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Effect of Professional Development On Chemistry Teachers' Understanding And Practice of Inquiry-Based Instruction in Kampala, Uganda

Authors
Fredrick Ssempala[1], **Joanna O. Masingila**[2]
[1,2]Syracuse University, Syracuse (USA)

ABSTRACT

Our purpose in this exploratory multi-case qualitative study was to explore the effect of a Professional Development (PD) workshop on Inquiry and Nature of Science (NOS) on chemistry teachers' understanding and practice of Inquiry-Based Instruction (IBI) in Kampala city public schools in Uganda. We used a purposive sampling procedure to identify two schools of similar standards from which we selected eight willing chemistry teachers (four from each school) to participate in the study. Half of the teachers (active group) attended the PD workshop on inquiry and NOS for six days, while the control group did not. We collected qualitative data through semi-structured interviews, classroom observation, and document analysis. We analyzed these data by grounded theory using an interactive, open coding approach. We established that all the participating chemistry teachers had insufficient understanding of IBI at the beginning of the study. Teachers from the active group improved their understanding and practice of IBI after attending the PD workshop. Based on the above findings, we conclude that the explicit reflective PD workshop on inquiry and NOS that we 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. Hence, there an urgent need for science educators to design PD programs that help teachers to reconstruct/refine both their teaching philosophy and practice and 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.

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

1. INTRODUCTION

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 [1, 2, 3, 4]. Not only do students of these teachers learn the rudimentary knowledge and skills possessed and employed by scientists, but they also learn about the NOS [5, 1]. 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 [6, 7]. Among these reasons is that science teachers often do not, themselves, possess a holistic understanding of scientific inquiry and the NOS [8, 9, 10]. This in all likelihood stems from the nature of traditional science teaching at college/university level that commonly uses didactic-teaching-by-telling approach [3]. In many teacher education programs, little attention is given to how the processes of scientific inquiry should be taught [11]. 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 (IBL) and inquiry-based teaching [12, 13]. [14] defined inquiry as the process by which scientific knowledge is developed other authors 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 [9], 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).

IBI is based upon constructivist views of learning where students develop their ideas. Research shows that IBI increases motivation, conceptual understanding, critical thinking, science content understanding and positive attitudes towards science [15]. 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 [5]. [16] 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 [17]. They found that beginning teachers often left out evidence, explanation, justification, and communication. Another study by [18] discovered that few highly-motivated teachers could describe what IBI was; most equated it with hands-on learning. [19] 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 IBI in developing countries. Explicit-reflective refers to the approach of training where NOS is directly explained to the learners by giving clear examples of NOS 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 [20, 21]. Most of the research studies have been carried out to establish the understanding and practice of IBI by science teachers in developed countries, primarily in general science and for prospective elementary science teachers. For this study, we 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 [19]. In this study we aimed to address the gap in knowledge about the effect of explicit-reflective PD workshop on inquiry and NOS on chemistry teachers' understanding and practice of IBI in developing countries using an exploratory multi-case study design.

1.1 Purpose of The Study

The purpose of the 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 IBI in Kampala city public schools in Uganda.

1.2 Research Questions

The study was guided by the following research questions:

1. How do in-service chemistry teachers understand and implement IBI before attending an explicit, reflective professional development workshop on inquiry and NOS?
2. How do in-service chemistry teachers understand and implement IBI after attending an explicit, reflective professional development workshop on inquiry and NOS?

1.3 Theoretical Constructs

1.3.1 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" [9].

1.3.2 IBL- This refers to the skills, knowledge and dispositions that are developed in students because of their engagement in classroom inquiry [22]. Embedded in the notion of IBL, therefore, is the understanding that students engage in some of the activities and thought processes that the scientists who construct scientific knowledge engage in.

1.3.3 IBI- IBI refers to those practices scientists engage in during the development of scientific knowledge [18; NGSS, 2013). It is 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 [9, 23]. Three different settings of IBI can be differentiated (Table 1).

Table 1. Settings of Inquiry Teaching

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

Source: Adapted from [24].

1.3.4 NOS- This is the epistemology of science underlying the practices embedded in investigations, field studies, and experiments, the values and beliefs inherent to the scientific enterprise, and the development of scientific knowledge [5]. According to the Next Generation Science Standards [23], 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 [23].

2. RELATED LITERATURE AND KNOWLEDGE GAP

2.1 Science Teachers' Understanding of IBI

Teaching science through inquiry is the cornerstone of good teaching. Regrettably, an inquiry approach to learning science is not the custom in schools. Instructors are often struggling to build a shared understanding of what science as inquiry means and what it looks like in the classroom. Science teachers have divergent views about what IBI is. They hold a variety of ideas about inquiry [17], which may affect the way they implement it [25]. Hence the need to find out how these ideas affect teachers' implementation of inquiry.

