"Scientists mainly use the scientific method." *[naive view]*
Differences between scientific theories and laws	"The scientific laws come from theory." *[naive view]*	"But the law is just stating; then the theory is describing" "The law is the summary of the theory." *[naive view]*	"Scientific law is proven, and the scientific theory is something like a hypothesis." *[naive view]*	"Scientific theories are tentative whereas scientific laws have been confirmed and therefore cannot be changed." *[naive view]*
Relationship between science, society and cultural values	"Some science attached to a culture of medicine." "There is a universal science which is not influenced by culture/ society	"Science and culture move hand in hand." *[Fairly Informed views]*	"There is no relationship between science, society and cultural values." *[positivistic views]*	"There is a lot of science related to culture." *[contradictory and mixed*]

Name of the Teacher	Mr. Bbosa	Mr. Ssentumbwe	Mr. Muhangi	Ms. Akello
	[contradictory and mixed]			

Chapter Summary. Teachers in Schools A and B had naïve and mixed NOS epistemological views at the beginning of the study, and they did not implement any inquiry-based instruction, except Mr. Opolot who tried to implement structured IBI (see Tables 22 and 23). However, after attending the PD workshop on inquiry and NOS, some chemistry teachers in School A improved their NOS views from naïve to informed. However, all the chemistry teachers still held a naive view about the difference between scientific laws and theories. All of them believed that scientific laws are proven, whereas theory is tentative (see Tables 22 and 23). Despite this naïve conception, the chemistry teachers in School A were able to implement guided inquiry-based instruction in their classrooms, except for Mr. Kigozi, who implemented structured inquiry. Therefore, the nature of inquiry implemented by the chemistry teachers in their classroom is related to their NOS epistemological views, accordingly. This relationship is influenced by some factors, as I discuss in Chapter 7.

Table 22: School A Chemistry Teachers' NOS Epistemological Views and the Nature of IBI Implemented in their Classrooms

NOS/IBI	Mr. Byamukama	Mr. Kigozi	Mr. Agaba	Mr. Opolot
Meaning of science	Positivist	Naive	Fairly Informed	Naïve
Tentativeness of scientific knowledge	Informed	Informed	Informed	Informed
Role of imagination and creativity in science	Mixed and positivist	Informed	Fairly Informed	Naïve
Differences between scientific theories and laws	naïve	Naive	Naive	Naïve

NOS/IBI	Mr. Byamukama	Mr. Kigozi	Mr. Agaba	Mr. Opolot
Relationship between science, society and cultural values	Mixed and contradictory	Mixed	Informed	Mixed and contradictory
Response on the Myth of Science questionnaire before PD workshop (%age score)	2D = 40%	2D = 40%	2D = 40%	1D = 20%
Response on the Myth of Science questionnaire after PD workshop (%age score)	3D = 60%	3D = 60%	2D = 40%	3D = 60%
Nature of IBI implemented in classroom before PD workshop	None	None	None	Structured IBI
Nature of IBI implemented in classroom after PD workshop	Guided IBI	Structured IBI	Guided IBI	Guided IBI

Table 23: School B Chemistry Teachers' NOS Epistemological Views and the Nature of IBI Implemented in their Classrooms

NOS/IBI	Mr. Bbosa	Mr. Ssentumbwe	Mr. Muhangi	Ms. Akello
Meaning of science	Positivist	Positivist and naive	Naive	Mixed
Tentativeness of scientific knowledge	Fairly informed	Fairly informed	Fairly Informed	Informed
Role of imagination and creativity in science	Positivist	Naive	Mixed	Naïve
Differences between scientific theories and laws	naïve	Naive	Naive	Naïve
Relationship between science, society and cultural values	Mixed/ Contradictory	Fairly informed	Positivist	Mixed/ complex
Response on the Myth of Science questionnaire at the Beginning of study (%age score)	1D = 20%	2D = 40%	2D = 40%	2D = 40%
Response on the Myth of Science questionnaire at the End of study (%age score)	1D = 20%	2D = 40%	2D = 40%	1D = 20%
Nature of IBI implemented in classroom at the Beginning of study	None	None	None	None
Nature of IBI implemented in classroom at the End of study	None	None	None	Pre-inquiry

Chapter 7: Factors Affecting Science Teachers' Understanding and Practice of Inquiry-based Instruction in Kampala City Public Schools

Introduction

In this chapter, I describe the factors affecting science teachers' understanding and practice of inquiry-based instruction as perceived by chemistry teachers who participated in the study. Some factors are inferred by me as I interacted with the teachers during the interviews, observed classroom lessons, and analyzed their lesson plans and schemes of work. I divide the factors into two main categories: internal factors and external factors. I hence, answers research question four: What are the perceived internal and external factors that influence science teachers' understanding and implementation of inquiry-based instruction in Kampala city public schools?

Internal Factors that Influence Science Teachers' Understanding and Practice of IBI in Kampala City Public Schools

In this section, I describe the two main internal factors that influence science teachers' understanding and practice of IBI in Kampala city public schools as perceived by participating chemistry teachers in Schools A and B. I support each factor by evidence that I obtained from my interviews of participating chemistry teachers in both schools.

Teacher attitudes (myth about inquiry). Some teachers think that inquiry-based instruction is only applicable to learners who are knowledgeable and intelligent. Mr. Byamukama noted this during my interview with him.

> Researcher: So, what are the challenges you face when using inquiry-based teaching when you are teaching chemistry?

Mr. Byamukama: As I said, you are teaching an abstract topic so if you use inquiry you find that you are teaching yourself and the learners are not benefiting from the learning process.
Researcher: But I thought that the topics that are abstract are the ones that need inquiry. I thought that inquiry is good to teach very difficult topics, isn't it?

Mr. Byamukama: What I have seen is that inquiry is more applicable for learners with some knowledge about something. When you find that there is a topic where learners really don't know anything about what you are talking about, and it is something very new; you find that instead of a two-way kind of interaction because I was saying that inquiry is a two-way kind of interaction, it becomes a one way, whereby you have to give each and everything.

Mr. Byamukama noted that IBI is not suitable to average learners because they will not be able to actively participate in an IBI. This attitude among science teachers influences their decision to utilize IBI to help learners understand science concepts effectively. The teachers look at IBI as a process rather than a vehicle of learning science content (Assay & Orgill, 2010).

Mr. Opolot also expressed that inquiry-based instruction is not useful to learners with low ability. This is one of several myths of inquiry many teachers possess (Wilcox, Kruse & Clough, 2015). Below is what Mr. Opolot said during the interview.

Researcher: Where else is inquiry teaching not a useful method or even possible?

Mr. Opolot: It also depends on the ability of the learners. At times when you use inquiry methods, there are some learners who are not curious to learn; you may ask your questions and not receive any response. That leaves you to mention what you wanted them to know directly without your first getting what they know before you can tell them.

Researcher: Isn't there any way you can provoke their curiosity? Do you have those skills?

Mr. Opolot: I can try to employ some.

Researcher: I know you are a chemist and there is something they call inert gasses, and now they call them rare gasses because originally in old textbooks they used to say inert gasses, but the new textbooks use rare gasses because the chemists learned how to …

Mr. Opolot: To make them react.

> Researcher: Exactly. So, do you have those skills if you have identified that these are rare students and where you used to use ordinary techniques, now you need other skills?
>
> Mr. Opolot: One is you should be polite, and secondly, you should be slow to make them understand what you want. Try to frame the question in several ways in simplified language.

Mr. Opolot noted that when he teaches using IBI to "slow learners," he is likely to use a lot of time and hence cover less content. Such an attitude is likely to influence science teachers practice of IBI because they think will not be able to finish the syllabus since most of learners are perceived to be average learners by science teachers. Hence, most teachers decide to avoid IBI to make sure they cover enough content in their lessons.

In the same vein, Mr. Ssentumbwe argued that he cannot teach using inquiry-based instruction due to "weak" classes, which take a lot of time. This implies that Mr. Ssentumbwe also holds one of the common myths of inquiry where teachers believe that inquiry-based instruction is not good for weak students. Mr. Ssentumbwe during the interview argued that "Some classes are weak and take a lot of time."

The teachers' myth of inquiry attitude is a barrier to their ability to practice inquiry-based instruction in their classrooms. Hence, this is one of the internal factors influencing science teachers' understanding and practice of inquiry that should be addressed by improving the pre-service and in-service science teachers' training to address these common myths about inquiry by science teachers in Uganda.

Another negative attitude is an authoritarian culture among science teachers. Some teachers have an authoritarian teacher-centered culture by being socialized in an African society. This culture is counter to an inquiry-based instruction where the learner is not given freedom to ask questions. In many African cultures, the student who asks questions is viewed as disrespectful to adults and a wiseacre. Hence, the centralized authority in the classroom negatively affects the ability of the teacher to teach using inquiry-based instruction. For example, Ms. Akello argued that “Teachers think that they are superior, the word of God in all situations and that they are final.”

This authoritarian culture also creates classroom management problems for many science teachers during inquiry-based instruction lessons.

> Researcher: So, what do you think are barriers to teaching inquiry in the classrooms in Uganda?
>
> Ms. Akello: One of them is superiority complex, teachers think that they are superior, the word of God in all questions, they are the final.
>
> Researcher: Another barrier?
>
> Ms. Akello: Another one is social skills in the teacher-student relationships. Like if a teacher is not social and not free with the learners then the learner will not openly tell the teacher any answer. For instance, we had a teacher in year two, and she was very tough so whenever she came to class and asked any question no one would answer. At one time, she beat us because we were talking during a practical. Don’t expect learners to keep quiet in a practical because people discuss during the practical, so when she would ask us if we had any questions even if we had a burning question we wouldn’t ask it.
>
> Researcher: How can we deal with these barriers? The first one was teachers think they are superior, how can we solve that?
>
> Ms. Akello: I think teachers should go and revise their code of conduct.

The authoritarian culture among science teachers is a unique concern that has not been articulated in the literature by science education scholars in developed countries like US, UK, and Canada. Hence, this concern may be affecting mainly science teachers’ understanding and practice of IBI in developing countries like Uganda.

Teaching experience. Another internal factor the participating chemistry teachers perceived to influence their understanding and practice of IBI is teaching experience. Some teachers argued that their teaching experience has helped them positively to improve on their ability to teach using inquiry-based instruction. For instance, Mr. Byamukama argued that "Every time you are handling a given concept or a given topic for the second time, you handle it better than you did previously. This is because you know the challenges and you redefine your approach. This helps you to improve your teaching skills with time." In this case, Mr. Byamukama thought that his ability to use IBI has improved with his years of teaching experience. Hence, teachers with more years of teaching experience are most likely to use IBI better than the novice teacher, according to Mr. Byamukama.

Mr. Kigozi also noted the benefits of teaching experience when I asked him, to what extent has your practical teaching experience improved or hindered your ability to teach science through inquiry-based instruction? He stated that" It has improved." Hence, Mr. Kigozi believed his understanding and practice of IBI is better than when he was a novice teacher from the college. In the same vein, Mr. Opolot argued that he has improved his use of IBI with experience.

> Researcher: To what extent has your practical teaching experience improved or hindered your use of inquiry-based instruction?
>
> Mr. Opolot: For me, I see it has improved my use of inquiry-based instruction.
>
> Researcher: So, you can see it has improved. Sometimes people start very well when they have just come out of college and then with time the graph goes down but for you is the graph going up?
>
> Mr. Opolot: The graph is going up.

Mr. Opolot believed that his understanding and practice of IBI in improving with years of teaching experience. Hence, he thinks he is better now than when he was a novice teacher from the college.

However, Mr. Muhangi argued that teaching experience may negatively affect many teachers' ability to teach science using inquiry-based instruction mainly because most experienced teachers do not want to plan for their lessons. However, since he is the coordinator of SESEMAT in School B and in-charge of the cyber project (a project about using ICT in teaching and learning science and mathematics in high schools in Uganda), he thinks he has had the opportunity for his teaching experience to improve his ability to teach science more effectively using inquiry-based instruction. Below is what Mr. Muhangi said during the interview.

