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UGANDA SCIENCE TEACHER EDUCATORS: A CONCURRENT MIXED METHODS INVESTIGATION OF PERSPECTIVES ON NATURE OF SCIENCE, PEDAGOGY, AND CLASSROOM LEARNING ENVIRONMENT

by

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A dissertation submitted to the Graduate College in partial fulfillment of the requirements for the degree of Doctor of Philosophy
Mallinson Institute for Science Education
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This study investigates the perspectives of Uganda science teacher educators on three areas foundational to science education reforms: Nature of science, preferred science pedagogy and classroom learning environment. Uganda has embraced science education reforms but classroom science teachers struggle to implement them. Could these struggles be attributed to their science teacher educators’ perspectives? Using a concurrent mixed method design, the study profiles the views of 63 science teacher educators in Uganda.

Data were collected using four instruments: Student Understanding of Science and Scientific Inquiry, Pedagogy of Science Teaching Test, Views of Nature of Science survey and Constructivist Classroom Learning Environment survey. Additional qualitative data were collected using semi-structured telephone interviews and content analysis of science methods course syllabi used by the participants.

Analysis of data yielded results showing that a majority of the participants’ views on nature of science are transitional, characterized by an objectivist worldview and do not
fully conform to the consensus view of teachable nature of science. A majority of their views favor pedagogies that portray classroom science as ‘science-in-the-making’. Although, results show reluctance to embrace uncertainty and critical voice manifestation during classroom discourse, their views on other aspects of classroom learning environment support a constructivist learning environment and current science education reforms. The study postulates that a Uganda government policy to ‘vocationalize’ classroom experiences influenced participating science teacher educators’ perspectives on classroom learning environments.

There were no statistically significant correlations between their views on the three foundational areas investigated signifying that their perspectives on these areas are disconnected, incoherent and still evolving.

This study also reveals that science methods course syllabi had limited to no reference to the nature of science. Syllabi at National teachers colleges reflect participants’ views on preferred pedagogy and classroom learning environment better than University syllabi.

This being a pioneer study on Uganda science teacher educators’ perspectives, its findings have practical and theoretical implications for professional development, science teacher education curriculum and teaching reforms, and accreditation of science teacher education programs. These are critical professional strategies that can lead to a successful realization of science education reforms in Uganda.
I dedicate this book to the women historically central to my academic pursuits.

My mother Princess Joyce Babirye Kagoya Kagumba who has encouraged me and worked hard to ensure payment of my school fees since my primary school years.

Aunt Alice Nabirye and Grandmother Yokoladin Wabuubi Mutesi who prayed and prophesied me into this journey at an early age and sang my song of greatness even before I budded as an academician.

Mama Honorable Cecilia Barbara Atim Ogwal Nalongo and Mama Brigitte Michael who loved me when I was a stranger, took me in, as their own son, into their homes and supported me financially to realize my potential during my secondary school years.

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“Surely it took more than a family to build my Doctorate”
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Robert Elisha Musookho Kagumba
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CHAPTER I

INTRODUCTION

Background of the Study

Uganda is one of the developing economies that has, for decades, been advised by global social economic development agencies such as the World Bank (WB) and the United Nations Developed Fund (UNDP) to invest in science education and scientific innovations necessary to acquire lasting and sustainable national social and economic development such as experienced by developed economies (Uganda-UNESCO, 2010; Wedgwood, 2005).

Uganda, in response, has embraced science education reforms and strategies implemented by the United States of America (USA) and the European Union (EU), seeking to duplicate their socio-economic transformations. Since 1997, Uganda has been emphasizing science education goals very similar to those of USA and Europe. It remodeled its science, technology, engineering and mathematics (STEM) education goals, and incorporated them into its larger vision of the Millennium Development Goals (MDG). Clearly, education globalization has caught up with this East African nation (United-Nations, 2013; Wood, 2008).

In Uganda, implementation of science education reforms is a task mostly left to classroom science teachers. These teachers are products of varying schools of education and their faculties meaning that their professional effectiveness in handling assigned reform tasks is in part dependent on how effective their pre-service professional
preparation was. Implied here is the fact that successful enactment of proposed science education reforms hinges on the knowledge and competences of science teacher educators. Consequently, understanding the quality of knowledge, skills and professional practices of science teacher educators, as teachers, is imperative in predicting the success of education reforms.

The study sought to understand and document Uganda science teacher educators’ perspectives on three areas foundational to science education reforms: nature of science (NOS), preferred science pedagogy (PSP) and classroom learning environment (CLE).

**The study’s central assumption.**

This study assumed that Uganda science teacher educators epistemologically reproduce themselves in their teacher candidates. In other words, teacher candidates exhibit most of the epistemological qualities or perspectives of the science teacher educators who prepared them for their career duties. Studies show that classroom science teachers endeavor, in most cases, to re-enact their college science classroom experiences (Berry, 2009; Major & Palmers, 2006). Science teacher educators have also been assumed to pass on to teacher candidates their held epistemological and professional perspectives pertaining to science, science teaching and the related research (McDiarmid & Clevenger-Bright, 2008). Moreover, Kennedy (1999) observed that passing on of these perspectives can occur actively or passively as part of the stipulated curriculum or the hidden (un-intended) curriculum.
Why perspectives on the NOS, PSP and CLE.

This study was specifically interested in Uganda science teacher educators’ perspectives on the nature of science (NOS), preferred science pedagogies (PSP), and classroom learning environments (CLE) being foundational areas in science education reforms.

Approaches to science education that emphasize these three foundational areas have potential to open up the sciences to more students by enhancing a deeper understanding of the scientific enterprise, an ability to love and defend scientific knowledge, and the ability to critically consume scientific products (DeBoer, 1991).

Specifically, learning and teaching aspects of NOS in science education can improve science learning experiences and outcomes by (i) making science relevant to the learners’ everyday mode of thinking, (ii) stimulating the development of positive attitudes towards science, and (iii) articulating valid scientific argumentation and analysis of evidence (Macdonald, 2009; Ogunniyi, 2006). Thus the understanding of aspects of nature of science is crucial to achieving the global goal of “scientific literacy for all” (American Association for the Advancement of Science ([AAAS], 1990; Driver, Leach, Millar, & Scott, 1996).

Also, improved understanding of science concepts partly depends on the way classroom science is experienced or taught (AAAS, 1990, 1993). Teaching classroom science in a manner that effectively develops social-cognitive habits of knowledge construction in the learners ensures critical, creative and collaborative thinking, problem solving, and argumentation. As such, the use of science pedagogies that promote active student participation in social construction of knowledge and development of
metacognitive skills is paramount. Such pedagogies lay the burden of curriculum mastery on the learner and not the science instructor (Trigwell, Prosser, & Waterhouse, 1999).

To improve science learning experiences using the two scenarios highlighted above requires that educators have knowledge useful in creating suitable classroom learning environments. Classroom learning environments should facilitate stimulation for deeper understanding of the scientific concepts being learned, inculcate positive attitudes towards science and enable an overall acquisition of personal and interpersonal habits necessary for furtherance of science as a way of knowing (AAAS, 1990, 1993). For this reason, instructors need to be able to create a science learning environments that consist of a community of learners freely learning from the instructor and from one another. Learners should have the freedom to challenge themselves, their classmates and their instructors on the usefulness and appropriateness of curriculum issues and other stipulated learning goals (AAAS, 1990).

So this study chose to investigate these three areas not only because they are at the center of current contemporary reforms in science education, but because they are also very closely associated to each other in terms of required expertise for curriculum enactment (Crawford, 2000). For example, if an instructor has goal conception of NOS (Informed perspective), such an instructor is ready and confident to address issues of pseudo-scientific nature, and ready to let students know and cope with scientific uncertainty in class. Knowledge of NOS also may determine readiness and comfort to use questions either generated by students or the instructor to lead scientific investigations so as to learn scientific concepts. Knowledge of how best to create a learning environment
in which the learners are encouraged to behave as scientists in the quest to answer given scientific questions therefore becomes vital for successful science teaching and learning (Crawford, 2000). The inter-connectedness of these three areas is ubiquitous in the USA science education reform “Science for All Americans by 2061” policy (AAAS, 1990, 1993; National Research Council [NRC] 1996).

The buzz word in the science education reform perspectives on the sub-disciplines of pedagogy and classroom learning environment has been ‘inquiry’ and it is considered to be progressive in nature (DeBoer, 1991; Barry J. Fraser, 2002). These perspectives have led the globalization of science education theory and practices. In this respect, the unifying factor in this globalization of science education seems to center on a unified epistemological commitment of science teacher educators to the Human Constructivist learning paradigm (Novak, 2005). The Millennium Development Goals (MDG) reflect this perspective on the science education subsector (Lewin, 2000).

**Importance of science teacher educators and held perspectives.**

Science teacher educators, worldwide, occupy a unique position in the science education service industry. They are teachers of classroom science teachers. As experts in science education, they are primarily entrusted with the task of effectively preparing science teacher candidates for their roles as classroom science teachers. However, their role extends beyond teaching and mentoring classroom science teachers. Their enormous influence on science education is beyond classroom issues. Scholars (Korster et al., 1996
cited in Cochran-Smith, 2003) have identified the following as other functions of science teacher educators that influence science education besides teaching and mentoring:

1.) They are the gatekeepers to the science teaching profession
2.) They lead inquiry efforts in the field of science education
3.) They are tasked with stimulating professional development in the field
4.) They are involved in curriculum development
5.) They encourage reflective skills in teacher candidates and in-service science teachers
6.) They are collaborators with others outside the education sector on matters affecting science education (Cochran-Smith, 2003). These roles have forced some scholars to think of science teacher educators as the linchpin in science education (Cochran-Smith, 2003).