Teachers' previous learning orientations and experiences may also impact their learning about inquiry [26]. This is supported by [27], 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).

Researchers [e.g., 28, 6] have found that teachers' ideas about the NOS as an objective body of knowledge created by a rigid scientific method hindered their teaching of an accurate view of inquiry. Teachers with a more accurate understanding of the NOS can implement a more problem-based approach to science teaching [28, 29]. What is learned from literature is that implementation of proper inquiry is a function of teachers' understanding of the NOS. [30] recommended developing reflective practitioners who can infuse personal conceptions and values into professional identity, resulting into 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.

Another tension highlighted in the literature is differences of teachers' perceptions of the NOS. [31] found that improving teachers' conceptions of the NOS appeared to improve on the use of inquiry. Teachers with more sophisticated NOS views conducted a less structured inquiry and more student-centered activities while teachers who did not possess adequate content knowledge were reluctant to change their teaching practices.

[31] found that the discipline in which teachers taught was a major influence on their 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, a uniform view of how to implement inquiry in science may not be attained. Hence, [31] provide justification for studying the impact of science teachers' disciplines on their understanding and practice of IBI.

Another research studied the effectiveness of teacher education programs designed to enhance prospective teachers' knowledge of inquiry. 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 concurrence, [32] argued that pre-service teachers could benefit from opportunities to navigate the border between learning and teaching science, thereby deepening their conception of inquiry.

[33] noted that even though mentors are normally experienced teachers, they have sometimes showed a lack of understanding of the features of inquiry. These found that many teachers and mentors do not teach science regularly in their classrooms since science is not included in state student achievement tests. [33] are useful in the sense that they call 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, so the findings may not be readily applicable to a country like Uganda. We conducted this study to close this among other gaps.

2.2 Science Teachers' Practice of IBI

Various writers have indicated that there are many differences in science teachers' practice of IBI including differences in teachers' curricular interpretation. In addition, while ICT is one of the tools used in IBL, teachers' attitudes and beliefs in the use of ICT in IBL also differ [34]—because science is a broad discipline with many sub-divisions wherein teachers practice IBL differently.

[18] 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. [35] 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 in India and Taiwan [36].

Science teachers' practice of IBI is also a function of their intentions and classroom practices. [37] 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 through inquiry. This proves that even experienced teachers face challenges in implementing IBI.

The literature reviewed also indicates that beliefs influence science teachers' practice of IBI. For example, [38] 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 key characteristics of how this teacher created an IBI classroom were linked to the teacher's 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 they teach. 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 [38].
[39] found out that students can have a substantive and generative influence on the nature and form of inquiry carried out by their teacher, underscoring the importance of context. The change in students from one year to the next is a component of the context. The inference here is that practice of IBI should be situational.
Science teachers' practice of IBI is also dependent on the curriculum. For example, [35] 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. These findings imply that it takes time for teachers to implement effectively innovative science curriculum and it is important that students engage actively in inquiry investigation. 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 re-trained to deliver the revised curricula. It is with this understanding that this study investigated the teachers' understanding and practice of IBI.
In Spain, a study concluded that professional development had improved science teachers' ability to implement IBI. This study provides evidence of the importance of context-specific qualitative studies to improve teachers' ability to implement IBL by listening to teachers' needs and addressing their concerns. Studies of this nature are required in African countries to address the problems science teachers face when trying to implement IBL. Our study was conducted to address this need.
[18] examined the teaching practice of inquiry of 26 qualified and highly motivated teachers. Although the teachers were qualified, few aspects of inquiry or NOS were evident in their teaching. 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. Motivation is an incentive factor. Taking this into account, this study interrogated the experience of teachers in Kampala.
[40] 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 beginning secondary science teachers tended to enact a teacher-centered form of inquiry, and could benefit from induction programs focused on inquiry. [40] found that experience 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 essential that new teachers have access to well-designed science induction programs. These programs should focus on all features of inquiry.
The way teachers incorporate learning about scientific inquiry (SI) into laboratory work, also influences science teachers' practice of IBI. For example, in Germany, a 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. 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. This 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 PhD. The findings of this study may not be generalized to such countries, so it is important to investigate the experiences of teachers in these countries.