> Researcher: To what extent do you think your college content and method content prepared you to teach science using inquiry? When you flash back when you had just finished college were, you ready to teach science using inquiry?
>
> Mr. Muhangi: In fact, when I had just come from college I was asking more questions than I am doing now. After I had just finished the university, I was following the methodology until when I came and they told me there was no need for a lesson plan, so I don't make one.
>
> Researcher: So here they don't demand for a lesson plan?
>
> Mr. Muhangi: They never demand for lesson plans.
>
> Researcher: What about schemes?
>
> Mr. Muhangi: They demand for schemes only. It is us who trained in SESEMAT who are saying that any lesson which is not planned, should not be taught. This is because if you have not planned a lesson, then you have planned to fail teaching. But, of course, they resist, and we are saying if you have failed to write it down at least have a sketch.
>
> Researcher: So, you think your college played a big role, but the real-life experience diluted it?
>
> Mr. Muhangi: It deters you.
>
> Researcher: In fact, it leads to my question. To what extent does your teaching experience improve or hinder your use of inquiry-based instruction?
>
> Mr. Muhangi: For me, I am lucky that I have been to SESEMAT and I am the one in charge of cyber here. I am also the coordinator of SESEMAT in this school. So, the two

> have improved me. But assuming I was not and I wanted to behave the way other people are behaving, I would be hindered; but I am not.

Mr. Muhangi, unlike his colleagues, believed that teaching experience may have a negative effect on science teachers' ability to implement IBI in their classroom. He argued that he was lucky because he participates in training in-service teachers in the SESEMAT program, which is why his ability to teach using IBI has improved with years of teaching experience. This implies that Mr. Muhangi thought that it not just years of teaching experience the teachers have, but the nature and quality of in-service training the teacher receives is what determines his ability to understand and practice IBI effectively in his/her classroom.

Science teachers' teaching experience may have either positive or negative influence on their understanding and practice of IBI because different teachers may react differently to the challenges they encounter in their teaching carrier. According to social cognitive theory, learning is social construct that is facilitated by language via social discourse. Hence, the context science teachers accumulate their experience plays a great role the nature of experience acquired over years.

Section summary. The intrinsic factors influencing science teachers understanding and practice of IBI as perceived by participating chemistry teachers in Kampala city public schools are mainly teacher attitude and teaching experience. The teachers' attitudes affect their decision whether to use or not use IBI in their classroom. Also, teaching experience may have both positive and negative influence as argued by participating teachers above.

External Factors that Influence Science Teachers' Understanding and Practice of IBI in Kampala City Public Schools

In this section, I describe the seven main external factors that influence science teachers' understanding and practice of IBI in Kampala city public schools as perceived by participating chemistry teachers in Schools A and B. I support each factor by evidence that I obtained from my interviews with participating chemistry teachers in both schools.

Lack of motivation. Most of the chemistry teachers I interviewed argued that they cannot teach using inquiry-based instruction because they are not motivated by the meager pay/salary given to them by the government of Uganda. For example, Mr. Kigozi said the following during the interview.

> Researcher: What are the barriers of teaching science using inquiry in Ugandan schools? You can mention the barrier and then tell me how you think we can address it.
>
> Mr. Kigozi: The barriers could be the limited knowledge of the teachers, and there should be some in-service training. Another barrier is little payment and motivation.
>
> Researcher: But the government is now paying science teachers 30% extra.
>
> Mr. Kigozi: The government of Uganda could convert our shillings to working hours. In a school, there are supposed to be two working days in a week that are used to teach chemistry in each class. So, time is also a barrier.

Mr. Kigozi argued that the government should pay them per lesson taught because currently there is limited time allocated to teach chemistry content. He noted that when the government pays them per lesson then teachers will be motivated to teach more topics in one school and this may prevent them moving from teaching in many private schools to supplement their income.

Mr. Agaba noted the lack of resources and low pay as the cause of low motivation to implement IBI by most science teachers in Uganda.

> Researcher: So, what are the main barriers that you see to inquiry-based teaching in Uganda?
>
> Mr. Agaba: Inquiry-based teaching has a major problem of resources, and the resources we are looking at are in the form of teachers. By the way, people normally forget that the major thing that matters is teachers; do we have time? That is the major problem. Does the teacher have time and that comes into resources? How much is the teacher paid? Because that means that like now I am about to run away, therefore, I may not sit and think how to sit and organize an inquiry-based teaching instructional material. So, that is the major barrier that we have. By the way, the other resources may be there because there is even improvisation, but do we do the preparation? The preparation is not done and why is it not done? Because we are running here and there to make money easily. So, that is the major barrier otherwise, there is nothing else.
>
> Researcher: How do you think we should address that? What is your suggestion?
>
> Mr. Agaba: Addressing it is just seeing how to motivate teachers and they remain in one station.
>
> Researcher: But science teachers are now paid 30% more than others.
>
> Mr. Agaba: But how much is that? I have a master, and I am earning 490,000 UGX (approximately $160)
>
> Researcher: But it was 400,000 UGX ($ 130) sometime back in year 2000 something.
>
> Mr. Agaba: I entered service when I still had a diploma. I upgraded, and I got a degree, but I am still paid as a diploma teacher. There is no provision for any increase.
>
> Researcher: Is it an issue of funding?
>
> Mr. Agaba: Funding aside I am renting a house and have other expenses to meet.
>
> Researcher: They didn’t add you the 30%? Because I thought that, that 400,000 was for these other teachers in U4 scale. That means that government is saying one thing and doing another thing.
>
> Mr. Agaba: The minimum which they could give a teacher to remain in one school here in Buganda is 1,500,000 UGX (approximately $ 500) If it were that, it would be okay.
>
> Researcher: That is $500 okay.
>
> Mr. Agaba: But Kenya pays that. Do you know that they pay 50,000 Ksh, which is about 1,500,000 UGX? So, with that, I can’t describe anything because we can’t do anything.

> We can teach, but when we are not innovative /creative. As for you, you have done research, and even if research is very hard if you give it time, you will come up with something. There is no other barrier apart from that.
>
> Researcher: So apart from that, which other resources, are there other than contextual factors which you think can help you to implement inquiry-based instruction in schools? There are those which require pay, what about those that are contextual?
>
> Mr. Agaba: I believe there is nothing else, and by the way, it is just only one thing, it goes to the will, government's will. Other than that, there is nothing.

Mr. Agaba noted that lack of appropriate pay is the main factor that affects him and other teachers to plan an inquiry-based lesson. I also personally experienced this especially when I discovered that all the eight chemistry teachers had at least two extra private schools where they were teaching, even on Saturday. This implied that these teachers are very busy moving from one school to another, including marking exams since most schools do three sets of exams per term (beginning of term, mid-term and end-of-term exams). In such a situation, the teacher will never get time to sit down and plan an inquiry-based instruction lesson where learners' activities are planned.

In the case of Mr. Agaba, he is not motivated because he holds a master's of science degree (chemistry), but he is still being paid money that he feels far below what he should be getting. Mr. Agaba is a part-time lecturer at Kyambogo University, in addition to the private schools he teaches in. He is also the head of the chemistry department in one of the private schools where he teaches. In the same vein, when I asked Mr. Opolot how his school could facilitate him, he stated that. "There should be motivation." By motivation, Mr. Opolot also meant good pay by the Uganda government. Hence, Mr. Opolot like his colleagues was not happy with the current salary is getting and he thinks would be able to implement IBI if the government improved his salary.

Most teachers employed by the Uganda government are underpaid. That is the reason why they try to earn more by teaching in some private schools. In this case, the Uganda government needs to consider the payment of science teachers, which affects the teaching and learning in public schools. This is one of the few unique factors affecting science teachers' understanding and practice of IBI in developing countries like Uganda. I have not come across this in the literature by science education scholars in developed countries like US, UK, and Canada. Hence, it is important for developing countries to conduct qualitative studies to establish such factors so that practical reforms in science education are implemented to improve the teaching and learning of science subjects.

Lack of necessary instruction materials. The second external factor influencing science teachers understanding and practice of IBI as perceived by participating chemistry teachers in Kampala city public schools is lack of necessary instructional materials. Some teachers argued that there are not adequate instruction materials.

> Mr. Byamukama: Another challenge comes from instruction materials. We don't have things like teaching aids and don't know how to use them alongside the method. At times in some topics, it becomes hard.
>
> Researcher: How?
>
> Mr. Byamukama: You will discover that learners don't know anything about what you are teaching and that means that to bring a teaching aid and use an inquiry method also becomes a bit abstract.

When I asked Mr. Opolot to state one of the barriers to implement inquiry-based instruction, he stated similar ideas.

> Mr. Opolot: Lack of the teaching aids and lack of inquiry aid.

Researcher: Like what, be specific, please. What are the examples of these aids that you lack?

Mr. Opolot: Like models and chemicals.

In this case, Mr. Opolot argued that he cannot implement IBI because he lacks necessary models and chemicals. Hence, if the school could provide the necessary instructional material, Mr. Opolot is most likely to practice IBI in his lesson.

Likewise, during the interview, I challenged Mr. Ssentumbwe to demonstrate real natural phenomena like mixing oils and water to help learners observe and try to explain what happens, instead of just telling students that oil cannot mix with water theoretically.

Mr. Ssentumbwe: Because you might go to a school which cannot afford to buy oil or even paraffin. Are you going to get money from the children?

Researcher: Personally, when I used to teach in more than one school I would get chemicals from one school and use them in another school.

Mr. Ssentumbwe: My dear, things have changed. You go to a school, and they can't afford to give you something like that.

Researcher: Then you are not a science teacher; it means you are a history teacher. Then you are teaching history of science.

Mr. Ssentumbwe: They are making you not to be a science teacher, and yet you are a science teacher.

In the same vein, Mr. Muhangi when asked to state the barriers to implement inquiry-based instruction in School B argued that:

Like for us here, we just don't have big labs. This one, for example, you can see is a lab, but there is nothing. If a lab can be repaired, renovated and equipped, then that would be very good. Then we could also have mobile projectors, white boards, etc. (Mr. Muhangi).

Mr. Agaba, in agreement with his colleagues, argued the same.

Researcher: What about the administration? Has the administration here facilitated you to use inquiry?

> Mr. Agaba: No, they have not. First, here we request for several things but they do not provide them.
>
> Researcher: But I can see you have a very good lab.
>
> Mr. Agaba: The lab is there but those taps, for example, are not working. And that is just an example all those taps you see do not work. That electricity there you see, I had first to shout then they provided it so that you can see.

In this case, Mr. Agaba argued that they use a lot of effort before they get the necessary instructional material to teach using IBI. Hence, they are demotivated by the unfavorable working environments that limit their ability to use IBI in their lessons.

Mode of assessment. Some teachers argued that the nature of examinations does not reflect inquiry-based questions. This has made teachers to continue teaching only about basic facts that help learners to perform well in examinations.

> Researcher: Okay. So, what do you think are the main barriers to using inquiry-based teaching from occurring in more classrooms in Uganda?
>
> Mr. Byamukama: The main barrier I would say is the mode of assessment.
>
> Researcher: Elaborate on that.
>
> Mr. Byamukama: The mode of assessment, I can say, does not reflect much the mode of teaching used in inquiry-based. Because mainly assessment is used to recall not to bring out understanding of the given concept.
>
> Researcher: That is one. What is the other barrier? How do you think we should deal with the first barrier?
>
> Mr. Byamukama: As you were saying, external exams should reflect more. Exams should not only ask questions like, what do you mean by this? Instead, it should be what do you understand by this? It should reflect that kind of thing. But now our examining bodies remain setting exams which just need recall and not understanding of concepts. People will find more relevance in using inquiry-based instruction in teaching-learning science when exam setting changes.