Globally, information about science teacher educators’ perspectives on the three areas covered by this study is scanty. Yet, empirically documented information about their perspectives is crucial for effective implementation of reforms in science learning and teaching. At best, knowledge of their perspectives on these areas is widely theoretical and anecdotal; in many cases it is assumed based on historical facts and policy documents. Generally, science teacher educators’ perspectives on these three critical sub-disciplines of science education are assumed to be supportive of the suggested reforms (Koster, Brekelmans, Korthagen, & Wubbels, 2005; Murray & Male, 2005b). This study submits that this is also the case for Uganda.

Science teacher educators’ held perspectives investigated in this study encompass their objective knowledge, beliefs, values and opinions, and dispositions concerning the three areas. This is because perspectives are a conglomerate of all these facets of
knowing, that is, their stock of information, skills, experiences, beliefs, and memories (Alexander, Schallert, & Hare, 1991).

Investigating perspectives is not easy since perspectives are constituted in part by the messy concepts of belief and values (Pajares, 1992). Included are some beliefs and values about science, teacher candidates, science pedagogy and the teaching profession as a whole that are not warranted by publicly shared evidence. It is this messiness of understanding perspectives that partly warranted this study to employ a mixed methods approach to research. The study wanted to deploy both objective quantitative investigative methods (QUAN) and subjective qualitative inquiry (QUAL) to fully survey, scrutinize, understand and document prevalent perspectives of Uganda science teacher educators in the critical areas of NOS, PSP, and CLE.

**Geo-Political and Education Context of Uganda**

Uganda is a member of the East African Community, an intergovernmental organization comprising five countries in the African Great Lakes region in eastern Africa. Its southern neighbor Tanzania, eastern neighbor Kenya, and south western neighbors Rwanda, and the nation of Burundi are the other four nations in the community.
Education system in Uganda.

Uganda’s current basic education system has been in place since the 1960s. It consists of seven years of primary education, four years of secondary education and two years of high school; it is a 7-4-2 system. There is a major national certification examination that students must take at the end of each of the levels: A Primary Leaving Examination (P.L.E) at the end of primary school education, an “Ordinary level” (O-Level) or Uganda Certificate of Education (U.C.E) examination at the end of secondary education and an “Advanced level” (A-level) or Uganda Advanced Certificate of Education (U.A.C.E) examination at the end of high school. Thereafter students may undertake three to four years of university education. Although this is the most direct path to reach the pinnacle of education in Uganda, some students pursue non-direct paths, involving a series of upgrades, to eventually attain a university degree. Such non-direct paths include vocational institutions such as Technical institutes and Teacher training colleges. The Teacher training colleges are categorized into Primary Teachers Colleges (PTC) and National Teachers Colleges (NTC).

Science teacher education in Uganda.

In Uganda one can become a science teacher by joining a PTC after their secondary education. Alternatively, if they have attained high school education, they may join a NTC or university for a major in science teaching. These are the specific paths to becoming a classroom science teacher.
However, the process of becoming a science teacher educator is still developing. For example, undergraduate teacher candidates who graduate with honors and high honors in the sciences can be retained at the university as Teaching Assistants (TAs) in science teacher education. These TAs can get into graduate school, in the school of education, to specialize in science teacher education.

Also, graduating teachers from NTC (they hold grade six teacher certificates) can upgrade by pursuing a Diploma in Teacher Education (DTE) and then return to the NTC/PTC as science teacher educators. Recent reforms have introduced two new programs: A Bachelor of Education in science (B.Ed (Sci)) and also a Bachelor of Teacher Education (BTE) that will phase out the existing DTE (Hardman, Ackers, Abrishamian, & O’Sullivan, 2011; Hartwell, Ong’uti, Aanyu, O’Sullivan, & Ojoo, 2003; O’Sullivan, 2010).

Statement of the Study Problem

Since 1997, Uganda has adopted major reforms into its education system in an attempt to achieve the Millennium Development Goals (MDG). Prominent among these reforms are:


2.) Promotion of the philosophy of science for all. Uganda made science studies compulsory at the secondary school level and apportioned 65% of government bursaries and scholarships to post high school students enrolling for natural science and technology
based fields. Additionally, the government earmarked more money for scientific research and better remunerations for scientists including science teachers (Munaabi, 2005).

3.) Adoption of a thematic curriculum, student-centered (conversational or discussion) approach to teaching and learning of science, continuous assessment of learning, and the use of mother tongue as a medium of instruction at the lower primary (P1 to P3) levels (Altinyelken, 2010a, 2010b).

Although these reforms increased accessibility to primary and secondary education, there has been a litany of negative observations about education in Uganda and science education in particular. These include:

- A dramatic fall in the overall quality of education
- Over 50% drop out rate at the primary level
- Chronic poor performance in science and mathematics subjects at all levels of education and poor attitude towards the sciences
- A decline in student enrollment into science and technology fields at university and college levels (Altinyelken, 2010a, 2010b).

Scholars have established that classroom science teachers very often exhibit epistemological and praxis perspectives that they experienced from their science teacher educators when they were science teacher candidates. In other words, they re-enact their own science classroom experiences during their teaching (Kagan, 1992; Kennedy, 1999; Rokeach, 1968).

In Uganda, the multi-national research organization, TESSA (Teacher Education across Sub-Sahara Africa), has been researching on how to improve teacher education.
TESSA testifies that their research has identified that for reform in education to successfully take place, change has to begin with teacher education. In the case of science education this call specifically points to science teacher educators’ knowledge and practices (Stutchbury & Katabaro, 2011). TESSA has been seeking to understand science teacher educators in Uganda and how to help them prepare classroom science teachers to implement the reforms initiated by government.

Broad studies on Uganda teacher educators and classroom teachers’ teaching competences in light of national and international reforms on teaching have unveiled an urgency to determine whether what these professionals know about education reform theories (e.g. Human Constructivism) is supportive to science education reforms that Uganda is currently implementing (Altinyelken, 2010a, 2010b; O’Sullivan, 2010). For example, classroom teachers, who were subjects in these studies, demonstrated inadequate knowledge of human constructivism during observed curriculum implementation and in their interview responses. This was in spite of having had professional development (PD) relevant to child centered pedagogy (CCP) based on human constructivism. Further, these studies report that these teachers complained that PD facilitators (teacher educators) did not fully know what and how CCP looked like in reality (Altinyelken, 2010b; O’Sullivan, 2010). These findings indirectly point to Uganda science teacher educators’ inadequate understanding of Human constructivism.

Additionally, the Uganda National Council on Science and Technology (UNCST) 2012 report on science education indicated that sciences in Uganda are taught less practically and more theoretically. Also classroom teachers, especially at the primary
level, lack the necessary competences to properly teach science subjects and science teacher education has concentrated more on content than on competences to teach (Tukacungurwa, Ssebbale, & Basiime, 2012).

These revelations inspired and initiated this investigation. Most of the empirical literature has focused on classroom science teachers. There is a general assumption that science teacher educators possess the desired epistemological perspectives and competences to affect science education reforms albeit their teacher candidates end up not exhibiting these qualities.

The current study disagrees with this global epistemological assumption that since science teacher educators contribute to NOS literature, their NOS views are implied in the views expressed in literature. In fact science teacher educators from developing economies contribute little to current NOS literature. Instead, they are normally more of consumers of this created knowledge than they are participators in its creation (Altinyelken, 2010b). The study is of the view that science teacher educators’ perspectives on foundational aspects in science education should be empirically investigated just like the other professional sub groups within the service industry. Only then would the global views on such issues like NOS, PSP and CLE perspectives be fully understood and improved, if need be.

In the same vein, only a few science education studies have focused on issues pertaining to science teacher educators’ pedagogical orientations and competences. Some researchers have investigated classroom science teachers and science teacher candidates’ beliefs (views or perspectives) about science teaching and how these beliefs are
manifested in their teaching (Haney & McArthur, 2002; M. J. Johnson & Hall, 2007). The few that have focused on University instructors (Kember, 1997, 2009; Kember & Kam-Porkwan, 2000) used only observation methods to investigate how science teaching was being accomplished at the university level. So they reported manifestations of perspectives and not necessarily understandings or views on teaching at this level.

Literature review also showed that the area of classroom learning environment (CLE) has not been spared the skewed research focus. Again science education researchers have concentrated on studying knowledge and perceptions about classroom learning environment of classroom science teachers, science students and science teacher candidates (Barry J. Fraser, 1994, 1998, 2002).

In summary, this study identified a gap in literature on science teacher educators perspectives or views on NOS, PSP and CLE. Its main goal is to contribute to the alleviation of this glaring gap in science education literature.

**Purpose Statement**

The purpose of this concurrent mixed methods study was to understand and profile Uganda science teacher educators’ perspectives or epistemological commitments concerning nature of science, preferred science pedagogy and classroom learning environment. Their perspectives on these three areas are central to their competences and professional efficiency in leading science education reforms in Uganda since these three areas are foundational to science education reforms (DeBoer, 1991).
Research Questions

Five research questions were used to investigate the uniqueness of the perspectives of Uganda science teacher educators on NOS, PSP and CLE.

**Question 1**: What do Uganda science teacher educators understand regarding the nature of science?

This question was designed to guide the search for data that specifically described what Uganda science teacher educators understood about epistemological assumptions that underlie scientific knowledge. Data collected by this question were used to describe the subjects’ views concerning nature of scientific knowledge as either Informed (goal), Transitional (developing) or Naïve (not yet developed).

**Question 2**: According to Uganda science teacher educators, what are their preferred science pedagogical approaches?

This question enabled the study to seek for data to understand how and why Uganda science teacher educators preferred to present learning experiences. The study was also able to use this data to determine if the assembled views on teaching approaches were crucial to science education reforms.

**Question 3**: What are Uganda science teacher educators’ perceptions of their classroom learning environment?

This question guided the study to understand Uganda science teacher educators’ views on the classroom learning environments they create for their teacher candidates. The study determined if the study subjects knew the changed roles of the teacher in reformed science learning environments.
**Question 4:** How are Uganda science teacher educators’ views on nature of science, preferred pedagogy and classroom learning environment correlated, if at all?