3. METHODOLOGY

3.1 Design

We employed a qualitative research approach and exploratory multi-case study design. This 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. The approach was applicable because there are gaps in literature on high school science teachers understanding and practice of IBI and the effect of explicit-reflective professional development on teachers' understanding and practice of IBI in developing countries such as Uganda. The case design was appropriate for this research to get an in-depth understanding of the knowledge and practice of the eight teachers involved in the study.

3.2 Participants

We utilized a purposive sampling procedure in which we identified two out of the 21 schools in Kampala District. Eight teachers participated in the study (Table 2). Four of the teachers were part of an active group (School A), while the other four were part of a control group (School B). We advised these teachers on the purpose and processes of the study and requested them to sign an informed consent form.

Table 2. Participants

School	Teachers (Pseudo-name)	Qualification	Teaching subjects	Teaching experience
A	Mr. Byamukama	B.Sc./ Educ.	Chemistry and Biology	6 years
	Mr. Kigozi	Dip. Edu, B.ED.	Chemistry and Biology	16 years
	Mr. Agaba	Dip. Edu., B.ED., MSc. (Chem.)	Chemistry and Biology	11 years
	Mr. Opolot	Dip. Edu., B.ED.	Chemistry and Biology	5 years
B	Mr. Bbosa	Dip. Edu., B.ED.	Chemistry and Biology	14 years
	Mr. Ssentumbwe	Dip. Edu, B.ED.	Chemistry and Biology	20 years
	Mr. Muhangi	Bsc.(Educ.)	Chemistry and Biology	11 years
	Ms. Akello	Bsc. (Educ.)	Chemistry and Biology	3 months

3.3 Data Collection

We collected data through semi-structured in-depth interviews, classroom observation and document analysis. We organized the explicit-reflective PD workshop on inquiry and NOS for School A after the first phase of data collection. The workshop lasted for six days. We adapted the transformational model of PD that involves a combination of some processes and conditions from action research. The main purpose of the workshop was to produce changes in deeply held beliefs, knowledge, and habits of practice of the participating chemistry teachers in School A. We involved the teachers in activities such as micro-teaching, planning IBI, preparing instructional pie, etcetera, to help them to reconstruct their practice of IBI. The workshop discussed the eight science practices [41] and eight tenets of NOS [23]. The teachers prepared inquiry-based lesson plans with our guidance based on the readings provided in the workshops, conducted peer teaching and then received feedback on their activities. The micro-teaching was based on chemistry topics covered in the first and second school terms because we 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, we 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.

3.4 Analysis

The data was transcribed and entered into NVivo. Subsequently, we coded it to identify themes using [42]'s criteria for coding data. Thereafter, we developed a rubric based on the themes identified to answer the research questions.

4. FINDINGS

4.1 Teachers' Pre-Professional Development Workshop Understanding of IBI

Prior to the professional development workshop, the teachers had insufficient understanding of IBI (Table 3). Apart from Mr. Agaba (School A) and Mr. Muhangi (School B), who had MU of the role of teacher, student and assessment in an IBI lesson, none of the teachers was aware of any type of IBI. They understood IBI as a question and answer technique, utilizing learners' prior knowledge and hands-on activities. Also, Ms. Akello had sufficient understanding of the role of students, and MU of the teacher's role in an IBI lesson.

Table 3. Pre-Professional Development Workshop Understanding of IBI

IBI theme	School A				School B			
	Mr. Byamukama	Mr. Kigozi	Mr. Agaba	Mr. Opolot	Mr. Bbosa	Mr. Ssentumbwe	Mr. Muhangi	Ms. Akello
Meaning of IBI	"IBI is utilizing learners' prior knowledge" [IU]	"IBI is question and answer techniques" [IU]	"IBI is hands-on-activities" [IU]	"IBI question and answer technique" [IU]	"IBI is utilizing question and answer technique" [IU]	"IBI is discovery learning" [IU]	"IBI is question and answer technique" [IU]	"IBI is a process of giving knowledge to learners" [IU]
The role of a teacher in IBI	"Teacher is center of instruction" [IU]	"Teacher is center of instruction" [IU	"Teacher is motivator" [MU]	"Teacher is center of instruction" [IU	"Teacher is center of instruction" [IU]	"Teacher monitor and evaluate learners" [IU	"Teacher is facilitator of learning process" [MU]	"Teacher is facilitator of learning process" [MU]
Role of students in IBI lesson.	"Students are passive learners" [IU]	"Students are passive learners" [IU	"Fairly active learners" [MU]	"Students are passive learners" [IU	"to answer questions" [IU]	"to discover new knowledge" [IU	"active learners/researchers" [SU]	"active learners/ researchers" [SU
Role of assessment in IBI.	"To determine pre-determined discrete knowledge" [IU]	"To determine pre-determined discrete knowledge" [IU]	"assessment for learning" [MU]	"To determine pre-determined discrete knowledge" [IU]	"To determine pre-determined discrete knowledge" [IU]	"To determine pre-determined discrete knowledge" [IU]	"Continuous assessment of knowledge and skills" [SU]	"To determine pre-determined discrete knowledge" [IU]
Science practices in IBI.	"not aware of the science practice" [IU]	"not aware of the science practice" [IU]	"not aware of the science practice" [IU]	"not aware of the science practice" [IU]	"not aware of the science practice" [IU]	"not aware of the science practice" [IU]	"not aware of the science practice" [IU]	"not aware of the science practice" [IU]