Under normal conditions, the curriculum should guide the instruction, however, in this case, Mr. Byamukama argued that the mode of assessment guides the instruction because teachers try to teach the basic facts which enable learners pass the national exams. This examination oriented type of education/ instruction is a challenge to many countries including Uganda. It discourages teachers to be creative and innovative. Hence, the mode of assessment is a key factor influencing science teachers practice of IBI in Kampala city public school because teachers are evaluated basing on the grade their students obtain in national exams.

Class size (number of students per class). Some teachers argued that they need moderate class sizes to enable them to teach using inquiry-based instruction.

> Researcher: Now what are the contextual factors that help or prevent you to implement inquiry in this school?
>
> Mr. Byamukama: I think to use inquiry we need a moderate classroom whereby the numbers of learners are not very many, and you can reach out to at least each and everybody and understand what each learner needs. So, we need moderate classrooms where learners are not many, and numbers are moderate. Here, the classrooms are not very big they are moderate; you can easily reach out to everyone and take each learner's idea.

Mr. Byamukama noted that the class size limits his ability to implement IBI in his lesson. I observed these teachers struggling with large class size in small labs during classroom observation. Hence, most teachers are likely to be discouraged to teach using IBI if the number of students are more than 40 in small labs that were planned for 25 students.

Likewise, Mr. Opolot, when asked to state the barriers to teaching science using inquiry-based instruction in Uganda, argued, "I think the size of the class affects many teachers' willingness to implement inquiry-based instruction in their classroom. In most schools, the teacher to student ratio is too big."

In the same vein, Ms. Akello argued, "At times the classroom population is so big that the teacher finds it impossible to interact with different learners when using inquiry-based instruction to teach science. "In this case, Ms. Akello emphasized the influence of class size on teachers practice of IBI. Hence, Ms. Akello faces challenges teaching using IBI in large classes like her colleagues.

The nature of pre-service and in-service Science teachers' training. Most teachers argued that there should be adequate pre-service training in inquiry-based instruction to enable teachers to use inquiry when teaching.

> Researcher: To what extent do you think your college content and method courses prepared you to teach through inquiry?
>
> Mr. Byamukama: I could say to an average extent. I don't know how I can term it.
>
> Researcher: To what percentage?
>
> Mr. Byamukama: About 50%.
>
> Researcher: Can you elaborate on that? Can you justify the 50%? You said Dr. Oonyu discussed some inquiry.
>
> Mr. Byamukama: These things (inquiry) need someone to have done some research, some research work. Thereby, these things are limited when it comes to universities. To me, I would say that in first year have a subject of research; second year have another subject so that by the time someone finishes three years he has some projects that will guide him when it's time to teach. When he gets to teach at least, he has had some experience.

Mr. Byamukama suggested that pre-service teacher training should include some research projects that help pre-service teachers to appreciate inquiry. He noted that this will help teacher trainees to come out with reasonable experience to teach using IBI. In this case, it seems that Mr. Byamukama did not had adequate research activities to help him appreciate scientific inquiry and hence, he faces challenges teaching through IBI in his lessons.

Mr. Kigozi claimed that his pre-service training did not prepare him to teach science using inquiry-based instruction.

> Researcher: So, did your college content and method courses prepare you to teach science as an inquiry when you flash back?
>
> Mr. Kigozi: No, it was all about passing exams.
>
> Researcher: So, what changes would you recommend in pre-service and in-service courses to help science teachers understand and practice inquiry?
>
> Mr. Kigozi: At colleges or universities?
>
> Researcher: Yes, at universities and colleges.
>
> Mr. Kigozi: Adding the course units required. They should understand inquiry. Then still with in-service, there should be some peer teaching about inquiry.

Mr. Kigozi noted that the current pre-service and in-service trainings needs improvement by adding some course units addressing IBI and have peer teaching. Hence, Mr. Kigozi realized the inadequacies in the current pre-service and in-service training in Uganda. Mr. Agaba argued in the same vein.

> Researcher: To what extent did your college help you to develop inquiry-based teaching skills?
>
> Mr. Agaba: Now it also goes to the colleges, you will find that these people are also moving up and down. By the way, in the college, it is a bit better, but in the university, there is very little teaching of inquiry-based skills. In college, the people there are more practical. Here at the University, it is where teaching of inquiry-based skills is dying from, because of the way we teach at the university. Perhaps you have been in the Universities, what have you found there? The practical approach is not there. So, if someone was not taught in the practical approach, unless he is creative he cannot use it. So, there is nothing that limits us other than the government education policy.

Mr. Agaba suggested that teacher training colleges (colleges train diploma teachers to teach lower secondary - form one to form four) are better than universities that train graduate teachers. Mr. Agaba was speaking from his experience, because he started as a diploma (grade five) teacher and now he has upgraded to a master of science degree (chemistry), and he is also a part-time lecturer in one of the public university where he teaches chemistry content and methods. Hence, he was passionately sharing the real experience he has observed in both colleges and university. He also thinks that government policy on science has a lot to blame about the failure by many science teachers to teach science through IBI.

Mr. Agaba continued to recommend that the professors in universities involved in teaching science content courses should be trained in teaching method courses so that they can train competent teachers who can use inquiry-based instruction in their lessons.

> Researcher: So lastly, what do you recommend the pre-service trainers to do? These are the people who are training teachers.
>
> Mr. Agaba: You know that in Universities, the people who are there are not trained even to teach. Those who are teaching teachers are not trained to teach, what will the teachers do? You will find that only two of those who are teaching, have the component of the education methods. Some of them do not even know the methods, and you can't ask them anything to do with methodology. So, what they do is that even those who did not go through the teaching process should go for refresher courses and they should have post graduate diplomas that are intensive and comprehensive. So, that is the major recommendation. I have part timed there, and I know that the way you teach pre-service teachers is the way they are going to teach.

Mr. Agaba passionately stated that most professors who teach science content to pre-service science teachers do not have formal training in education, and hence this has a negative effect on pre-service teachers. He therefore strongly recommended that all the professors in universities who teach content to pre-service teachers should be trained in pedagogy so that they improve the way they deliver the content. This will go a long way to improve the quality of pre-service teachers understanding and practice of IBI since most teachers tend to teach the way they are taught (Hornbach, 2004; Karmas, 2011; Kennedy, 1991; Oleson & Hora, 2013; Pringle, 2006)

Mr. Opolot noted some of the same points as his colleagues.

> Researcher: To what extent did your college content and method courses help you to teach science using inquiry-based instruction?

> Mr. Opolot: College didn't help a lot. The issues being addressed in the college are not at all the issues on the ground. The college would not help but when you come to the ground you get challenged, it is only that college prepares you to handle any challenge that will come, but they are not specific.

Mr. Opolot noted that the training in colleges was too general without addressing specific challenges a teacher is likely to face in a real classroom when teaching through IBI. Hence, he stated that his college training was not adequate to prepare him to teach science using IBI.

In the case of Mr. Muhangi, he argued that the nature of lesson plans he received in colleges were not adequate to help him teach science using inquiry-based instruction. He thought teacher training colleges should improve on the nature of lesson plans they give pre-service teachers to help them plan and implement inquiry-based instruction lessons.

> Researcher: So, what changes would you recommend in pre-service training? When you flash back to your college training are there any changes you feel that if those people could train teachers like this, they could facilitate teachers to be able to teach using inquiry-based instruction effectively and efficiently?
>
> Mr. Muhangi: I think that the changes could be that, the type of lesson plan they were giving us was not right. The best lesson plan could put emphasis on learning points for the learners which the teacher must emphasize and emphasize the hands-on or minds-on activities for the learners. And then I would imagine that every lesson must have a rationale, why are you teaching this content, what is its value which we do not have in the trainings. Kyambogo and Mbarara Universities are trying to change, but others are not.
>
> Researcher: Others are using a generic way. I don't know whether it was for geography, and that was a primary approach, but people use copy and paste, and there is nothing like customizing. Okay, apart from the lesson plan, is there any other thing the teacher trainers in institutions can improve upon?
>
> Mr. Muhangi: Let the teachers who are being trained do the real content, the experiments they are going to teach.

Mr. Muhangi recommended both minds on and hands on in teacher training colleges/ universities so that the pre-service teachers can implement IBI after graduating from colleges/

universities. He noted that this will improve the way science teachers teach sciences in high schools in Uganda.

Unlike the other teachers, Ms. Akello argued that the micro-teaching she did at the University helped her learn to teach science using inquiry-based instruction. Ms. Akello is a new graduate teacher from one of the private universities in Uganda.

> Researcher: To what extent do you think your college training in content and method has helped you here to teach inquiry?
>
> Ms. Akello: It is helping me because in our university before you come to your school practice you are supposed to teach your peers and department members before you come here. And they assess you before you leave.
>
> Researcher: Is that Mbarara University?
>
> Ms. Akello: It is Nkozi University. The branch of education is in Kisubi, and by then we were very few in the chemistry class; we were about seven, so we could do micro teaching.
>
> Researcher: But in Makerere where people are a hundred, isn't that tricky?
>
> Ms. Akello: Even when we are doing our experiments it is individual not in groups, so you write your observations and conclusions individually.

Ms. Akello differed from her colleagues because she argued that her pre-service training helped her to improve her understanding and practice of IBI because she was involved in micro-teaching and conducted experiments individually. This may have been because Ms. Akello trained in one of the private University in Uganda, where there were few students taking chemistry and hence they had an opportunity to engage in microteaching and perform the required practical.

Support from peer teachers. Some teachers acknowledged that support from their peers has helped them to improve their ability to teach science using inquiry-based instruction. For instance, when I asked Mr. Byamukama whether he has been helped by other teachers to improve his knowledge and skill to teach using IBI, he stated that "I can say yes because during departmental meetings we can exchange ideas on how we can handle different topics using different methods." Mr. Byamukama appreciated the role of support from his colleagues to improve his understanding and practice of IBI. Likewise, Mr. Kigozi noted similar practices.

> Researcher: How have the other teachers in the school helped you to improve your teaching practice using inquiry-based instruction?
>
> Mr. Kigozi: Guidance.
>
> Researcher: Do you have guidance in chemistry?
>
> Mr. Kigozi: Not guidance and counseling, but guidance on those hard topics in chemistry.
>
> Researcher: Is guidance done by the head of chemistry department? Who is the head of chemistry by the way?
>
> Mr. Kigozi: Mr. Byamukama is the head of chemistry department. We share with him, and you could not touch anything until you know theory. There are those things of activity, like when there is a titration, there are things they call schemes and lesson plans where we share our experience before teaching. Theory is very important if you are going to teach using inquiry-based instruction in your lessons.

Mr. Opolot argued in the same vein.

> Researcher: Then another question is how have other teachers helped you or not to promote inquiry-based instruction in your lesson since you started teaching?
>
> Mr. Opolot: Senior teachers and heads of department have taught us how to use suitable questions that will help you to achieve the objective that you want. He can help you to frame them, that if you are teaching this, you can guide the learners like this with this question and that question.

Mr. Opolot agreed with his colleagues about the role of peer support in improving the science teachers understanding and practice of IBI.

However, Mr. Agaba, unlike his colleagues, noted that sometimes his peers may negatively affect his ability to teach science using inquiry-based instruction.

> Researcher: What about the teachers, like when you have been in school, have your teachers helped you to improve your inquiry?

> Mr. Agaba: Yes. The moment you are lucky, and you are with someone who is creative then you go that inquiry way, but if you are unlucky and you meet someone in the early stages who is not, then you go the other way.

Mr. Agaba was of the view that peer teachers' effect depends on the type of peer teachers you interact with. If you interact with those who are creative, your understanding and practice of IBI improve, but if you interact with those who are not, then you will not improve.

Limited time in relation to many lessons and much content to cover. Some teachers argued that they cannot teach using inquiry-based instruction because the chemistry syllabus has too much content to cover in limited time.

> Researcher: Are there times you will find that inquiry teaching is not a useful method? Tell me about those times.
>
> Mr. Opolot: There are several times when it can't be applicable. In private schools, you might find that you are given a certain load that you are supposed to cover within a certain period. So, what you will be mostly interested in is to cover the load instead of seeing whether you have given it in a proper way and the learners have got it.