The study examined, statistically and qualitatively, data on the three areas of NOS, PSP and CLE to describe the relationship(s), if any, that existed between the subjects’ perspectives in these three areas of science education. In other words, this question guided the study to find out if there existed a nexus within which the perspectives are associated so as to determine the quality of interconnectedness of the subjects’ conceptual ecology on the philosophy undergirding science education reforms.

**Question 5:** How are Uganda science teacher educators’ views on nature of science, preferred pedagogy and classroom learning environment evident in their science methods course syllabi?

The study sought for evidence that characterized the subjects’ perspectives on the three areas of science education in their science teaching method syllabi. This question required the study to analyze the syllabi for the subjects’ views on the three areas of science education.

**Significance of the Study**

This study focused on the most influential professional subgroup in the science education industry, science teacher educators. An empirical examination and documentation of perspectives held by Uganda science teacher educators in the critical areas of NOS, PSP and CLE, the outcomes of the study are especially useful to three
groups of actors in the science education industry: Policy makers, Practitioners and the global science education committee.

Policy makers may now access empirical and scientifically assembled knowledge on science teacher educators’ perspectives in the three foundational areas of science education reform. This information is useful to their process of developing policies that address reform issues such as scientific literacy for all and quality of science teacher preparation in Uganda.

Practitioners may use the findings of this investigation for planning necessary curricular and professional development interventions or reinforcements accordingly. Furthermore, knowledge garnered by way of this study is useful when assembling professional certification, and science education program accreditation to address current reforms in science education matters.

Lastly, this study brings to the global science education community knowledge of Uganda science teacher educators’ understanding of nature of science, preferred science pedagogy and classroom learning environment. Considering international emphasis on goal conception of the scientific enterprise, this study opens up the Uganda chapter. In view of globalization of child centered pedagogy (CCP), this study describes the pedagogical commitments of Uganda science teacher educators. In terms of classroom learning environment, this study’s results may be used to make data based judgment on inputs necessary for successful handling of science classrooms.
Definition of Important Terms

The terminologies core to the study, are defined below:

Nature of science: The philosophical and sociological assumptions inherent to construction or assembling of scientific knowledge (Lederman, 1992)

Perspective: The mindset, view, working knowledge or the epistemological commitment that an individual holds concerning an aspect. This term or concept is a combination of one’s knowledge, belief, values and disposition concerning that aspect.

Science pedagogy: The different orientations, approaches and teaching techniques science teacher educators employ to ensure that intended learning takes place. Teacher/teaching centered pedagogies hold that scientific knowledge is best learned if transmitted in the classroom. Contrary to this is the perception that scientific knowledge is best learned if actively constructed (through learning activities) which manifests as student/learner centered in the classroom. In the latter, science is perceived as ‘science-in-the-making’ while in the former, science is perceived as ‘already-made-science’.

Classroom learning environment: The psycho-social environment (context) created for the expressed purpose of facilitating teaching and learning (Fraser, 1994)

Science teacher candidate: Pre-service teachers undergoing their professional education at university or two year college level.

Science teacher educator: University or two year college level professors, teachers, instructors, tutors, or lecturers who primarily prepare science teacher candidates to become classroom science teachers.
Classroom science teacher: Professional teachers at primary to high school (K-12) that teach science to students.

Science methods syllabus: The professional document that guides the teaching of science teacher candidates and the pedagogy of classroom science.

Mixed methods design: A research approach in which both quantitative and qualitative methods are combined to answer the research problem (Creswell & Plano-Clark, 2007).

Limitations of the Study

This study was limited to:

- Science teacher educators at public universities and Teachers colleges to ensure some level of homogeneity of the curriculum used and the scope of its coverage
- Science teacher educators teaching the science teaching methods courses and at least one course in mathematics, life, vocational, and or physical sciences. Those in other science disciplines were excluded due to limited time and logistical support
- Self-reported views by its participants as it did not observe any classroom sessions

Generalizing its results to only participating science teacher educators as the study sample was not representative of Uganda’s science teacher educators.
CHAPTER II

LITERATURE REVIEW

Perspective an Amalgam of Different Forms of Knowing

The concept of perspectives has been studied in the field of science education under different aliases: Views as in “Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners’ Conceptions of Nature of Science” Norm G. Lederman, Abd-El-Khalick, Bell, and Schwartz (2002), conception as in “Examining Student Conceptions of the Nature of Science” (David M. Moss, Abrams, & Robb, 2001), belief as in “Teachers Beliefs and Intentions Concerning Teaching in Higher Education” (Norton, Richardson, Hartley, Newstead, & Mayes, 2005), and understanding as in “Understanding the Process of Science by Students Exposed to Different Curricular in Israel” (Tamir, 1972). All these studies point to a general understanding or epistemology of the various relevant aspects referred to therein. The Merriam-Webster dictionary gives the following synonyms for the word perspective: view point, perception, opinion and belief. Others are attitude, objectivity and simply view.

Perspective represents an individual’s understanding of or knowledge about an aspect sieved through their held beliefs, values and opinions, and dispositions. This makes the concept of a perspective similar to what cognitive science calls knowledge. Taken in the sense of cognitive science, knowledge encompasses all that a person knows or believes to be true, whether or not it is verified as true by some sort of objective or
external way. That is, knowledge is a person’s stock of information, skills, experiences, beliefs, and memories (Alexander et al., 1991). Knowledge, therefore, subsumes belief. On the other hand, philosophically, knowledge is defined as, “a belief which is always warranted by a truth condition or evidence” (Green, 1971, p 69). In this case, not all belief can be counted as knowledge. Cobern suggests that for instructional/pedagogical reasons, there is no need to labor to distinguish knowledge from belief (B. Cobern, 2004). He reasons that the distinction is not of any advantage to science instructors nor students since the major concern of instructing is to make scientific evidence believable by allowing open discussions that expose student held beliefs of the natural world. This study holds this same view for perspective

Value based knowledge are knowledge propositions premised or associated with beliefs. So, just like beliefs, values are psychologically held premises, understandings or propositions about the world that a person holds as true (Richardson, 1996). There is no complete agreement between cognitive science and philosophy if a value being a belief is a salient form of knowledge or not since knowledge philosophically must always have a ‘truth’ condition, a condition that sometimes values do not fulfill (Green, 1971; Richardson, 1996). To allay fears created by these two aspects of knowing, Cobern, argues that people have reasons for their beliefs even when not warranted by publicly shared evidence (W. Cobern, 2000). This study shares this view of values being contributors to one’s held perspective or knowledge on any subject.

Although there is no universal agreement on what constitutes values, they are known to influence pedagogical matters. Values have been identified as major
contributors to personal professional knowledge and attract great attention in the inquiry of teacher professional behavior with aliases such as personal epistemologies, opinions and views (Nespor, 1987; Pajares, 1992; Prawat, 1992; Samuelowicz & Bain, 2001). Kagan, (1992) statement that “as a teacher’s experience in the classroom grows, his or her professional knowledge grows richer and more coherent, forming a highly personalized pedagogy-belief system that constrains the teacher’s perception, judgment and behavior” (p.74) attests to this. Gudmundsdottir also suggests that the values that teachers hold form a great part of the hidden curriculum and have lasting impact on the students even long after they have forgotten the subject specific knowledge they acquired from those teachers (Gudmundsdottir, 1990). Thus, every curriculum is value-laden. Values are premised on beliefs, so they may have belief characteristics such as being subjective constructs. They can originate from direct life experiences (thus called un-derived values) or indirect life experiences (derived values) (Kagan, 1992). Un-derived values are existential experiences that form core values that are hard to change compared to the derived ones, which are peripheral and are relatively easy to change (Rokeach, 1968). Values generally are context specific and highly connected within those contexts (Pajares, 1992). So far, the study has observed that knowledge, belief, and values are core aspects of one’s held perspective concerning a subject. Next, the study considers the relationship between dispositions and held perspectives.

Dispositions are commonly defined as the natural or prevailing aspects of one's mind as shown in behavior and in relationships with others. In common language it is what one does based on their informed decisions. In another sense, dispositions are
someone’s knowledge or perspective concerning a subject being acted out. For example, if a classroom science teacher prefers cook book laboratory learning experiences to inquiry type laboratory learning experiences, this manifested preference and the enthusiasm that accompanies it has a direct relationship to the held knowledge or perspective by this teacher on what works best for students to learn science.

In Crawford (2007), the researcher, studied the effect of science teacher candidates’ held knowledge and beliefs on their ability to enact reform based science teaching. The study involved five science teacher candidates in their internship year in a mid-western university. The study design was a multiple case study and data collection methods included open-ended and semi-structured interviews, classroom observations, and the examination of various teaching artifacts (Crawford, 2007).

One result of this study which directly appeals to the current study is that the beliefs (perspectives) of the high school experienced classroom science teachers (mentors) had a very strong influence on their novice (mentee) counterparts’ enactment of reform based teaching (Inquiry). Although the mentees had been trained and given enough experiences in enacting inquiry classes, including planning for an eight day inquiry class, the beliefs of the mentors prevailed over their willingness to follow their training. The excerpt below from the study expresses how the mentors’ beliefs completely demobilized the subjects’ abilities to respond to their professional training.

Most of the prospective teachers admitted they were concerned about the risk of creating inquiry-based lessons. Some felt fearful of teaching their original lessons and deferred to their mentors’. As expressed by one prospective teacher, “my mentor already has ideas about how to teach a
certain lesson.’’ These reluctant prospective teachers expressed concern that they did not want, as one put it, ‘‘to step on any toes.’’ Evidence of an unwillingness to take the risk includes Helen’s statement. ‘‘When I realized that my teacher was a traditional style teacher who favored direct instruction, cookbook lab, and worksheets, I was discouraged and very pessimistic”. (Crawford, 2007, p. 11)

This observation left this study wondering, ‘‘If a mentor-teacher’s perspective can have such an influence on a novice counter-part during internship, what would be the effect of a science teacher educator on a teacher candidate over several years of professional education?’’