KEY: IU = Insufficient understanding; MU = Moderate understanding; SU = Sufficient understanding

4.2 Implementation of IBI

4.2.1 Implementation of IBI before the Professional Development Workshop in School A

Mr. Byamukama. Mr. Byamukama generally did not implement IBI 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 [41]. 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).

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 IBL 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.

$$\text{Magnesium + Oxygen} \longrightarrow \text{Magnesium oxide}$$

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 IBI 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.

4.2.2 Implementation of IBI at the beginning of study in School B

Mr. Bbosa. Mr. Bbosa generally did not implement any IBI in his chemistry lessons that WE 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.

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.

The reaction of acids with metal oxides (insoluble bases)

Acid + metal oxide → salt + water

e.g. Hydrochloric acid + magnesium oxide → Magnesium Chloride + Water

The reaction of acids with metal hydroxides

Acid + Metal hydroxide (alkali) → Salt + Water

e.g. Hydrochloric acid + Sodium hydroxide → Sodium hydroxide + water

The reaction of acids with metals

Acid + Metal → Salt + Hydrogen

E.g. Sulphuric acid + Magnesium → Sulphate + Hydrogen

The reaction of acids with metal carbonates

Acid + Metal carbonates → Salt + Water + Carbon dioxide

e.g. Sulphuric acid +Copper (ll) carbonate → 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 IBI in his lesson accordingly

4.3 Post-Professional Development Workshop Understanding of IBI

Generally, all the four chemistry teachers in School A improved their understanding of IBI 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 IBI 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 (Table 3) 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 WE 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.

4.4 Teachers' understanding of IBI at the end of study in School B

Generally, teachers in School B maintained their understanding of IBI 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 IBI 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 IBI is to ask questions, while the role of students is to answer questions and carryout activities given by the teacher."

Mr. Ssentumbwe stated that, "IBI 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, "IBI 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 IBI from the above quotation.

Ms. Akello mentioned that, "In a typical IBI 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 IBI 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.

4.5 Post-Professional Development Workshop Implementation of IBI 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. We observed at least two lessons for each participant and then selected one that the participant and we 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 we 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 IBI 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 IBI 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 IBI 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.

4.6 Implementation of IBI at the end of study in School B

We continued to observe the chemistry teachers in School B up to the end of the study. In this section, we present findings from 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 IBI 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 $\longrightarrow$ salt +hydrogen
- Acid + base $\longrightarrow$ salt + water
- Acid + carbonate $\longrightarrow$ 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), we 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.

5. DISCUSSION

5.1 Teachers' Pre-Professional Development Workshop Understanding and Implementation of IBI

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 IBI 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 [41]. 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 "IBL 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 [10]'s 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. In the same vein, [43] in Rwanda established that many science teachers associated inquiry teaching with a few of its specific characteristics while some had a very different understanding.

A 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 [41]. 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 [44] who established that different teachers carry out reform-based curricula in different ways, something curriculum designers need to take into account. Additionally, [18], 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.

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 we 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.

5.2 Teachers' Post-Professional Development Workshop Understanding and Implementation of IBI

We 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 we discuss above. Most teachers could state the eight science practices promoted by the [41] 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 [45] 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. We 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.

[46] 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, we 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). We then told them to prepare another pie chart showing what instructional strategies they desire to utilize in teaching science. We 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.

The teachers' challenges of incorporating NOS issues in their lesson findings agrees with a 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. We also found out that most teachers rarely utilized ICT/Internet during IBI lessons. This finding agrees with [34] who established that teachers' beliefs, knowledge and skills predicted their technology use in biology lessons.

Studies conducted by other researchers [47, 48, 49] 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 we found in our study.

6. CONCLUSIONS

It was concluded that 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. It was also concluded that 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.

7. RECOMMENDATIONS AND FURTHER RESEARCH

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. There is also 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.

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