Ms. Akello state similar sentiments.

> Researcher: Are there times and situations where inquiry teaching is not a useful method?
>
> Ms. Akello: Yes, especially when time is very limited.
>
> Researcher: Is that all? Only time?
>
> Ms. Akello: Yes, mostly it is about time.

Most teachers argued that they have limited time to teach science through inquiry-based instruction. This may be because all the science teachers I interviewed in Schools A and B were teaching in more than two private schools, in addition to School A or B. Mr. Muhangi and Mr. Bbosa had enrolled in a Master of Science (Chemistry) program. This made it difficult for them to plan for their lessons adequately.

Some teachers argued that they have too many lessons to teach. Hence they cannot sit down and plan effectively. For instance, Mr. Opolot argued that “I would say the number of lessons should be reduced, instead of a teacher like having 32 lessons, where you have no time for planning.”. In this case, Mr. Opolot believes that he is unable to plan his lesson because are too many. To make matters worse, most teachers teach in more than one school to supplement their income. This further reduces their effectiveness and efficiency to teach through IBI.

Mr. Muhangi argued that most teachers do not have enough time to plan their lessons because they teach in more than one school to improve their income. This is also due to the scarcity of science teachers in Uganda, but there are many private high schools who cannot afford employing a full-time science teacher. Hence, these private schools depend on part-time science teachers to minimize their operating costs and maximize the profits. This results in science teachers having too many lessons to teach, hence affecting their effectiveness and efficiency in teaching science using inquiry-based instruction.

> Researcher: What do you think are the challenges teachers face when using inquiry-based instruction in Uganda?
> Mr. Muhangi: First, it is the big number of students in class and an examination-driven curriculum. Because of the big numbers, I have a big load that deters me from planning adequately yet inquiry-based instruction must be well planned. Another problem is that science teachers are very marketable. So, they move from one school to another, and there is too much work to cover in a limited time.

Mr. Muhangi argued that he has too many lessons to teach because he moves from one school to another. This is mainly because in Uganda science teachers are not adequate hence they are on demand by very many private schools. This makes them ineffective because they do not settle down to plan their lessons. This problem can only be solved by recruiting more science teachers and improving their payment. Hence, the problem of limited time is a factor of limited teachers, poor payment, and overloaded science curriculum.

Section Summary. Generally, the external factors the participating in-service chemistry teachers perceive to influence their understanding and practice of IBI in Kampala city public schools are: lack of motivation, lack of necessary instructional materials, mode of assessment, class size, the nature of pre-service and in-service training, support from peer teachers and limited time in relation to many lessons and much content to cover.

Chapter Summary

Table 24. Internal and External Factors Influencing Science Teachers Understanding and Practice of IBI in Kampala City Public School in Uganda

Internal factors	External factors
1,Teachers' attitudes (myth about inquiry)	1. Lack of motivation
2.Teaching experience	2. Lack of necessary instructional materials
	3. Mode of assessment
	4. Class size (number of learners per classroom)
	5. The nature of pre-service and in-service training.
	6. Support from peer teachers
	7. Limited time in relation to many lessons and much content to cover,

Some of the above factors affect science teachers' understanding and practice of inquiry positively, whereas other factors affect them negatively. For example, teacher attitudes (myth about inquiry), lack of motivation, lack of necessary instruction materials, limited time in relation to many lessons and much content to cover, class size (number of learners per classroom), and inadequate in-service training negatively affect science teachers' understanding and practice of inquiry-based instruction. Whereas teaching experience and support from peer teachers positively influence science teachers' understanding and practice of inquiry-based instruction. However, teaching experience, nature of pre-service training and support from peer teachers, may have a positive or negative influence on science teachers' understanding and practice of inquiry-based instruction as discussed by the participating chemistry teachers above

Chapter 8: Discussion, Conclusions and Recommendations

In this chapter, I discuss the findings of the study based on the four research questions. I connect the findings of the study with the related literature in Chapter 2. Finally, I make conclusions and recommendations accordingly.

Discussion

Research question one: How do in-service chemistry teachers understand and implement inquiry-based instruction before attending the explicit reflective PD workshop on inquiry and NOS? All the eight participating in-service chemistry teachers in Schools A and B had insufficient understandings of the meaning of IBI at the beginning of the study as indicated in the interviews and summaries in Tables 9 and 10. Most of the teachers held a common misconception about inquiry and equated inquiry-based instruction to mean a question and answer technique, utilizing learners' prior knowledge, and hands-on activities. However, Mr. Agaba (School A) unlike his colleagues, had moderate understanding of the role of the teacher, role of the student, and assessment in IBI at the beginning of the study. Also, Mr. Muhangi (School B) had sufficient understanding of the role of students and assessment in IBI, and moderate understanding of the role of teacher in IBI lesson at the beginning of the study. Whereas Ms. Akello (School B) had a sufficient understanding of the role of students and a moderate understanding of the role of a teacher in an IBI lesson. However, Mr. Agaba, Ms. Akello and Mr. Muhangi, like their colleagues, were not aware of any type of IBI and the eight science practices learners develop in IBI lessons as outlined in US documents (NRC, 2012). Moreover, most of them considered IBI to be teacher-directed learning where the teacher asks the learners questions, and the learners respond to the teacher's questions. For example, Mr.

Byamukama argued that “Inquiry-based learning is where the teacher asks the learners about something that he is teaching and then the learners reveal what they know, or they explain to him what they have been asked.” This finding aligns with Osborne’s (2014) argument that, “The primary challenge of teaching science as inquiry has been a lack of common understanding of what real teaching science through inquiry is and mixing doing science with learning science” (p. 178). Some of my participants believed that inquiry is discovery learning, where learners discover their knowledge. This aligns with Wilcox, Kruse and Clough’s (2015), “Seven common myths about IBI.” Wilcox, Kruse and Clough (2015) argued that most teachers equate IBI with discovery learning, where learners discover their knowledge. In the same vein, Mugabo (2015) in Rwanda established that many science teachers associated inquiry teaching with a few of its specific characteristics while some had a very different understanding.

The possible reason why Mr. Agaba was more informed about IBI more than his colleagues in School A may be because he holds a Master’s of Science (chemistry) degree. Hence, his experience in research during the master’s degree may have improved his understanding of IBI. Also, Mr. Agaba is a part-time lecturer of a chemistry content and method course in Kyambogo University (one of the public universities in Uganda). Hence, he might have more exposure to literature about IBI than his colleagues in School A. Likewise, Mr. Muhangi is a national in-service science teacher trainer under the SESEMAT program, and hence he was most likely exposed to more literature about learner-centered types of instruction like IBI. This may be the reason why he had a sufficient and moderate understanding in some aspects of IBI compared to his colleague in School B. In the case of Ms. Akello, she was a new graduate (three months of teaching experience) from one of the private universities where they used micro-teaching to train them in teaching pedagogy. Hence, this may be the reason why she had a sufficient understanding of the role of students and a moderate understanding of the role of a teacher in an IBI lesson compared to her colleagues in School B.

During the interviews, all the chemistry teachers claimed that they use IBI in their lessons. However, during the lesson observations, most of them (except Mr. Opolot) were using a traditional question and answer method without involving the learners in the eight science practices called for by the NRC (2012). This implied that these teachers did not know whether they implement IBI or not. Hence, the science teachers' implementation of IBI may have been influenced by their insufficient understanding of what IBI is or their aim to complete the syllabus in time. This is in agreement with McNeil (2009) who established that different teachers carry out reform-based curricula in different ways, something curriculum designers need to take into account. Additionally, Capps and Crawford (2012), in a study in the US, established that many teachers do not practice IBI despite their high level of qualifications. They attributed the lack of practice of IBI to low motivation on the part of teachers. This is the case with Mr. Agaba, who holds a Master's of Science degree (chemistry) but is still paid a salary of a diploma holder because he started as a grade five teacher. Hence, he is demotivated by the low pay he is getting per month (420,000 UGX = $150). During the interviews, he argued that he should be paid at least $500 (1,500,000 UGX) so that he can be motivated to teach using IBI. This finding also agrees with the Englen et al. (2013) study in European countries where they established that implementation of daily practices of IBI depends significantly on the country. This is evidenced from the factors chemistry teachers perceived to influence their practices of inquiry in Chapter 7.

There is a possibility that Mr. Opolot, immediately after the interviews about IBI, went on to do some reading about IBI and hence by the time I observed his lesson he had improved his understanding of IBI. That may be the reason he tried to implement structured IBI before attending the explicit reflective PD workshop on inquiry and NOS compared to his colleagues in Schools A and B. Otherwise, Mr. Opolot had insufficient understanding of the five aspects of IBI as shown in Table 9 in Chapter 5. He believed that IBI is a question and answer technique and the teacher is the center of instruction, like most of his colleagues in School A. This implies that the improvement of science teachers' understanding has a great role in influencing their teaching practice.

Research question two: How do in-service chemistry teachers understand and implement inquiry-based instruction after attending the PD workshop on inquiry and NOS? I established that the understanding and practice of inquiry improved in the chemistry teachers in School A (active group) after attending the explicit reflective PD workshop on inquiry and NOS. This can be seen in the lesson observation excerpts that I discuss in Chapter 5. Most teachers could state the eight science practices promoted by the NRC (2012) and describe the three types of IBI (structured, guided and open inquiry). All the four teachers were also able to engage learners in some of the eight science practices during their IBI lessons. However, some teachers had difficulty in teaching with and about NOS and infusing social scientific issues into the IBI lessons.

This finding of the positive effect of the PD workshop on the teachers' understanding and practice of inquiry aligns with the Pozueloso et al. (2014) study where they established that PD activities improved science teachers' ability to implement IBI through listening to the needs of the teachers and addressing their concerns. I conducted the PD workshop, after interviewing the teachers and observing their lessons. This allowed me to interpret their concerns in my PD workshop. This also helped me to be realistic when discussing the literature about IBI by relating to their problems and concerns. In fact, during the PD workshop, Mr. Agaba claimed that they had rejected SESEMAT trainings because they think the trainings do not address the problems they face in their classrooms. This means that if the PD workshops are to be effective, researchers need to conduct qualitative studies that put teachers' interests at the center. Researchers need to go to the classrooms/labs and experience the challenges the teachers face, such as crowded classrooms (more than 50 students in a classroom) and dysfunctional labs (e.g., water taps not working). These issues cannot be captured by quantitative studies that only consider the quantitative aspects of teachers' perceptions about inquiry.

Wenning (2005) also emphasized the role of science teachers' teaching philosophy in improving their ability to practice IBI in the classroom. He argued, "It is from philosophies that beliefs arise, and beliefs give rise to decisions. Decisions bring about actions, and actions have consequences," (p. 14). Therefore during the PD workshop, I involved the School A teachers in an activity where they prepared a pie chart indicating their current instructional strategies with percentages under each teaching strategy (e.g., 40% lecturing, 20% discussion and 40% question and answer approach). I then told them to prepare another pie chart showing what instructional strategies they desire to utilize in teaching science. I discussed with them how they can move from the current instructional strategies that were teacher-centered to the desired learner-centered instructional strategies, like IBI. This activity played a big role in improving their teaching philosophy and hence their practice of IBI in the classroom as it is seen in the classroom observation notes in Chapter 5.

The teachers' challenges of incorporating NOS issues in their lesson findings agrees with Summer's (2015) study in Germany where he established that teaching NOS was not a primary goal of teachers. Also, some aspect of the Nature of Scientific Inquiry (NOSI) seemed more easily incorporated in the chemistry lessons, for example, critical testing, hypothesis, and prediction. I also found out that most teachers rarely utilized ICT/Internet during IBI lessons. This finding agrees with the Sun and Xie (2014) study where they established that teachers' beliefs, knowledge and skills predicted their technology use in biology lessons.