In another study, Brickhouse investigated teachers' beliefs about the NOS and the relationship between their beliefs and classroom practice. This was a qualitative case study design involving Cathcart, Lawson and Mcgee (all pseudonyms). Cathcart and Lawson were experienced high school physics teachers, and Mcgee a novice classroom science (physics) teacher at the middle school level (Brickhouse, 1990). Data sources were multiple, including, semi interviews, teaching artifacts, and classroom observation. This study revealed that teacher Cathcart had a perspective or understood NOS represented by the scientific processes (methods). Also in this perspective he perceived science as the truth path used to solve problems (science is defined by the problems it solves). He therefore approached teaching science by strict adherence to the scientific method as a sure way for getting solutions. His students were encouraged to meticulously know and follow given paths (process) of science sometimes (for example in physics), and to memorize scientific knowledge (products) during earth science lessons. On the
other hand, Lawson understood scientific theories as vehicles for explaining natural occurrences. This teacher used actual occurring problem activities to teach about scientific theories and how they are used to make sense of given sets of observations (explanations). Mcgee on the other hand, being a novice, was hard to characterize as he was all over the NOS conception spectrum.

The two studies clearly show how a held belief or perspective concerning a professional aspect may influence praxis. Understanding the relationship between dispositions and held perspective is so crucial to the extent that dispositions and how they are addressed is one of the considerations during accreditation of science teachers and science teacher programs.

The Standards of the National Council for Accreditation of Teacher Education (NCATE) define dispositions of educators as the values, commitments, and professional ethics that influence behavior towards students, families, colleagues, and community that affect students’ learning, motivation, and development as well as the educator’s own professional growth ([NCATE], 2006). This NCATE’s definition of disposition is similar to what the current study is calling a perspective.

Implied in this characterization of perspectives is that for a study to fully capture any science instructor’s perspective on say science pedagogical issues, it cannot merely depend on classroom observation. For such a study, data collection should be extended to include self-reflection through interviews, personal journals etc. in order to allow the instructor to reveal more of what goes on during preparation to teach and during the enactment of the prepared lesson (Schussler, 2006)
This study therefore, considered science teacher educators’ perspectives to be a combination of their objective knowledge, beliefs, and values that manifested in the science teacher educators’ classroom dispositions. Of particular interest is the amalgamation of science teacher educators’ understandings concerning nature of science (NOS), preferred science pedagogy (PSP) and classroom learning environment (CLE). This study assumed that just as it is with classroom science teachers, perspectives held by science teacher educators greatly influence what they teach and how they teach it. In other words, a science teacher educator’s perspective about any discipline colors or filters what to teach and how to teach it.

This study recognized the complexity of teaching and that of the three reform foundational areas of NOS, PSP and CLE. It also recognizes that there are many other factors other than just held perspective that determine what a science teacher educator may teach and how he may teach it. These factors can include among others, content knowledge of the subject, pedagogical content knowledge specific to the subject or topic, and readiness of students to learn, availability and quality of teaching aid materials, and self-motivation.

This study however, did not focus on the process of teaching and learning or how science teacher candidates acquire their held perspectives from the science teacher educators and the literature thereof. Instead, the study devoted and limited its efforts to understanding the perspectives that the science teacher educators bring to the learning-teaching contexts especially those perspectives concerning NOS, PSP and CLE.
Science Education Reform Perspectives in the USA

To fully appreciate the role of perspectives in science education and its reforms, the study reviewed literature on the history of science education in the USA. For decades, science education has been undergoing numerous reform efforts as compiled by DeBoer (1991). In his book *A History of Ideas in Science Education: Implication for Practice*, DeBoer precisely shows how perspectives on science education held by science educators, politicians, philosophers of education, and social-politically significant others shaped science learning and teaching then and even now in the USA.

At the beginning of the nineteenth century, a group of American scholars who tasted the fruits of scientific development developed a perspective of general science education and education in general; education that insisted on use of body senses, for example, sense of observing and inborn curiosity. These scholars led by Edward Livingston Youmans, Thomas Huxley, and Herbert Spencer, among others, held a perspective that science learning develops the individual child for life in society and argued that classical studies (literature, mathematics, music and drama) premised on fact memorization, had many limitations and was at the expense of science which capitalized on body senses and curiosity of the learner. They held a utilitarian view of scientific knowledge acquired through engaging body senses and promotion of curiosity. Operating under the umbrella name of ‘modernists’, they advocated for more science in schools and colleges and a drop of the classical education.

Later in the same century this perspective (teach science for a lifetime benefit by capitalizing on senses and in born curiosity) was fueled by developments in science and
science teaching in European Academies. When they were introduced in the USA, Academies were schools for alternative education (science based education). They developed between 1750 and 1850 starting with Benjamin Franklin’s Academy in Philadelphia. Notable among European influence on Academies was the work of Johann Heinrich Pestalozzi, a Swiss educator, who had been a student of the French educator Jean-Jacques Rousseau. By 1820 the work of Pestalozzi was introduced to America by the works of educational writers John Griscom and William Woodbridge. This European influence on American science education system is important because it introduced European colonial education values.

Fast forward to the twentieth century, the modernist perspective had been incorporated in the public school system that had fast replaced the Academies. Classical elitism was so perverse in the public schools leading to a quest for more science time on the school curriculum. By this time, the argument was widened to include pedagogical aspects such as effective use of laboratories to support independent discovery by the students as well as the development of meaningful understanding of the facts and principles of the subjects (instead of rote memorization) and to allow the students to question scientific knowledge. These new demands introduced an interest in teaching scientific processes, using student-centered approaches, and teaching in ways that employ student curiosity and questioning of scientific knowledge. This required the teaching of NOS/NOSI as an educational outcome. The study assumes that this was the foundational interest in what would later be known as classroom learning environment.
The work of Alexander Smith and Edwin H. Hall in 1902 fuelled this advocacy by echoing the words of Herbert Spencer’s 1864 essay “What Knowledge is of most Worth” just as they did Thomas Huxley’s 1899 essay “A Liberal Education and Where to go and Find It.” Smith and Hall were part of the committee of ten that was tasked to reform the public education curriculum in 1895 (DeBoer, 1991). These two were determined to ensure that teaching of science and the classroom environment would change since science had been given more time on the curriculum. Smith advocated that if science is taught well it could accomplish the following:

1.) Training in the powers of observation of the natural world
2.) Training in a powerful method of generating new knowledge that is based on observation and experiments
3.) Exercise of the imagination and creative impulses
4.) Training to view problems objectively
5.) The generation of new useful information. (DeBoer, 1991, pp.54-55)

Hall further advocated for the use of school laboratories that were only two decades old then as school science tools and to abandon the use of the textbook in an encyclopedic manner during teaching. Hall recognized the need to craft a preferred science pedagogy and pay close attention to a classroom learning environment that is capable of giving students a better taste of learning science as science in the making (Latour, 1987). One of his bold statements was:
It is a cardinal principle in modern pedagogy that the mind gains real and adequate knowledge of things only in the presence of the things themselves. Hence, the first step in all good teaching is, an appeal to the observing power. (DeBoer, 1991, p.59)

In this statement the study postulates that Hall was speaking of using pedagogy, like today’s inquiry, which can allow the teachers teach both the subject matter and help learners develop scientific inquiry knowledge and habits of the mind supportive of scientific literacy. Scrutiny of the path of science education reform up to the 1950s, shows that it moved from traditional to Modernism to Revisionism to Progressivism and it was moving back to traditional mode before the post Sputnik (1957) when another curriculum reform momentum began (DeBoer, 1991). Socio-educational thinkers Dewey contributed to this new momentum by advocating that communities and their institutions should promote observation and imagination as valued qualities in their members (Dewey, 2009). In his own words, Dewey (2009, p. 34) states “...primitive social customs tend to arrest observation and imagination upon qualities which do not fructify in the mind.”

Dewey, Smith and Hall science education advocacies discussed here targeted changing pedagogy in science, changing the classroom learning environment, and increasing effort to teaching about science and scientific thinking. They were not merely targeting curriculum content, but how this content is organized, taught, and the classroom context during enactment of this curriculum. They were interested in how the classroom learning environment facilitated learning of preferred scientific skills and habits of the mind, knowledge and attitudes. These science education reform elements are very similar
to those suggested in science education in Uganda today. These leading USA science education reform philosophers and the historical perspectives they held influenced science reform efforts and practices especially concerning teaching and learning of nature of science, PSP and CLE. Reflecting on the works of Dewey, Smith and Hall, this study questioned the quality of Uganda science teacher educators’ perspectives in these three reform foundational areas; how this is shaping the path to success of the currently pursued reforms. This questioning led to this investigation.

As recently as the 1950s, the USA science education service industry underwent another reform. At the time of these reforms in the USA, science was already a prominent part of the Uganda school curriculum. This is because by this time, Uganda had its first University where natural sciences and human medicine featured prominently (Ssekamwa, 1997). Following is a summary of perspectives in science education that have shaped USA science education reforms (Mintzes & Wandersee, 2005a).

First is the Academist Period: (1958-to late 1970s). This period followed immediately after the launch of the Sputnik to the late 1970s, a period that was pre-occupied with epistemological revolutions. This period, marked by accelerated research activities from science educators, also saw the establishment of a journal (Journal of Research in Science Teaching) devoted to their endeavor. There was also a rapid expansion of graduate programs to produce individuals with masters and doctoral degrees in science education that further accelerate research in the field. This period also experienced a high infusion of funds from the National Science Foundation (NSF) for research to improve science teaching and learning. In the Academist period, the works of
Dewey were still very influential just as those of Piaget, Bruner, Schwab, and Gagne, most of who were human cognitive theorists of behavioral change.

The rush to catch up with the Soviets in the fields of science and technology demanded reforming curriculum and coming up with innovations in instruction methods, instruction and curriculum that stressed the learning of the structures of science subject disciplines and the nature of scientific inquiry (DeBoer, 1991; Mintzes & Wandersee, 2005a). Mintzes and Wandersee (2005a) reported that the era embraced an “epistemology that was decidedly empiricist in theory and behavioral in action” (p. 63).

Two education theorists (Jerome Bruner from MIT and Joseph J. Schwab from Chicago) historically were reported to feature prominently in these science curriculum reforms. Bruner concentrated on organizing science curriculum content and its structure. He was interested in curriculum content that was relevant to the life experiences of the students and was a very strong advocate of teaching science from the students perspective (what they know already) first, then extrapolating or applying this knowledge to situations unknown to them. For example, writing about folk pedagogy, Bruner said “The challenge is to situate our knowledge in the living context that poses the present problem…………..and that living context where education is concerned, is the school room situated in the broader culture?.” On the other hand, Schwab was more interested in teaching the process by which scientists developed scientific knowledge as a curriculum goal (DeBoer, 1991, Ch. 8). Schwab (1962) advocated for a science curriculum that mirrored the present conception of science as “principles of enquiry, conceptual structures which could be revised when necessary” (DeBoer, 1991, p.163). Schwab here,
was directly referring to teaching NOS. He further argues, “…this is because scientific research has its origin, not in objective facts alone, but in a conception, a construction of mind” (p.163).

Schwab described the process of using enquiry to teach science as “enquiry into enquiry” (p.165). He advocated for science classes that give students opportunities to dissect textbooks and lectures for evidence to back the scientific concepts being taught (inquiry teaching) and to actively analyze this evidence. Clearly, Schwab had teaching by inquiry, teaching NOS and Nature Of Scientific Inquiry (NOSI) on his mind as he advocated for science not to be taught as rhetoric of conclusions. In so doing Schwab envisioned teachers’ roles in the science classrooms changing from presenting information and explaining concepts to facilitating/coaching students on how to ask questions, how to look for evidence and how to evaluate results of their enquiry.

Second is the Human Constructivist Period (1978 to present): This includes current science education reforms. Leading theorists including Ausubel, Novak, Wandersee, Mintzes, Duschl, Bybee, Cobern, Aikenhead, Osborne, Lederman, among others espouse an epistemology that is post positivist in theory (Karl Popperian) and constructivist (Piaget) in action. In their conception of science learning and teaching they are partly guided by Ausubel’s statement that “the single most important factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly” (Mintzes & Wandersee, 2005a, p. 39) among other insights into learning and teaching of science.
These theorists primarily were concerned with meaningful learning through knowledge construction involving restructuring of mental structures and conceptual change. They argue that meaningful learning may result from either a process of discovery or through interaction with well-designed instructional materials of a more traditional, didactic nature.

Scrutiny of science education reforms advocates in this period reveals that science educators had a perspective of teaching and learning science that is interested in students learning of scientific knowledge which goes beyond the disciplines’ knowledge facts, and principles. Meaning that the educators were not just satisfied with the mental ascent of scientific principles by students, rather they desired that students learned to explain how those principles come to be and the epistemological assumptions underlying their construction. In this, these educators were referencing NOS as an expected learning outcome. In other words, there is genuine interest in understanding scientific explanations beyond the rote reproduction of the scientific facts by students. They are interested in meaningful learning of the principles of the subjects. They are desirous of developing students that are thinking like scientists whenever they encounter any scientific claim; individuals who can analyze evidences. They have a perspective of teaching that views students working as scientists to construct personal knowledge of the subject and sharing their knowledge together in their learning community.
The National Science Education Standards

Current science education reforms in the USA which the study named, the “Science For all American” (SFA) era, have a clearly laid out vision for science education in the USA as seen in the American Association for the Advancement of Science (AAAS) publication ‘Science for all Americans, Project 2061.’ Implementations of this vision are guided by the new reform based standards of science education (National Science Education Standards-NSES) ((NRC), 1996). These standards articulated this vision of science education as follows:

- The vision of science education described by the Standards requires changes throughout the entire system
- What students learn is greatly influenced by how they are taught
- The actions of teachers are deeply influenced by their perceptions of science as an enterprise and as a subject to be taught and learned
- Student understanding is actively constructed through individual and social processes
- Actions of teachers are deeply influenced by their understanding of and relationships with students. (National Research Council [NRC]-NSES, 1996, p. 28)

Judging from the above, it is clear that the SFA reformists’ vision for science teaching and learning, has determined that Nature of science (NOS), Preferred science Pedagogy (PSP) and the classroom learning environment (CLE) are foundational to
envisioned reforms. The following extract from NSES show specifics about each of these three critical areas:

**History and Nature of Science Standards**

In learning science, students need to understand that science reflects its history and is an ongoing, changing enterprise. The standards for the history and nature of science recommend the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science, and the role that science has played in the development of various cultures.

**TABLE 6.7: HISTORY AND NATURE OF SCIENCE STANDARDS**

<table>
<thead>
<tr>
<th>LEVELS K-4</th>
<th>LEVELS 5-8</th>
<th>LEVELS 9-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science as a human endeavor</td>
<td>Science as a human endeavor</td>
<td>Science as a human endeavor</td>
</tr>
<tr>
<td>Nature of science</td>
<td>Nature of scientific knowledge</td>
<td></td>
</tr>
<tr>
<td>History of science</td>
<td>Historical perspectives</td>
<td></td>
</tr>
</tbody>
</table>

(National Research Council [NRC]-NSES, 1996, p. 105)

Although this study did not focus on science teacher educators’ perspectives concerning scientific inquiry and its nature (NOSI), the study acknowledges that both NOS and NOSI are closely related and feed off each other during reform based science teaching. This relationship implies that the inquiry activities during science teaching can accord classroom science instructors contexts for teaching NOS. Teaching NOS in these contexts reinforces the validity of the various mind activities the students are required to accomplish and the questions they have to think of during these activities. Therefore the
study noted the guidance in the following extract from the NSES concerning scientific inquiry:

**Science as Inquiry Standards**

In the vision presented by the *Standards*, ([NRC], 1996) inquiry is a step beyond "science as a process," in which students learn skills, such as observation, inference, and experimentation. This new vision includes the "processes of science" and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. Engaging students in inquiry helps students develop

- Understanding of scientific concepts
- An appreciation of "how we know" what we know in science
- Understanding of the nature of science
- Skills necessary to become independent inquirers about the natural world
- The dispositions to use the skills, abilities, and attitudes associated with science.

**TABLE 6.1: SCIENCE AS INQUIRY STANDARDS**

<table>
<thead>
<tr>
<th>LEVELS K-4</th>
<th>LEVELS 5-8</th>
<th>LEVELS 9-12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abilities necessary to do scientific inquiry</td>
<td>Abilities necessary to do scientific inquiry</td>
<td>Abilities necessary to do scientific inquiry</td>
</tr>
<tr>
<td>Understanding about scientific inquiry</td>
<td>Understanding about scientific inquiry</td>
<td>Understanding about scientific inquiry</td>
</tr>
</tbody>
</table>

Science as inquiry is basic to science education and a controlling principle in the ultimate organization and selection of students' activities. The standards on inquiry highlight the ability to
conduct inquiry and develop understanding about scientific inquiry. (National Research Council [NRC]-NSES, 1996, p. 105)

So in the perspective of the framers of the National Science Education Standards (NSES), inquiry in science education goes beyond just learning the processes of science to include understanding of NOSI or “knowing how we know what we know about the natural world” and “the knowledge assumptions that underlie how we come to know” or NOS. The framers of the standards considered knowledge of NOS and NOSI to be legitimate learning outcomes of school science that need to be fully planned for and assessed. In this regard science educators in this SFA era have to investigate their own views and those of students, classroom science teachers, scientists, and pre-service teachers on NOSI and NOS.

**Nature of Science and Science Education Reforms**

*Definition*: Nature of science broadly refers to science as a way of knowing - referencing the epistemological underpinnings of scientific knowledge and the process that produces it or the values and beliefs inherent to the development of the scientific way of knowing (Abd-El-Khalick, Bell, & Lederman, 1998). Scientists and science educators agree that the scientific enterprise has three components: (1) The products of science, which include but are not limited to scientific theories, concepts, laws, principles, and terminologies. (2) The processes of science, which include physical instrumentation and
mental activities, involved in the production of scientific knowledge. (3) Science as a way of knowing - referencing the epistemological underpinnings of scientific knowledge and the process that produces it (Gess-Newsome, Southerland, Johnston, & Woodbury, 2003; Southerland, Gess-Newsome, & Johnston, 2003). The third component has been labeled knowing about science (Norman G Lederman & Niess, 2000). Science education literature commonly refers to this component as Nature of Science (NOS) ([AAAS], 1990, 1993; Renee S. Schwartz, Lederman, & Crawford, 2004) and component number two as Nature of Scientific Inquiry (NOSI). Renee’ S. Schwartz and Lederman (2006) conceptualize NOSI as the cognitive, social and psycho-motor activities involved in the process of generating scientific knowledge.

Education reform documents in the USA emphasize that classroom science should not only concentrate on teaching the products of science (specific science subject discipline knowledge). They suggest that teaching NOS is equally important for proper understanding of scientific knowledge and the human activities that produce it. These goals are spelt out in the National Science Education Standards (NSES), some of whose excerpts we examined earlier.

Despite the strong emphasis on teaching nature of science as elaborated in the policy statements, there is not yet an agreed upon definition of what constitutes NOS among the wide spectrum of scholars of science and science education. Scores of science education scholars and reform documents have explicitly advocated for teaching some form of NOS, being paramount for making students better at becoming scientifically literate, informed consumers of scientific products, active democratic participants in
discussion involving science, better understanding of science and increased interest in
(1996) are among those who contributed to this debate by forwarding the following
argument on why all citizens should learn NOS and formal education should teach NOS.
These scholars argued that understanding NOS has the following benefits to the
population:

**Utilitarian**: Individuals need to understand NOS if they are to make sense of
science and its products and to manage technology and science processes in everyday
life.

**Democratic**: Understanding NOS is crucial for the formation of informed
opinions and decision making on matters concerning science and society.

**Cultural**: Since people practice science, it has become part of the national
culture. Therefore, understanding its nature is necessary for appreciating it as a value to
national contemporary culture.