Studies conducted by other researchers (Jones & Egley, 2007; Miller, 2011; Pegg, Schmoock & Gummer, 2010; Powell-Moman & Brown-Schmidt, 2011) have established that PD can provide the encouragement and confidence that teachers need to implement inquiry-based science investigation. Although these researchers conducted studies mainly among elementary science teachers, their findings agree with what I found in my study.

Research question three: To what extent do chemistry teachers' understanding of NOS relate to the nature of inquiry-based instruction implemented in their classrooms? I established that participating chemistry teachers in Schools A and B had naïve and mixed NOS epistemological views at the beginning of the study, and that they did not implement any inquiry-based instruction except for Mr. Opolot who tried to implement structured IBI (see Chapter 6 Tables 22 and 23). On a positive note, all the participating chemistry teachers had an informed view about the tentativeness of scientific knowledge at the beginning and end of the study. However, after attending the PD workshop on inquiry and NOS, some chemistry teachers in School A improved their NOS views from naïve to informed. However, all the chemistry teachers still held a naive view about the difference between scientific laws and theories. All of them believed that scientific laws are proven, whereas theories are tentative (see Chapter 6, Tables 18 and 20). One of the reasons why these teachers did not improve their understanding about the difference between the scientific laws and theories may be because they equated scientific laws with social laws in our society that always must be approved by the parliament/ legislative arm of any government. Despite this naïve conception, the chemistry teachers in School A could implement structured and guided inquiry-based instruction in their classrooms. Therefore, the nature of inquiry implemented by the chemistry teachers in their classroom is somewhat related to their NOS epistemological views accordingly.

However, this relationship is not simple and linear. It is very complex due to the factors discussed in Chapter 7, especially the political dilemma (e.g., lack of necessary instructional materials, mode of assessment, class size, support from peer teachers, support from school administration, too much content to cover in limited time). This political dilemma was noted by Windschtl (2002) and Wenning (2005). For developing countries like Uganda to improve science teachers' ability to implement IBI, these political and cultural dilemmas need to be addressed, in addition to improving the pre-service and in-service training of science teachers.

Research question four: What are the perceived internal and external factors that influence chemistry teachers' understanding and practice of inquiry-based instruction in Kampala City public high schools? I established that the main internal factors that my participants perceived to influence their understanding and practice of IBI in Kampala City high schools were teacher attitudes (myth about inquiry) and teaching experience. Whereas the external factors were lack of motivation, lack of necessary instructional materials, mode of assessment, class size, the nature of pre-service and in-service training, support from peer teachers and limited time in relation to many lessons and much content to cover.

There are two internal factors and seven external factors, which implies that most of the factors participating teachers perceive to influence their understanding and practice of IBI in Kampala city schools is beyond their control. This finding agrees with Wenning (2005) who established that apart from science teachers’ understanding of inquiry, there are other contextual factors that affect science teachers’ practice of IBI. Other science education researchers established that class size (Jouszka & Dixon-Kraus, 2008; Jarman & Boyland, 2011; Johnson, 2011), classroom management (Doyle, 2009; Urial & Urial, 2012; Wong Wong, Rogers & Brooks, 2012), pre-service preparation (Carner, 2009; Tar, 2012), and state assessment (Cocke, Buckley & Scott, 2011; Judson, 2012; Rothstein, 2008) have a negative effect on elementary science teachers’ ability to practice IBI. Much as their studies focused on elementary science teachers in the US, there are similarities with the high school science teachers in Uganda, especially with the effect of the mode of assessment on science teachers’ practice of IBI. However, factors like class size and classroom management may have a different magnitude in Kampala City public high schools. Hence, we need different strategies to address such factors in developing countries like Uganda. I realized during classroom observations that teachers struggled to deal with very large classes (more than 50 students per class) in a small laboratory that had been constructed to accommodate an average of 25 students. Additionally, Crawford (2000) established that the classroom itself may be a barrier to the implementation of IBI. This agrees with my finding that classroom environment influences science teachers' ability to use

IBI. However, one participant, Ms. Akello, argued that she had a good classroom environment that helped her to implement IBI in her classroom.

Windschtdl (2002) classified the challenges teachers face into four domains of dilemma: conceptual, pedagogical, cultural and political. Hence, the nine factors that I established from my study may also be classified using Windschtl's (2002) classification as follows: *conceptual dilemma*, which includes lack of knowledge about IBI (myth about IBI); *pedagogical dilemma*, which includes teaching experience; *cultural dilemma,* which includes an authoritarian culture by many teachers; and *political dilemma,* which includes lack of motivation, lack of necessary instruction materials, mode of assessment, class size, support from peer teachers, the nature of pre-service and in-service training, limited time in relation to many lessons and much content to cover. It is evident that about 77 % of the factors are political in nature. This implies that the contextual factors may have a large influence on science teachers' practice of IBI. Therefore, if science teachers are to practice IBI, there is a need to improve their working conditions in addition to equipping them with knowledge about IBI. This finding is aligned with Wenning's (2005) research that asserted that teachers' understanding of IBI is not the only factor affecting the practice of IBI. There are many contextual factors that influence science teachers' implementation of IBI. Wenning (2005) asserted that IBI can only be successfully implemented when confounding variables, like instructional and curricular concerns, personal teaching philosophy, and concern about students, are satisfactorily addressed by key stakeholders in education.

However, these factors are context specific, and hence each country must conduct qualitative studies to establish these factors so that they can be practically addressed. Some of the above factors affect science teachers' understanding and practice of inquiry positively, whereas other factors affect them negatively. For instance, teaching experience and support from peer teachers may have either a positive or negative influence depending on the school context and nature of peers the teacher gains his/her experience. If a teacher associates with teachers with a teacher-centered philosophy, then the teacher is most likely to gain bad peer influence and hence will have insufficient understanding and practice of IBI. Also, some concerns such as poor pay, teachers teaching in many school (limited time in relation to many lessons), authoritarian culture among science teachers and ability to use learners' indigenous knowledge to explain the science content are not articulated by science education scholars in developed countries like the US, UK, and Canada. Hence, these factors may be unique in developing countries like Uganda. Therefore, it is better for policy makers and science teachers' trainers to address internal and external factors that affect science teachers' understanding and practice of inquiry-based instruction to improve the teaching and learning of science subjects in each country.

Factors such as lack of necessary instructional recourses, mode of assessment and too much content to cover in limited time have been evident in other African countries, such as South Africa (Ramnarain, 2016). In the US, Anderson (2007) established that time constraint was a dilemma to most teachers who attempted to implement IBI in their classrooms. Hence, addressing these factors by examining the contexts the science teachers are facing with these challenges will help improve the teaching and learning of science subjects in developing countries like Uganda.

Conclusions

Through this multi-case exploratory qualitative study, I sought to explore (a) how in-service chemistry teachers understand and implement IBI before and after attending the explicit reflective PD workshop on inquiry and NOS, (b) the relationship between chemistry teachers' NOS understandings and nature of inquiry implemented in their classrooms, and (c) the internal and external factors participants perceived as influencing their understanding and practice of inquiry-based instruction in Kampala City public high schools. The research involved two schools of similar standards and eight chemistry teachers as described in Chapter 4. I collected data through interviews, classroom observation, and document analysis. I also conducted a six-day explicit reflective PD workshop on inquiry and NOS for School A chemistry teachers spread out over a period of three weeks.

Some findings emerged from this research. First, the chemistry teachers in Schools A and B had insufficient understanding of IBI because most of them equated IBI to mean question and answer technique and had a teacher-centered attitude towards IBI. Also, most teachers held a common misconception of inquiry; for example, they took IBI to be suitable only for very bright students. Secondly, all the chemistry teachers in Schools A and B, except Mr. Opolot, did not implement IBI in their classrooms at the beginning of the study (before attending PD workshop) even though during the interviews they claimed that they sometimes implemented IBI. Thirdly, there was a positive effect after the explicit reflective PD workshop on inquiry and NOS on science teachers' understanding and practice of IBI in their classrooms. All the chemistry teachers in School A (active group) could engage students in the science practices as called for by the NRC (2012) after attending the PD workshop on inquiry and NOS. However, most chemistry teachers had challenges teaching with and about NOS in their classrooms during IBI. Fourthly, most chemistry teachers had naïve/positivistic NOS epistemological views at the beginning of the study. All of them scored less than 50% on the myth of science questionnaire (see Tables 18, 19, 20 and 21, Chapter 6). There was also a weak relationship between chemistry teachers' NOS epistemological views and the nature of IBI implemented in their classrooms (see Tables 22 and 23 in Chapter 6). However, this relationship was not linear due to some factors discussed in Chapter 7.

Fifthly, I established the nine factors that affect science teachers' understanding and practice of IBI in Kampala City public high schools. Among these nine factors, two are internal factors, and the rest are external. The seven external factors can be classified under political dilemma, according to Windschitl (2002). Therefore, there are more external than internal factors that influence science teachers' understanding and practice of IBI in Uganda. Hence there is an urgent need to address these political "dilemmas" in addition to working on the internal factors (teachers' attitudes).

Lastly, the findings of research by Osborne (2014), Wnidschtldt (2002) and Wenning (2005) has shown that science teachers' understanding of inquiry influences their ability to practice IBI and also there are external factors in addition to science teachers' understanding of IBI that must be addressed before teachers practice IBI in their classrooms. The conclusions based on the findings of this research are that:

First, the current pre-service and in-service teacher training in Uganda may not be improving science teachers' understanding and practice of IBI because most of them equated IBI with question and answer techniques, and held many myths about IBI.

Secondly, the explicit reflective PD workshop on inquiry and NOS that was conducted after listening to the in-service science teachers' concerns and challenges over time within the school context improved their understanding and practice of IBI and helped them to drop some of the common myths about IBI.

Thirdly, these science teachers' NOS understandings were, to some extent, related to the nature of IBI implemented in their classroom. Hence, NOS understanding may be one of the factors influencing science teachers' understanding and practice of IBI in Kampala City schools.

Fourthly, most of the factors affecting science teachers understanding and practice of IBI as perceived by participating teachers in Kampala City public high schools are beyond their control (external/political dilemmas). Therefore, science educators and policymakers have a greater role to play in improving science teachers' understanding and practice of IBI in Uganda.

Recommendations and Further Research

The findings of this research are important because they show the need to pay attention to both the internal and external factors affecting science teachers' understanding and practice of IBI in developing countries like Uganda. There has been consistent blame by the Ugandan government on science teachers' inability to teach science using the IBI approach. However, my study shows that external factors, such as pre-service training, in-service training, and mode of assessment, need to be addressed by key stakeholders like teacher educators and policy makers (government). Hence, there is an urgent need for the key stakeholders, like teacher training colleges, to revise their content and method courses to integrate an IBI approach. Also, it appears that the current SESEMAT in-service training needs to address context-specific problems/challenges teachers face in Uganda, instead of just adopting the Japanese model they are currently using. Secondly, the Ugandan government needs to address issues like large classes by recruiting more science teachers and constructing adequate laboratories for all public schools.

Although the curriculum development center has tried to review the lower secondary curriculum, there is need to sensitize teachers very soon about the changes of the curriculum that will be launched in 2018. This curriculum was adopted based on the US and UK curricula that require teachers to be able to teach using IBI. However, to date, the teachers are not yet prepared to do so.

Lastly, there is need for further research involving teachers of other science disciplines, like physics and biology, in Uganda since this is the first qualitative study to investigate science teachers' understanding and practice of IBI. Future studies may use both qualitative and quantitative approaches, based on the factors outlined in Chapter 7, to come up with path analysis models explaining how different factors influence science teachers' understanding and practice of IBI in developing countries like Uganda. This may lead to improvement of teaching and learning of science subjects in developing countries.

Appendix A: Interview Protocol

A. Background Information

1. Please describe your teaching experience.

2. What is your education background (undergraduate and graduate level)?

3. Please describe your science content background.

B. Nature of Science (NOS) Views (VNOS D+)

1. What is science?

2. What makes science (or a scientific discipline such as physics, biology, etc.) different from other subject/disciplines (art, history, philosophy, etc.)?

3. Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.

4. In order to predict the weather, weather persons collect different types of information. Often they produce computer models of different weather patterns.

(a) Do you think weather persons are certain (sure) about the computer models of the weather patterns?

(b) Why or why not?

5. The model of the inside of the Earth shows that the Earth is made up of layers called the crust, upper mantle, mantle, outer core and the inner core. Does the model of the layers of the Earth represent *exactly* how the inside of the Earth looks? Explain your answer.

6. Scientists try to find answers to their questions by doing investigations/experiments. Do you think that scientists use their imagination and creativity when they do these investigations/experiments?

   a. If NO, explain why.

   b. If **YES**, in what part(s,) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.

7. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

8. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.

9. Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

10. Do you agree, uncertain or disagree with the following statements?

    i. Hypotheses are developed to become theories only.
    ii. Scientific theories can be developed to become laws, so theories are less secure than laws.
    iii. Scientific knowledge cannot be changed.
    iv. Accumulation of evidence makes scientific knowledge more stable.
    v. A scientific model expresses a copy of reality (e.g. the atomic model).

C. **Understanding and Practice of Inquiry**

1. (a) How would you describe Scientific Inquiry, Inquiry-based learning, and Inquiry-based Instruction?

   (b) How did you develop these understandings about Scientific Inquiry, Inquiry-based learning, and Inquiry-based Instruction?

2. Do you teach using inquiry-based instruction? If yes, describe in your own words what a typical Inquiry lesson looks like in your classroom? Include the following in your description:

   i. What are you doing? [What is your role as a teacher?]
   ii. What are your students doing?
   iii. How are resources used?
   iv. How is science content taught?
   v. How do you assess/ evaluate learners' understanding of the concept?

   If NO, is there a particular reason why you do not use inquiry-based instruction? State the reason(s).

3. What is the type/ nature of inquiry-based instruction do you usually utilize in your lesson (i.e. Is it structured, guided or open inquiry?), and why?

4. What are the scientific and engineering practices do you usually engage learners in your inquiry chemistry lessons?

5. (a) To what extent do you think inquiry teaching is a good approach to teaching science content? Why or why not?

(b) Are there times or situations where inquiry teaching is not a useful method? Tell me about these?

(c) What do the constraints/ challenges do you face when using inquiry-based instruction to teach chemistry?

(d) What do you think are the barriers preventing an inquiry-based instruction from occurring in more classrooms in Uganda? How might the above barriers be mitigated?

(e) What do you think should be done to improve the teaching of inquiry-based instruction in your school?

(f) What are your needs to implement inquiry-based instruction in this school?

6. (a) What are the contextual factors which help you to implement inquiry-based instruction in this school?

(b) How would you like the school to facilitate you to teach science by inquiry-based instruction?

(c) To what extent did your college content and method courses prepare you to teach science using inquiry-based instruction?

(d) To what extent has your practical teaching experience improved or hindered your use of inquiry-based instruction?

(e) How have other teachers helped you or not to promote inquiry-based instruction in your lesson?

(f) To what extent has the school administration facilitated you or hindered you in understanding and practicing inquiry-based instruction?

(g) What changes would you recommend pre-service and in-service training courses to help science teachers understand and practice inquiry-based instruction?

(h) What is the most significant experience that you had that led you to using or not using inquiry-based instruction?

END

APPRECIATION: Thank you very much for your time. I look forward to observing your lessons.

Appendix B: Classroom Observation Protocol

Classroom observation guide (Adapted from Cavas, Holbrook, Kaska, & Rannikmae, 2013)

1. **Identifying and posing appropriate scientifically oriented questions**

- **Structured Inquiry**: The teacher supplies scientific questions to be answered by students
- **Guided Inquiry**: The teacher and students discuss and create scientific questions together which students then attempt to answer
- **Open Inquiry**: Students are given opportunities to create scientific questions as part of teaching

2. **Contextualizing research questions in current literature/resources**

- **Structured Inquiry**: The teacher provides students with the relevant literature and other resources to develop their plans for investigations
- **Guided Inquiry**: The teacher guide students to think about the relevant literature and other resources they need to find to develop their investigations
- **Open Inquiry**: Students find related literature and resources by themselves to develop their investigations

3. Making prediction / developing hypothesis

- **Structured Inquiry:** The teacher helps students to develop hypotheses about the solution to a scientific problem
- **Guided Inquiry:** The teacher provides students with a hypothesis which the students test through investigations

- **Open Inquiry:** Students are given opportunities to develop their own hypotheses aligned with scientific questions

4. Designing and conducting investigations

- **Structured Inquiry**: The teacher gives students step-by-step instructions so that they can conduct investigations
- **Guided inquiry:** The teacher guide students to plan investigation procedures
- **Open Inquiry:** Students design their own procedures for undertaking studies

5. Identifying Variables

- **Structured Inquiry**: The teacher tells students the variables they need to control in undertaking their investigations
- **Guided Inquiry**: The teacher guide students on identifying the variables to be controlled in an investigation
- **Open Inquiry:** Students identify the variables that they need to control in carrying out investigations

6. Collecting data

- **Structured Inquiry**: The teacher gives students step-by-step instructions for obtaining data/making observations
- **Guided Inquiry**: The teacher guides students on how to collect data to solve a scientific problem
- **Open Inquiry**: Students determine which data to collect for their investigations

7. Analyzing data to develop patterns

- **Structured Inquiry**: The teacher undertakes to interpret the data collected by students and ask them to make a record
- **Guided Inquiry:** The teacher guide students to develop conclusions to scientific evidence
- **Open Inquiry:** Students use data to develop patterns and draw conclusions by themselves

8. Communicating and connecting explanation (Drawing conclusions)

- **Structured Inquiry**: The teacher gives students step by step instructions to allow them to develop conclusions from their investigations
- **Guided Inquiry**: The teacher guide students to use experimental data to explore patterns leading to conclusions
- **Open Inquiry:** Students develop their own conclusions from their investigations

9. Socio-scientific Issues

- **Structured Inquiry:** The teacher provides guidelines for students to relate the results of their investigations to make decisions about socio-scientific issues
- **Guided Inquiry:** The teacher guide students to consider their scientific results when making decisions on socio-scientific issues
- **Open Inquiry:** Students propose and use scientific evidence to evaluate risks such as those related to environmental or health related issues

Appendix C: Details of the Explicit Reflective PD Workshop on Inquiry and NOS for In-service Science Teachers in Active Group

Overall Goal of the PD Workshop

To improve the science (chemistry) teachers' understanding and ability to implement inquiry-based instruction in their chemistry lessons in order to help learners to learn science successfully.

General Objective of the PD Workshop

By the end of six days, science teachers should be able to:

5. Utilize ICT/Internet resources competently to prepare and conduct inquiry-based instruction lessons.
6. Conduct inquiry-based lessons successfully.
7. Teach with and about NOS in their inquiry lesson.
8. Assess/evaluate students' understanding in inquiry lessons.

Method of Training/ Learning

- Case studies
- Demonstrations
- Experimentation
- Micro-teaching
- Inquiry-based approach
- Discussions
- Reflective writing
- Co-operative learning.

Materials /Equipment

- Chemicals (e.g., bases, acids, salts, anti-acids, universal indicator, litmus paper)
- Heating source
- Test tubes
- Flip charts
- Markers

Duration of the Workshop

The PD workshop will take six days in the span of three weeks (Friday and Saturday). Starting from 8.00 am and going to 5.30 pm each day, with 30 minutes' tea break (10.30-11.00am) and one-hour lunch break (1.00pm-2.00pm). Hence, a total of 7 hours of activity/ discussion will be utilized for 6 days (overall total time = 42 hours).

Details of Daily Activities

1. Day One (7 hours) [8.00am-5.30pm]

Objectives

By the end of day one, science teachers should be able to:

i. Describe the eight tenets of NOS
ii. Identify NOS aspects in the chemistry content to be used in chemistry lessons (e.g., discovery of polythene bags, the history of periodic table, the model of an atom)
iii. Demonstrate how to teach with and about the nature of science in inquiry-based instruction lessons.

NOS Key Readings to Guide the Discussions and Activities

Abd-El-Khalick, F. (2013). Teaching with and about nature of science, and science teacher knowledge domains. *Science & Education*, *22*(9), 2087-2107, doi: 10, 1007/s11191-012-9520-2

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: factors that facilitates or impede the relationship. *Journal of Research in Science Teaching, 36*(8), 916-929.

Lederman, N. G., & Abd-El-Khalick, F. (1998). Avoiding de-natured sciences: Activities that promote understanding of the nature of science. In McCommas (Ed.). *The nature of science education: Rationales and strategies* (pp. 83-126). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Lederman, N.G. (2015). Guest Editorial. Nature of science and its fundamental importance to the vision of the Next Generation Science Standards. *Science and Children*, pp. 8-10.

Lederman, N.G., Lederman, J.S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology, 1*(3), 138-147.

Nature of Science Activities

- The participating chemistry teachers will be engaged in ten different activities that explicitly address the eight-target aspect of NOS. Detailed description of these activities can be found in Lederman & Abd-El-Khalick (1998).

- ❖ Two of these activities address the function of, and relationship between, scientific theories and laws. Two of the other activities ("Trick tracks" and "The whole picture") addresses difference between observation and inferences, and the empirical, creative, imaginative and tentative nature of scientific knowledge. Examples from chemistry will also be cited to emphasize the tentativeness of scientific knowledge during the activities.
- ❖ The four other activities ("The aging president," "That is part of life!" "Young? Old?" and Rabbit? Duck?") target the theory landenness and social and cultural embeddedness of science. Here also some examples from chemistry will be highlighted during the discussion to emphasize the influence of society on the development of chemistry knowledge (e.g., the discovery of artificial color/dyes in Germany were highly facilitated by the need for the Germany military to manufacture the military uniforms).

  Finally, the two black box activities ("The tube" and "The cubes") will be used to reinforce participants' understanding of the above NOS aspects. Also during the discussion, examples from chemistry will be highlighted during the discussion.

2. Day Two (7 hours) [8.00am-5.30pm]

Objectives

By the end of day two, science teachers should be able to:

i. Explain scientific inquiry, inquiry-based learning and inquiry-based instruction
ii. Describe structured inquiry, guided inquiry and open inquiry lessons.
iii. Describe the seven myths of teaching science through inquiry.

iv. Prepare inquiry-based instruction lesson plans with detailed learners' activities (structured inquiry, guided inquiry and open inquiry lesson plans).

Inquiry Key Readings to Guide the Discussions and Activities

Barrow, L., H. (2006). A brief history of inquiry: From Dewey to standard. *Journal of Science Teacher Education,* 17, 265-278.

Cavas, B. (2012). The meaning of and need for "Inquiry-Based Science Education (IBSE)". *Journal of Baltic Science Education*, 11 (1), 4-6.

Crawford, B., A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44 (4), 613-642.

Kramer, P., Nessler, S. H., & Schluter, K. (2015). Teacher students' dilemmas when teaching science through inquiry. *Research in Science & Technological Education*, 33(3), 325-

Marshall, J. C., Horton, B., Smart, J., & Llewellyn, D (2008). *EQUIP: Electronic Quality of Inquiry Protocol*: Retrieved from Clemson University's Inquiry in Motion Institute, www.clemson.edu/iim.

Wilcox, J., Kruse, J., W. & Clough, M. P. (2015). Teaching Science through Inquiry: seven common myths about this time honored approach. *The Science Teacher*, pp-62-67.

339, doi: 10.1080/02635143.2015.1047446.

Activities/Discussion to Engage Chemistry Teachers in Inquiry

- A key to understanding scientific inquiry and developing the abilities to conduct inquiry-based instruction lessons is actually participating in scientific inquiry (NRC, 2000). In this PD workshop, the in-service chemistry teachers will participate in guided and open inquiry model for their own instruction. As Loucks-Horsely et al. (1998) point out, teachers must be challenged at their own level of competence, rather than doing students activities.