**Moral**: Science and its practice are guided by known norms. Therefore,
knowledge of NOS is important to understanding the general morals and values of
science as reflected in the general national morals and value commitments.

**Science Learning**: It is a legitimate conclusion that understanding NOS makes
science subject matter learning easier and enjoyable. These reasons, though not
empirically assessed as valid, are quite compelling.

These are baseline reasons why NOS is one of the expected learning outcomes in
science education and why now most science education standards of the developed world
emphasize this goal. As developing economies, like Uganda, start embracing the reforms that have occurred in the Western world, they need to gain goal understanding of NOS.

**Development of NOS education in the USA.**

Understanding the nature of science has been an educational goal for students in the USA since 1907 (N. Lederman, 1992; Norman G. Lederman, 2007). NOS teaching started taking a more prominent position in science curriculum during the reforms that occurred after the former USSR then commonly called Russia, sent the Sputnik into space in 1957. Schwab (1962) a great author up until 1967 was one of the influential science education theorist of that time. He advocated for a science curriculum that mirrored the present conception of science as “principles of enquiry, conceptual structures which could be revised when necessary” (DeBoer, 1991, p.163). Schwab was directly referring to teaching NOS. He continued to asserted that, “…scientific research has its origin, not in objective facts alone, but in a conception, a construction of mind” (p.163).

Even without agreement on what constitutes teachable NOS, science educators in the USA made initiatives to actively advocate for development of fields of research centered on the teaching, learning and conception of NOS. Science educators developed research tools and instruments to measure conceptions of NOS at different levels of formal education. Despite this advancement in NOS Inquiry, there is still no consensus among philosophers of science, historians of science, and scientists on what surely constitutes the nature of science. This dilemma also extends to science teacher educators (W. Cobern, 2000). The differences are so rife that Alters (1997) had to ask, ‘whose
nature of science?” Lederman, Abd-El-Khalick, Bell and Schwartz (2002) have tried to mitigate the situation by offering what they called the ‘consensus’ view of teachable NOS but with this epistemological caveat:

It is our view, however, that many disagreements about the specific definition or meaning of NOS that continue to exist among philosophers, historians, sociologists, and science educators are irrelevant to K–12 instruction. The issue of the existence of an objective reality compared with phenomenal realities is a case in point. Moreover, at one point in time and at a certain level of generality, there is a shared wisdom (even though no complete agreement) about NOS among philosophers, historians, and sociologists of science. (p. 499)

What Lederman et al. (2002) are suggesting here is a recognizable level of agreement about the knowledge of NOS teachable at the K-12 level. Their propositions constitute the ‘consensus view’ of nature of science. They go on to suggest that NOS is a moving target just as science is a moving target considering the differences among the works of Popper in 1959, Kuhn in 1962, Lakatos in 1970, Feyerabend in 1975, Laudan in 1977 and Gire in 1988 (see Lederman 2007 for further details). This position, although shared by philosophers of science, does not fit the position taken by practicing scientists who consider their fields of research as well established entities (Bell, 2006). Lederman (2007) further argues that NOS is as tentative as scientific knowledge itself, a perception that should not immensely deter efforts of those considering advancement of research and teaching of NOS.
Moreover, the popular ‘consensus’ view is under disputation by Irzik and Nola (2011) who advance the “Family Resemblance Approach to the Nature of Science” conception. This view of NOS considers NOS and NOSI as one and the same. Further, it considers the resemblances and differences between the different scientific fields to characterize science. That is, science is characterized by being one of the fields (life, physical science etc.) not by the general way of knowing or building (theories, principles, etc.) that goes on in all these fields. Meanwhile the resemblance approach to the nature of science accused the consensus view of being simplistic. This view is still recent, awaiting scrutiny by scholars and philosophers of science. Furthermore, although not surprising, there are members within the science teacher education community who not only disagree on the wider aspect of which nature of science to teach, but also on the detail of what constitutes acceptable depth of NOS/NOSI coverage and, how to teach it (William F. McComas, Almazroa, & Clough, 1998).

Allchin (2011) does not only disapprove of the consensus view of NOS. He also does not recommend using history of science as a vehicle for enriching curriculum experience intended for learning NOS. Actually Allchin envisions teaching NOS being totally devoid of any tenets as suggested by the consensus view and the reform document. Allchin suggests teaching interpretive NOS which does not treat NOS and NOSI as separate distinct epistemological experiences. He recommends especially the use of sociology and philosophy of science to teach a form of knowledge that will help all learners to check the reliability of scientific claims.
On the other hand, scholars like Lawson hold the view that scientists use the hypothetical-deductive method as their choice method in knowledge construction (Lawson, 1982, 2003). In essence, he is advocating for the hypothetical-deductive method as “the” method of science. This assertion was called by Allchin (2002), a dogma of a method. Surprisingly in doing so, Allchin was in agreement with the consensus view that, there is not one single method, used by scientist, to be anointed as “the” scientific method.

This study was saddled in the consensus view of teachable NOS. The study acknowledged, just like the consensus view, that there is a clear difference between NOSI and NOS even though these two aspects of the scientific enterprise are closely related. Moreover, just like the consensus view, the study held to the perspective that the use of tenets is unavoidable for targeted, planned learning and teaching of NOS. This is because NOS is a wide, complex and evolving aspect of understanding the scientific enterprise which requires breaking down to chewable portions (tenet) if it is to make sense to K-12 students.

Regardless of these disagreements, there is a minimal but recognizable agreement among philosophers and historians of science, science educators, and scientists that some aspects of nature of science are coherent and suitable to be taught at the K-12 level of education. These aspects are core to the consensus view of NOS and they include: Scientific knowledge is tentative; empirical; theory-laden; partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the
lack of a single recipe-like method for doing science, and the functions of and relationships between scientific theories and laws that are attested to by the reform documents (Abd-El-Khalick, 2005; N. G. Lederman & J. S. Lederman, 2004). The study believes that the consensus view of NOS has these qualifiers in its perspective of NOS teachable to K-12:

1. It rejects the notion that there is no difference between NOS and nature of the process of scientific inquiry or NOSI. This view differentiates the epistemology and sociology (NOS) involved in the science knowledge construction and the physical mental and psychomotor processes involved during the process of creating scientific knowledge. For example, observing and hypothesizing are processes involved in scientific inquiries so they constitute towards (NOSI). However, every observation is value laden and hypothesizing involves a lot of human creativity and imagination aspects that contribute to (NOS).

2. It rejects the absolutist / empiricist view of science but embraces the constructivists’ view of science that scientific knowledge is constructed by the practitioners of science just like any other form of knowing and therefore like all other forms of knowledge it shares human attributes of subjectivity and fallibility.

3. It is based on the generalities; those aspects of nature of science that have broad consensus among most scientist, historians of science, philosophers of science, and science educators as accessible by the intelligence of K-12 students. Moreover, these aspects can be approached at different levels of pedagogical
difficulty making them teachable to K-12 students (Norm G. Lederman et al., 2002).

The aspects suggested by the consensus view of NOS are reflective of those stipulated by the NSES on teaching NOS as cited below. The suggested aspects include:

1. How science differs from other modes of knowing
2. How science cannot provide complete answers to all questions
3. The knowledge that scientific ideas are subject to change
4. That scientific knowledge is durable but mutable
5. That scientific inquiry demands and seeks for evidence
6. Science being a blend of logic and imagination
7. Science is not authoritarian
8. Science explains and predicts
9. Science tries to identify and avoid biases, and

This study adopted the perspectives of the consensus view of NOS. It agrees with the core principles of the consensus view, especially, the fact that the consensus view saddles NOS understanding in a constructivist view of knowledge of science and its development. Consequently, the study conceived NOS simply as the characteristic of scientific knowledge, a consequence of how it is developed (Lederman, 1992). So the study was interested in science teacher educators’ views on the epistemological underpinnings or assumptions inherent in the process of making scientific knowledge. The study is however cognizant of the difficulty of a universally agreed upon NOS.
Empirical NOS studies done recently in this SFA era have enabled the science education field to understand NOS views of the subjects as they manifest in their professional activities. Examples include what they emphasize during planning, teaching, grading and recitation. The study reviewed some of these to inform it on what may be worth looking for among Uganda science teacher educators.

**Common NOS perspectives.**

Studies have shown that no one can hide their perspective on nature of science because their epistemological commitments to NOS are evident in their professional artifacts. Some perspectives on what NOS is, encountered during research studies, include the following:

1. *NOS is equivalent to knowledge of science disciplines.* This perspective holds a general misunderstanding that knowledge of NOS is the same as understanding the different science disciplines (Southerland et al., 2003). It is a belief embedded in the thinking that scientific knowledge, especially that of Western origin, is value free, objective and very close to the truth if not the truth itself (William W. Cobern & Loving, 1998; William W. Cobern & Loving, 2001). This conception of NOS carries with it the emotions that science has ‘liberating’ values because knowledge and facts about the natural world can enable man to better understand the environment he lives in from a purely physical and natural standpoint as opposed to an anthropocentric stance. It also conceives (science as establishing truths, therefore not tentative) science as uniform or universal because of its methodology, “the scientific method’ among other things.
Boujaoude (1996) did a VOSTS study to investigate the epistemology and sociology of science among Lebanese school science products. His study included 24 university science professors, 118 university science students, 124 high school science teachers, and 512 high school students. This study found out that a majority of his respondents had NOS knowledge resembling the traditional view of science; a purist view of nature of science (truism) that science is very objective. They viewed NOS as the same as understanding a field of study (scientific subject discipline) e.g. Biology, Chemistry, Physics or Geography. This perspective on NOS could be a result of thinking that; for example, since all life scientists study biological entities, then they observe and know exactly the same things. This view does not recognize the influences of scientific theories on scientific investigations. Boujaoude (1996) established that this conception of science was shared by a majority of university professors, including science teacher educators (54%), university science students (67%), high school science teachers (66%) and their students (59%) in Lebanon.