- ❖ This particular inquiry activity is selected because it includes a focus on chemistry content (PH) and a product about which the chemistry teachers will have a prior knowledge (commercially available antacids like Magnesium tablets). After an overview of the PH concepts, teachers will be given the question "Which antacids neutralizes stomach best?" A solution of 0.1 HCl will be used to simulate stomach acid, and the teachers will be provided an assortments of generic and name-branded antacids to test, such as Rolaids, Tums Ex, Mylanta, Maalox, and Pepeid AC. The teachers will be expected to clarify the operating definition of "best" (i.e., fastest neutralizing? Longest neutralizing? Longest lasting neutralizer?) through discussion before designing the experiment to test their hypothesis/ models. The teachers then will be required to design tests to determine the best antacid. After each teacher obtaining their findings, the will present to the whole group their findings/ conclusion and also providing the evidence to support their arguments. This will help participating teachers appreciate the role of evidence to support scientific arguments.

3. Day Three (7 hours) [8.00am-5.30pm]

Objectives

By the end of day three, science teachers should be able to:

i. Prepare inquiry-based instruction lesson plans with detailed learners' activities.

ii. Utilize ICT/Internet resources competently to prepare and conducting inquiry based instruction lessons.

iii. Integrate science practices activities in inquiry lessons.

Key Readings to Guide Discussions and Activities

Llewllyn, D. (2013). *Teaching high school science through inquiry and argumentation*. 2rd Edition. Curwin Press. [Chapters 2, 3, 4, 5, 6, 7, 8, 10]

Luft, J., Bell, R. L. & Gess-Newsome, J. (2008). *Science as Inquiry in secondary settings*. NSATA Press. [Chapters 4, 10]

Osborne, J. (2014). Teaching scientific practices: meeting the challenges of change. *Journal of Science Teacher Education*, 25: 177-196, doi: 10.1007/ s10972-014-9384-1

Trumbull, D. J., Bonny, R. & Grudens-Schck, N. (2011). Developing materials to promote inquiry: lesson learned. *Science Education*, 89, 819-900.

Activities/Discussion to Engage Chemistry Teachers to Prepare Inquiry Lessons

- ❖ Chemistry teachers will be involved in discussion of different types of inquiry-based instruction lessons (i.e., structure inquiry, guided inquiry and open inquiry) basing on specific chemistry topics. The focus will be on the role of the teacher and students in each type of inquiry-based instruction lesson, and which chemistry topics are suitable for a inquiry.
- ❖ Using the U-tube, science teachers will watch different types of inquiry lessons [ambisiousscience.org] to appreciate different types of inquiry lesson.

- ❖ Then, the chemistry teachers will prepare three lessons (i.e., one structured inquiry lesson, one guided inquiry lesson, and one open inquiry lesson) utilizing the ICT/Internet resources accordingly.
- ❖ Teachers will present their lesson to the peers for discussion and feedback/improvement.

4. Day Four (7 hours) [8.00am-5.30pm]

Objectives

By the end of day four, science teachers should be able to:

i. Prepare inquiry-based instruction lesson plans with detailed learners' activities.
ii. Teach with and about NOS in their inquiry lesson.
iii. Assess/evaluate students understanding in inquiry lessons

Key Readings to Guide Discussions and Activities

Marshall, J. C., Horton, B., Smart, J., & Llewellyn, D (2008). *EQUIP: Electronic Quality of Inquiry Protocol*: Retrieved from Clemson University's Inquiry in Motion Institute, www.clemson.edu/iim.

Kramer, P., Nessler, S. H., & Schluter, K. (2015). Teacher students' dilemmas when teaching science through inquiry. *Research in Science & Technological Education*, 33(3), 325-339, doi: 10.1080/02635143.2015.1047446

Crawford, B., A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44 (4), 613-642.

Llewellyn, D. (2013). *Teaching high school science through inquiry and argumentation*. 2rd Edition. Corwin Press. [Chapters 9, 10, 11]

Luft, J., Bell, R. L. & Gess-Newsome, J. (2008). *Science as Inquiry in secondary settings*. NSATA Press. [Chapters 10, 11]

Activities/Discussions to Engage Chemistry Teachers to Prepare and Micro-teach Inquiry Lessons

- Chemistry teachers will prepare sample inquiry lesson plans.
- Discuss the challenges and opportunities of inquiry-based instruction.
- Discuss how to develop and assess the eight science practices among learners during inquiry lessons.
- Conduct micro-teaching of their lesson plan and receive the feedback from their colleagues and the facilitator in order to improve their lessons,

5. Day Five (7 hours) [8.00am-5.30pm]

Objectives

By the end of day five, science teachers should be able to:

i. Prepare comprehensive inquiry lessons plans.
ii. Micro-teach inquiry lessons
iii. Give peer feedback on micro-lessons.
iv. Revise and re-teach the improved micro inquiry lessons.

Key readings to Guide Discussions and Activities

Crawford, B., A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44 (4), 613-642.

Llewellyn, D. (2013). *Teaching high school science through inquiry and argumentation*. 2rd Edition. Corwin Press. [Chapters 8, 10]

Day Five Activities

- Prepare comprehensive inquiry lessons
- Micro-teaching of inquiry lessons
- Give pear feedback on micro-lessons.
- Revise and re-teach the improved micro inquiry lessons.
- Write reflective memo about the key knowledge and skill about inquiry and NOS they have gained for the last five days of the PD workshop.
- Share their reflection with their peers.

6. Day Six (7 hours) [8.00am-5.30pm]

Objectives

By the end of day six, science teachers should be able to:

i. Prepare comprehensive inquiry lessons plans.
ii. Conduct inquiry-based lessons successfully.
iii. Teach with and about NOS in their inquiry lesson.
iv. Assess/ evaluate students understanding in inquiry lessons.

Key Readings to Guide Discussions and Activities

Crawford, B., A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44 (4), 613-642.

Llewellyn, D. (2013). *Teaching high school science through inquiry and argumentation*. 2rd Edition. Corwin Press. [Chapters 8, 10]

Day Six Activities

- Prepare comprehensive inquiry lessons
- Micro-teaching of inquiry lessons
- Give pear feedback on micro-lessons.
- Revise and re-teach the improved micro inquiry lessons.
- Write a reflective memo about the key knowledge and skill about inquiry and NOS they have gained for the last five days of the PD workshop.
- Share their reflection with their peers

Appendix D: Refined Coding List of Themes/Categories I developed from Data Analysis

Understanding of Inquiry-based Instruction (IBI)

- Meaning of IBI,
- The role of teacher in IBI lesson.
- The role of students in IBI lesson.
- The role of assessment in IBI lesson.
- Science Practices in IBI lessons.

Nature of Science (NOS) Understanding

- Meaning of science.
- Tentativeness of scientific knowledge,
- The role of imagination and creativity in science.
- Differences between scientific laws and theories.
- The relationship between science, society, and cultural values.

Factors Affecting Science Teachers Understanding and Practice of IBI

- **Internal factors**
  - Teachers' attitude (Myth about inquiry).
  - Teaching experience
- **External Factors**
- Lack of motivation,
- Lack of necessary instructional materials,
- Mode of assessment,
- Class size,
- The nature of pre-service and in-service training,

- Support from peer teachers and
- Limited time in relation to many lessons and much content to cover.

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EDUCATION

PhD, Science Education Expected graduation date: May 2017
Syracuse University, *School of Education*
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PhD dissertation: "Science teachers' understanding and practice of inquiry-based instruction in Uganda"

Master of Science, Science Education (Chemistry) 2005
Makerere University
Kampala, Uganda

Post-Graduate Diploma in Education (Chemistry & Biology) 2001
Makerere University
Kampala, Uganda

Bachelor of Science (Hons) (Chemistry, Botany & Zoology) 1999
Makerere University
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Diploma in Science Technology (Chemistry/ Biochemistry) 1993
Kyambogo University
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UNIVERSITY TEACHING EXPERIENCE

LECTURER August 2009-Present
Busitema University, Faculty of Science and Education Kampala, Uganda
As a faculty member, taught the following courses for the B.Sc./Education program:

- EDB 2101: Teaching Techniques and Planning for Teaching
- EDB 2207: Teaching and Learning Chemistry
- EDB 3207: Teaching and Learning Resources Development in Chemistry Education
- EDB 2206: Teaching and Learning Biology
- EDB 3206: Teaching and Learning Resources Development in Biology Education

GRADUATE TEACHING ASSISTANT January 2014-Present
Syracuse University, School of Education Syracuse, NY, USA
Co-taught courses to Bachelor of Science Education and Master of Science Education students. Courses include the following:

- SCE 413/613: Methods and Curriculum in Teaching Science
- SCE 416/616: Assessment and Data Driven Instruction in Science
- SED 415/ 615: Teacher Development in Education
- EDU 508: Candidacy Student Teaching in Science
- SCI 544: Teaching of College Science
- EDU 300/ 600: Media, Democracy and Social Studies

LECTURER August 2011 -Present
Islamic University in Uganda-Female Campus (IUIU-FC), Kampala, Uganda
Faculty of Education, Department of Curriculum and Instruction
As a faculty member of education, taught the following courses:

- ECS1101: General Methods of teaching.
- ECS2102: Instructional Technology.
- EPX2101: Research Methods in Education.
- ECS2202: Micro-teaching-I
- ECS3101: Curriculum Studies.
- ECS3202: Micro-teaching-II
- GTM2201: Research Methods for BBS and BBA program students.
- SWA2103: Statistical Tools in Social Research for SWSA program students.

LECTURER (part-time) March 2009-March 2011
Kampala International University Kampala, Uganda
Taught the following courses to B.Ed. (Science):

- CHE 1102: Basic Organic Chemistry I
- CHE 1201: Basic Organic Chemistry II
- CHE 2202: Methodology of Chemistry Education

LECTURER 2004–2007
Kampala University Kampala, Uganda
Taught the following courses to B.Sc./Education students:

- CHE 1101: Basic Physical Chemistry
- CHE 1201: Basic Inorganic Chemistry
- CHE 1103: Practical Physical and Inorganic Chemistry

- CHE 1204: Practical Organic Chemistry I
- CHE 2101: Chemical Thermodynamics
- CHE 2102: Poly-functional Aliphatic and Alicyclic
- CHE 2103: Aromatic Chemistry
- CHE 2202: Methodology of Chemistry Education
- CHE 3104: Organic Synthesis

HIGH SCHOOL TEACHING EXPERIENCE

EDUCATION OFFICER (Secondary School teacher) 1999–2005
Ministry of Education and Sports Kampala, Uganda

Key duties:

- Teaching Chemistry and Biology (senior one to senior six).
- Guiding and counseling students.

Key achievements:

- Taught students who are currently qualified in different professions.
- Instilled discipline and values in the students.

CURRICULUM DEVELOPMENT EXPERIENCE

CURRICULUM SPECIALIST August 2008–March 2010
Mulago – Mbarara Teaching Hospitals Joint AIDS program (MJAP) Kampala, Uganda

Key duties:

- To develop, modify and sustain curricula for training courses in care and prevention of HIV/AIDS, TB and other infectious diseases, and support the training program to implement and disseminate these curricula among stakeholders.

Key achievements:

- Carried out the Training Needs Assessment (TNA) in eight Districts of Uganda for the Medical Laboratory Management Curriculum in conjunction with the Ministry of Health (MoH) and the Central Public Health Laboratory (CPHL).
- Developed a National Medical Laboratory Management Curriculum in conjunction with CPHL/MoH which is being used to train the Medical Laboratory Technologies in Uganda today.
- Developed the Pre-Internship Medical Student Curriculum in HIV/AIDS management after carrying out the TNA.
- Participated in the development of the Nutrition and HIV/AIDS training curriculum representing MJAP in the Ministry of Health.
- Acted as Training Coordinator from October 2009 to March 2010, coordinating all the training programs in MJAP.