(2) NOS equals problem solving (Southerland et al., 2003). In other words, that NOS constitutes the methods science uses to solve problems and the problems it solves. This perspective is founded on the belief that understanding the nature of the scientific processes (NOSI), how scientists approach their investigations about the natural world, is what really gives science its epistemology. In this view, science is therefore more about solving the problems of the world than learning how the natural world behaves for its own sake. Science teacher educators holding this view on NOS emphasize classroom inquiry activities and deeper conception of the so-called ‘scientific method’ above all
other aspects of the scientific enterprise (Southerland et al., 2003). Waters-Adams (2006) in an action research based case study on the relationship between four English primary teachers’ understanding of the nature of science and their practice established that it was common for primary school science teachers in the United Kingdom to believe that science was solving problems using the hypothetico-deductive rules. Along the same line of inquiry, Guerra-Ramos, Ryder, and Leach (2010), studied Mexican science teachers’ understanding of science and found that these science teachers believed that whenever one tackled a problem systematically, they are practicing science.

(3). NOS is knowledge about science as an inquiry. This perspective views NOS as knowledge about science as a way of knowing. Science as a way of knowing shares certain salient properties or features inherent in any human investigative efforts e.g. creativity, imagination, assumptions, observations, and transfer of experiences. Science then, is conceived as man applying his investigative lens to understand the physical world in which he lives. This view considers science to be a lens that allows the human mind to better understand the behavior and properties of the natural world. It embraces that mastering of scientific content is done better by understanding the epistemology of science (NOS) and the nature of the scientific process (NOSI) (AAAS, 1993). In other words, one understands the products of science by mastering the process that produces them and the epistemological assumptions and values inherent in the production procedures there in.

Currently, in this SFA era, empirical studies have established that school experiences (formal and informal learning) can help students develop acceptable NOS.
The study reviewed a few studies that demonstrate that there is a slow albeit steady acquisition of the needed NOS perspective at K-16 among students, science teacher candidates and classroom science teachers.

Abd-El-Khalick, Bell and Lederman (1998) did a qualitative study to examine the NOS understanding of 14 pre-service science teachers (science teacher candidates). The study further examined how these subjects enacted reform science teaching targeting NOS knowledge as a central learning outcome. Results of this study showed that the perspectives of the subjects were consistent with contemporary understanding of the scientific enterprise including the tentativeness of scientific knowledge, the role of creativity and subjectivity in science, and the difference between scientific laws and theories.

Another study Renee S. Schwartz and Lederman (2002), was a case study whose subjects were two pre-service science teachers (science teacher candidates). One had deep science content knowledge, while the other did not. An open ended questionnaire, classroom observation and clinical style interviews were used to collect data about the subjects’ views on NOS and their competence to teach it. The two subjects were exposed (as teacher candidates) to explicit reflective teaching of NOS. They were also given all the necessary support they needed as teacher candidates to develop not only an understanding of NOS but the pedagogical content knowledge (PCK) to prepare, instruct and assess NOS content. Then for a period of more than one year, the two subjects were followed to their initial stages of their career as science classroom teachers to see how
they enacted reform based science teaching targeting NOS knowledge as a learning outcome.

The results of this study showed that the subject with deep knowledge of science content also had a more informed and coherent perspective of NOS. The subject with shallow science content was found to have consistent but compartmentalized views of NOS. The subjects had developed different quality of informed views of NOS even if they had received the same instruction and support. This confirms that if science teacher educators have got informed views of nature of science, they can assist teacher candidates to do the same. However, the quality of NOS knowledge developed may depend on other qualities of the students that extend beyond mere exposure to NOS instruction.

Another study, David M. Moss et al. (2001) involved pre-college students. This was a multiple data source qualitative study that followed the development of NOS views of five pre-college students. All the subjects were females in 11th and 12th grade with low to high achievements in science. Data sources included: Semi structured interviews, classroom observation, and document analysis of teaching materials and other artifacts. Aspects of NOS examined included tentativity of scientific knowledge, scientific method, empirical nature of science, and the role of curiosity, creativity and imagination in science. The results of this study showed that the subjects had views consistent with the model used to examine them on at least half of the aspects examined.

The three studies reflect the current perspectives on NOS, its learning and teaching in the USA. These studies show that subjects with naïve views of NOS can be assisted to develop an evolving conception of NOS that has the potential to develop to a
level where they are able to teach others about NOS. Although there is not yet a full nor complete development of a contemporary understanding of NOS, these studies indicate that reform based teaching of science and NOS are helping change NOS perspectives of the consumers of classroom science.

Finally, the Southerland et al. (2003) study was a qualitative case study involving university scientists. The study subjects co-taught an integrated general science course for non-majors. The subjects were: Physicist (Brian), Biologist (Randall) and a Physicist/Chemist (Albert). Brian had the least experience of teaching (two years). The study sought to understand how science was portrayed in reform based curriculum as the scientist taught. The teaching process was also used to capture the manifested beliefs (held perspectives) of the scientist about what science and NOS were. The known barriers to enacting reform curriculum were addressed in the design of the study. Data collection methods included, formal and informal semi structured interviews, classroom observations and analysis of teaching artifacts from the scientists. The researchers were present during course planning and debriefing sessions (these were recorded and transcribed). Instructor interviews (recorded and transcribed) sought information about the instructors’ educational and scientific backgrounds and experiences, instructional experiences, influences on their teaching outside of academia, their perceived importance of science to students, general goals for science instruction, and specific goals for this class.

The researchers were also participant observers during class sessions. Data sources included participant field notes, field journals, and transcripts from select days of
instruction. Classroom artifacts analyzed included syllabi, handouts, and student work. Data from each of these multiple sources was analyzed separately and used to triangulate (confirm/disconfirm) data from other sources. Since the course was co-taught, the data used to describe each instructor’s perspective of NOS was taken from those classes that were solely prepared and taught by that particular scientist. Analysis of data led the researchers to conclude that each of the three scientists had a different belief of what science is.

Albert, who was the team leader, believed that science was for the most part problem solving in nature. During instruction, Albert emphasized the process of science in problem solving (process skills). Although Albert had an informed view NOS, this was not explicit in his teaching as he never emphasized NOS as a learning objective. The fact that this instructor was knowledgeable and knew that understanding NOS was one of the required and expected learning outcome, yet he over emphasized the process of science, may tell a bit about his perspective on NOS. May be his perspective is that NOS equals process of science or his NOS pedagogy perspective is that when they learn the process of science they inductively develop the goal understanding of NOS.

Randall envisioned NOS to be the knowledge that science generates (facts, principles and laws) or the products of scientific endeavors. So during instruction, Randall emphasized this knowledge. He considered it the story that a science instructor should ably tell his or her students, and expressed the fact that it is not necessary to spend time on the process of science. Randall labored to find the best story to convey the prepared scientific knowledge to his students. This Randall example helps us see that
even at the university level, perspectives are directing instructors on what to emphasize during teaching.

Clearly, Randall’s perspective overshadowed the learning of NOS and scientific process as stipulated learning outcomes. Judging by his content delivery, he held the perspective that if the students understand the facts, principles and laws etc. of the science discipline they will inductively come to know the process and NOS aspects as inherent in the development of the scientific knowledge.

Brian was the novice (rookie) on the team. He held a perspective of science that conceives science as another way of knowing. In all his teaching he wanted the students to understand the multiple ways scientists approach problems and wanted them to know what science is and what it is not. The study noted he desired to let the students learn that science does not have answers to all natural problems; theories never become laws, and scientific knowledge is tentative, among other aspects of NOS. These manifested and unfolded in his teaching and the researchers needed not to ask him what he perceived to be science or not science. Unlike Albert, Brian’s professional classroom disposition and content presentation showed his well-informed perspective of NOS and he explicitly made this manifest in his teaching. This reviewed study carries good evidence on how the instructors’ NOS perspectives color or filter what portions of the curriculum instructors take as important and as un-important. The study also shows how held perspectives may govern what contributes to the un-official or hidden curriculum as seen in the case of Randall.
Literature review further shows that there has been an improvement in NOS conceptions after 1992. The Lederman (1992) study, based on a large scale review of literature, had concluded that students, in-service teachers and pre-service teachers possessed generally uninformed views or perspective of NOS. The good news is that in the last decade studies have emerged that indicate improved pedagogy, well planned and structured learning experiences are improving learning of NOS at these levels (Khishfe & Abd-El-Khalick, 2002). This study did not focus on the teaching and learning of NOS but acknowledges that instructors’ or teachers’ mere possession of informed NOS perspectives does not automatically translate into planning and teaching NOS (Schwartz & Lederman, 2002). Instead empirical studies have shown that instructors’ personal perceptions concerning the value of NOS to science and science learning may determine whether NOS will be taught or not. Schwartz and Lederman (2002), Lederman (1992), and Abd-El-Khalick, Bell and Lederman (1998), have shown that classroom science teachers (at K-12) are more likely not to plan to teach or never attempt to teach NOS altogether, if they hold contrary perceptions such as:

(i) Perception that NOS is hard to teach therefore hard for their students to learn and (ii) NOS is separate from main science content therefore planning to teach NOS requires extra time which is not available.

Second generation studies may want to investigate if these militating perspectives are a result of the individual instructor’s experience during professional training. In other words, did they learn this from their own teachers? Is it possible to ameliorate such
epistemological and pedagogical situations to benefit the science classroom teachers and their students?

**More than just informed views of NOS needed to teach NOS.**

In general, current approaches to NOS teaching are broadly categorized as either implicit or explicit/reflective. The implicit approach proposes that by engaging learners in inquiry-based activities (hands on minds on activity) they will also come to understand NOS. For example, when students are allowed to go through experiences of generating data through observations, using the data to answer scientific questions and explain certain problems, learners are expected also to develop an understanding of how science is empirical in nature, or how imagination and creativity are part of the scientific knowledge fabric (Abd-El-Khalick & Lederman, 2000). Research adopting this approach has provided little evidence for its effectiveness on learning of NOS.