CURRICULUM DEVELOPMENT SPECIALIST (CHEMISTRY) December 2005–July 2008
National Curriculum Development Centre Kampala, Uganda

Key duties:

- o Initiated new curriculum reform ideas in the subject of chemistry in Uganda.
- o Serviced the chemistry panel members by convening meetings and forming data and information to panel members.
- o Developed and prepared subject syllabuses.
- o Organized and conducted curriculum materials writing workshops.
- o Prepared teachers' manuals.
- o Wrote, coordinated and edited curriculum materials developed by teachers.
- o Organized and conducted teachers' orientation courses.

Achievements:

- o Developed the chemistry curriculum for community polytechnics in Uganda.
- o Developed the e-Learning chemistry CDs.
- o Developed the draft syllabus and teachers' manual for Integrated Chemistry with Technology (this is currently under pilot in 12 Districts of Uganda).
- o Wrote a project on "Research in Utilizing Indigenous Scientific Knowledge in Teaching-Learning Science and Eradicating Poverty," which was submitted to UNESCO, and approved. It was successfully implemented last year (2010) under my coordination.
- o Participated in planning and organizing National Science Week and school visits in 2007 and 2008 by the Uganda National Council for Science and Technology – Inter-Agency Planning Committee, of which, I was a member representing NCDC. The function of the committee was to popularize science subjects in secondary schools, organize school visits, and organize Science Week.
- o Acted as Administrative Secretary for six months (May 2006 – October 2006) where I performed all administrative duties including taking minutes of the NCDC Governing Council and Academic Steering Board.
- o Participated in inspection of schools, organized by the Directorate of Education standards in the Ministry of Education and Sports.
- o Participated in moderating the Uganda National Examination Board (UNEB) chemistry exams.
- o Attended all UNEB award meetings to discuss chemistry results.
- o Participated in scouting UNEB exams (primary, secondary and tertiary levels).

OTHER WORK EXPERIENCE

LABORATORY TECHNICIAN/ RESEARCH ASSISTANT November 1992 –October 2002
Makerere University, Faculty of Science Kampala, Uganda

Key duties:

- o Assisted in the research activities in the Geology Department, Faculty of Science.
- o Organized and supervised students' practical.
- o Managed the laboratory, library and lecture rooms.

Achievements:

- o Participated in the training of geologists in Uganda, who have played a big role in our current oil and mineral exploration.

- Participated in many postgraduate pieces of research which lead to geology staff receiving PhDs.
- Organized the Geology Department laboratory and museum while acting as Chief Technician (October 1995 – July 1996).

LICENSED SECONDARY TEACHER (Biology/Chemistry) April 1990–August 1990
Modern S.S.S. Kampala, Uganda

FITTER TECHNICIAN/TRAINEE January 1988 –May 1988
Sugar Cooperation of Uganda Limited (SCOUL) Kampala, Uganda

CONSULTING EXPERIENCE

CURRICULUM CONSULTANT 2010
Law Development Center Kampala, Uganda
The purpose of this consulting work was to infuse child protection issues in the bar course for lawyers trained by Law Development Center in Uganda.

CURRICULUM CONSULTANT 2009
Ministry of Health Kampala, Uganda
The purpose of this consulting work was to develop the HIV/AIDS nutrition curriculum for the Ministry of Health in Uganda.

RESEARCH INTERESTS

- Gender and science education
- Inquiry-based learning and instruction
- The influence of science teachers' "Nature of Science" epistemological beliefs on their teaching practice
- Influence of teachers beliefs on their teaching styles
- Role of indigenous knowledge in teaching-learning science
- Curriculum development and evaluation
- The role of ICT in teaching and learning sciences
- Science, Technology and Society (STS) issues
- How to increase scientific literacy among citizens

PUBLICATIONS

Ssempala, F. (2016). *Chemistry professors' conception of the nature of science.* Saarbrucken, Germany: Lambert Academic Publishing. ISBN: 978-3659889400

Ssempala, F. (2015). *Experiences of international graduate students in United States universities.* Paper presented at the 8th International Conference on Education, Research, and Innovation, Seville, Spain, November 18-20. ISBN: 978-84-608-2657-6

Ssempala, F. (2013). *The level of scientific attitude / superstition among Bachelor of Science Education students: Implication for science education in Uganda*. Paper presented at the International Conference on Education, Kenyatta University Conference Centre, Nairobi, Kenya, July 10–12. ISBN: 978-84-616-3847-5

Ssempala, F. (2013). *Improving relevance of ordinary level science curriculum by integrating science subjects with technology in Uganda*. Paper presented at the 7th International Technology, Education and Development Conference, Valencia, Spain, March 4-6. ISBN: 978-84-616-2661-8

Ssempala, F. (2013). *Opportunities and challenges of mainstreaming Adolescent Sexual Reproductive Health/Life Planning Skills (ASRH/LPS) in Uganda upper primary school curriculum.* Paper presented at the 7th International Technology, Education and Development Conference, Valencia, Spain, March 4-6. ISBN: 978-84-616-2661-8

Ssempala, F., & Lukyamuzi, A. (2013). *Integrating learning technology into the classroom: The importance of pre-service teachers' and lecturers' perceptions.* Paper presented at the 6th International Conference of Education, Research and Innovation, Seville, Spain, November 18-20. ISBN: 978-84-616-3847-5

Ssempala, F. (2011). *How to prepare relevant science educators for 21st century*. Paper presented at the International Conference on Education, Kenyatta University Conference Centre, Nairobi, Kenya, July 20-22, pp.102-128 of conference proceedings.

Ssempala, F. (2005). *Gender Difference in Performance of Chemistry Practical Skills among Senior Six students in Kampala District* (Master's thesis). Available from Dissertation.com. (URL:http://www.dissertation.com/book.php?method=ISBN&book=1-59942-700-1) ISBN: 978-1599427003

PRESENTATIONS

Ssempala, F. (2008). *The way forward for institutionalization of Adolescent Sexual Reproductive Health (ASRH) and Life Planning Skills in Uganda Primary School Curriculum*. The paper presented in NCDC/UNFPA/SAREH training workshop of primary teachers and CCTs of five districts (Wakiso, Kibaale, Gulu, Arua and Kapchorwa), Sports View, Kireka, Uganda, May 5-15 and May 19-22.

Ssempala, F. (2006). *Using Science Technology and Society (STS) approach to teach/learn science (chemistry).* Paper presented at the first science colloquium organized by Secondary Science and Mathematics Teachers (SESEMAT) Project, Kampala, Uganda, June 30.

Ssempala, F. (2006). *Framework for a National Curriculum* (NCDC format). Paper presented at the workshop to review the hotel and tourism curriculum organized by the Ministry of Education and Sports, Crested Crane Hotel, Jinja, Uganda, June 19-22.

Ssempala, F. (2011). *An overview of curriculum development/review process*. Paper presented in the curriculum review workshop of Bachelor of Science Education program, Busitema University, Faculty of Science and Education, TLT Hotel, Tororo, Uganda, September 15-16.

COURSES/WORKSHOPS FACILITATED

Ssempala, F. (2010). Writing the Management Training for Improved Health Services Curriculum. Workshop was organized by the Ministry of Health/Central Public Health Laboratories (CPHL). Rider Hotel, Seeta, Uganda, March 5-12.

Ssempala, F. (2009). Writing the Nutrition and HIV Curriculum. Workshop was organized by the Ministry of Health. Hotel Africana, Kampala, Uganda, November 2009.

Ssempala, F. (2008). Integrate Entrepreneurship in Business, Technical, Vocational Education Training (BTVET) Curriculum in Uganda. Workshop was organized by UNESCO. Crested Crane Hotel, Jinja, Uganda, March 2008.

Ssempala, F. (2008). NCDC / UNFPA / SAREH training workshop of primary teachers and CCTs of five districts (Wakiso, Kibale, Gulu, Arua and Kapchorwa), to trial test the re-designed syllabi which are infused with Adolescent Sexual Reproductive Health (ASRH), and Life Planning Skills Education (LPSE). Sports View, Kireka, Uganda, May 5-15 and May 19-22.

Ssempala, F. (2006). Review of hotel and tourism curriculum for technocrats in educational institutions, e.g. UNEB, ESA, UNCHE, MUBS, UQFW, etc. Workshop was organized by the Ministry of Education & Sports and a Hotel and Tourism Training Institute (Crested Crane- Jinja) (HTTI). Crested Crane, Jinja, Uganda, July 17-19.

COURSES/WORKSHOPS ATTENDED

- Attended an International Conference on Education at Kenyatta University Conference Centre, Nairobi, Kenya, July 10-12, 2013.
- Attended the 7th International Technology, Education and Development Conference, Valencia, Spain, March 4–6 2013.
- Attended an International Conference on Education at Kenyatta University Conference Centre, Nairobi, Kenya, July 20-22, 2011.

- Participated in a 10-day workshop to write the Primary Teachers' Manual / Resource Book for the re-designed syllabi of Science, Social Studies (SST) and Religious Education (CRE / IRE) subjects infused with ASRH/LPSE content, Sports View Hotel Kireka, Uganda, April 20 – 30, 2008.

- Participated in one-day workshop of human rights organized by UNESCO, representing NCDC Science and Math Department, Kampala, Uganda, August 25, 2006.

- Participated in a workshop about integrating democracy and human rights in secondary school curriculum, organized by MS Uganda, Kampala, Uganda, August 25, 2006.

- Participated in Thematic Curriculum stakeholders workshop organized by the Ministry of Education & Sports and NCDC, Kampala, Uganda, July 3-4, 2006.

- Participated in the first science colloquium organized by Secondary Science and Mathematics Teachers' (SESEMAT) Project, Uganda, June 30, 2006.

- Participated in the review of a hotel and tourism curriculum organized by the Ministry of Education & Sports and a Hotel and Tourism Training Institute (HTTI), Crested Crane, Jinja, Uganda, June 19-22, 2006.

- Participated in Integrated Production Skills (IPS) National Stakeholders Workshop organized by the Ministry of Education & Sports and NCDC, Kampala, Uganda, May 29-30, 2006.

- Participated in a HIV/AIDS and life skills integration in secondary school curriculum workshop, organized by the Ministry of Education & Sports and NCDC, Kampala, Uganda, May 1-5, 2006.

- Participated in an HIV/AIDS streaming in secondary school curriculum workshop, organized by the Ministry of Education & Sports and NCDC, Uganda, April 24-26, 2006.

GRANTS

Ssempala, F. (2008). Conduct research on indigenous knowledge and poverty reduction in Uganda. Grant proposal submitted to UNESCO, $260,000 (USD). Funded 2009.

AWARDS

Berj Harootunian Award by the faculty of the Teaching and Curriculum program, Syracuse University, New York, USA for 2016-2017 in recognition of my outstanding academic achievement and meritorious dissertation research study in the field of teacher education.

GRADUATE TEACHING ASSISTANTSHIP January 2014- May 2017

Syracuse University, Department of Teaching and Leadership
This Graduate Teaching Assistantship was awarded to pursue PhD in Science Education from January, 2014-May, 2017 with a scholarship of 24 credits per year for 3.5 years' worth $126,000 (1 credit = $1500).

PHI BETA DELTA, Honor Society for International Scholars 2016

Science Educator Award, 2008, by Uganda National Council for Science and Technology (UNCST) in recognition of my participation in organizing the National Science week Activities for 2006, 2007, and 2008 years.

PROFESSIONAL AFFILIATIONS

Commonwealth Association of Science & Mathematics Educators (CASTME)

Association for Supervision & Curriculum Development (ASCD)-USA-Member-ID: 1-924935

American Chemical Society (ACS) Member number: 30902717

Busitema University Academic Staff Association (BUASA)

Uganda Management Forum-British Council.

CERTIFICATION

Chemistry & Biology Graduate Teacher, by the Ministry of Education and Sports, Government of the Republic of Uganda, July 2001.

HUMANITARIAN SERVICES OFFERED

Donating blood since 1999 (a minimum of three times a year). So far, have donated blood fifty-eight (58) times.

Offer free guidance and counseling services during my free time to primary, secondary and college students.

LANGUAGE SKILLS

Fluent in English and Luganda