On the other hand, empirical research shows that explicit/reflective instruction of NOS aspects as stand-alone NOS generic experiences, or when embedded in science content and history or philosophy of science learning experiences can help students learn and understand NOS better (Abd-El-Khalick & Lederman, 2000; Lederman & Lederman 2004; Schwartz & Lederman, 2002). The explicit approach argues that, like any other cognitive learning outcome, NOS should be a specific and tangible content that teachers intentionally plan to teach and assess in classroom instruction. Reform documents also advocate teaching NOS as ‘content’ that K-12 student should possess as a component of scientific literacy (AAAS, 1993; NRC, 1996). In regard to explicit teaching of NOS, Lederman and Lederman (2004) had this insight:
It should be noted that the explicit approach does not refer to a didactic strategy. Rather, the explicit approach to instruction is comprised of NOS and NOSI relevant activities, questioning, discussions, and guided reflection to help learners understand targeted aspects of NOS. (p.5)

**Pedagogical content knowledge for NOS.**

Literature cited above, has already shown that possession of informed or acceptable views of NOS was not enough to spur instructors to comfortably teach NOS. They need supportive perceptions on the importance and how easy it is to teach NOS. Literature also shows that ease of teaching NOS does not come until instructors develop pedagogical content knowledge (PCK) for teaching NOS. This knowledge is useful in delineating when to access a particular domain specific knowledge, and where and how to access that knowledge, and what procedures relevant to the specific domain one has to employ during such tasks (Fernandez-Balboa & Stiehl, 1995; Shulman, 1986, 1987; Zeidler, 2002). PCK is craft knowledge that instructors need to effectively create and present learning experiences (tasks and activities) through which their students can deeply learn knowledge and develop relationships with the content. PCK for NOS is supportive to enacting reform based science education. Shulman (1986) made the following statement about PCK: “*No one asked how subject matter was transformed from the knowledge of the teacher into the content of instruction. Nor did they ask how particular formulations of that content related to what students came to know or misconstrue*” (p. 6).
Shulman argued that knowledge of transforming subject matter into content for instruction, or PCK is context specific and is at the core of effective science teaching. PCK, unlike content knowledge is not taught but caught (crafted as one takes time to understand the teaching task and one’s role as a science teacher or as a teacher generally-developing into a reflective practitioner). PCK is not easy to delimit. The best one can do is to describe aspects of it.

The overall conclusion is that PCK, more than content knowledge, will directly determine what students learn or misconstrue during the learning-teaching activity. So even in their efforts to teach NOS, science teacher educators need to develop special PCK for NOS (Schwartz & Lederman, 2002). As is the nature of PCK, even PCK specific for NOS, is an invention of the instructor. It is assembled from subject content knowledge, content knowledge of NOS, knowledge of how students learn the material (Pedagogical Knowledge), and knowledge of the context in which learning is to occur (Contextual Knowledge) (Shulman, 1986, 1987).

Although, PCK is a hard construct to measure (Baxter & Lederman, 1999), inquiry into PCK for NOS teaching and science teaching is growing. Empirical research on how to develop PCK for NOS bears support for the effectiveness of explicit/reflective approach to NOS teaching (e.g., (Abd-El-Khalick & Lederman, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Ryder, Leach, & Driver, 1999). However, a paucity of peer-reviewed literature on assessing and establishing science teacher educators’ PCK specific to NOS (Lederman, 2007). The good news is that there are plenty of studies focused on K-12 level, for example, (Akerson & Volrich,
2006) and (Khishfe & Abd-El-Khalick, 2002; Lederman, 1992; Schwartz & Lederman, 2002). These studies are insightful for gleaning what kind of PCK for NOS should be exhibited by science teacher educators and indeed at post high school science education level. The study examined some of these.

Studies on classroom science teachers show that they lack well formed PCK for NOS. Even some classroom science teachers with deep knowledge of science and vast experiences as science classroom teachers, empowered through regular professional development activities and with acceptable conceptions of NOS (Lederman 1992) can still exhibit poorly formed PCK for NOS.

The question that came to this study concerning this situation was, since science teacher educators were the instructors in these studies, does this situation reflect the quality of their NOS views? Moreover, even in matters of professional development, these very science teacher educators are most as favored facilitators.

The pride of giving their students hands on experiences is ubiquitous in K-12 studies. Therefore, these science classroom experiences are missed opportunities for students to learn about science since their teachers may not have the required PCK for NOS (Akerson & Volrich, 2006; Khishfe & Abd-El-Khalick, 2002; Lederman, 1992; Schwartz & Lederman, 2002).

S. Magnusson, Krajcik, and Borko (1999) developed a model of PCK for use by McComass (1998) study of science teaching. It included five components. One of them was “knowledge and beliefs about instructional strategies for teaching science” (topic
specific activities, e.g., NOS; as well as subject-specific strategies, e.g., inquiry. (p. 97) (W. F. McComas, 1998)

In the case of PCK for NOS, and competences to teach it, the overall acceptable instructional perspective is that good quality NOS specific PCK should manifest as the instructor’s competences or ability to teach NOS explicitly and reflectively (Abd-El-Khalick & Lederman 2000; Abd-El-Khalick 2005; Khishfe & Abd-El_Khalick, 2002; Lederman et al., 2003; Schwartz & Lederman, 2002). Schwartz and Lederman (2002) suggested that some of the components of this PCK include (i) Deep knowledge of science subject matter. (ii) Well formed (none compartmentalized) view of NOS and (iii) Possession of supportive perception of the relationship between NOS and the subject matter.

So how would one recognize quality NOS PCK? In other words, how is quality PCK, being a complex construct manifested in a NOS teaching-learning context? PCK for NOS, just like PCK for Inquiry teaching, has an overall goal of presenting scientific knowledge experiences as 'science in the making' as opposed to already made science (Latour, 1987). This way, learners (teacher candidates) are given a rendition of the epistemology and values inherent in scientific knowledge in recognizable and understandable mental pictures. This is enhanced especially if teaching NOS is explicit with opportunities for reflection on the relationship between the scientific knowledge and its related epistemological assumptions and values. Activities rich in science process experiences (inquiry) make this coupling easy to visualize and understand (Akerson &
Arkerson and Volrich (2006) explain what explicit and reflective instruction in NOS may mean in this extract:

…drawing the learner’s attention to key aspects of NOS through discussions and written work following activities in which they are engaged. Reflective instruction requires learners to think about how their work illustrates NOS, and how their inquiries are similar to or different from the work of scientists. (p. 378)

In matters of PCK for NOS, this current study referenced Abd-El Khalick, (2005) study, Project ICAN (Schwartz & Lederman, 2002; Lederman et al., 2003; Lederman & Lederman, 2004). Other studies included Akerson and Hanuscin (2007). These studies suggested ways PCK specific for NOS teaching (explicit/reflective NOS teaching) may manifest in views or in teaching contexts. These manifestations may include:

1.) Quality PCK for NOS targets NOS as a curriculum outcome. Therefore, instructors (science teacher educators) overtly express their intentions to teach NOS. They include it in the lesson plans and plan strategies for assessing it. In the case of science teacher candidates, they are taught and given multiple opportunities to plan and execute their NOS loaded lessons during microteaching experiences (Abd-El Khalick, 2005). This same procedure is manifested in empirical studies involving in-service classroom science teachers for example, project ICAN (Schwartz & Lederman, 2002; Lederman et al., 2003; Lederman & Lederman, 2004), and others like the Akerson and Hanuscin (2007) study.
2.) Quality PCK for NOS accords the science teacher educators (instructors) the ability to use multiple NOS generic inquiry experiences to help science teacher candidates (learners) to examine and confront their own NOS views (Abd-El Khalick, 2005; Schwartz & Lederman, 2002).

3.) Quality PCK for NOS also manifests in the multiple science standard content contextualized inquiry experiences given to science teacher educators (learners). These accord science teacher candidates first hand progressive, reform based science learning experiences similar to what they are expected to enact when they become classroom science teachers (Abd-El Khalick, 2005; Lederman & Lederman, 2004).

4.) Again, quality PCK for NOS is manifested when the science teacher educators grant science teacher candidates multiple opportunities to internalize NOS and develop relevant metacognitive skills for this particular stock of cognitive experiences. These experiences usually are in form of readings, moments to reflect, requirements to write reflections (journal keeping), and also open discussions of what it means to claim to know NOS and what it requires for one to teach and assess NOS during their instructional practices (Abd-El Khalick, 2005; Schwartz & Lederman, 2002). In as much as the multiple NOS generic inquiry experiences will help the teacher candidates (learners) to confront and examine their held views of NOS, the multiple reflection opportunities help these teacher candidates to reconcile their prior NOS views and their new NOS learning experiences. This may facilitate deep understanding of NOS and lead to enhanced and sometimes coherent views of NOS.
5.) Quality PCK for NOS is also manifested when science teacher educators pick particular NOS aspects to target for the lessons they plan and enact. Rather than assuming any if not all aspects of NOS will somehow be covered during their instructions, science teacher educators with quality PCK for NOS are strategic and focused on particular aspects for specific lesson experiences planned and executed (Schwartz & Lederman, 2002).

Lastly, the study referenced one empirical study on science teacher candidates’ learning of NOS and its teaching, to highlight learning contexts that are helpful to science teacher candidates’ development of acceptable NOS knowledge and supportive perspectives. These studies also made visible the five claims made above about quality PCK for NOS that science teacher educators need for effective NOS teaching.

Abd-El-Khalick, (2005), was a study that involved 67 pre-service elementary teachers and 8 graduate students of science education. He treated both groups to two methods courses, one in the fall and the other in the spring. In the spring, the graduate students also enrolled in a philosophy of science (POS) course. In all the courses (Methods I, II and the POS) there was intentional explicit/reflective treatment of NOS. To ascertain that the students gained knowledge of NOS, the researcher administered the VNOS-C and its subsequent interviews in a pre-post instruction manner.

In these courses, students were also given a chance to write reflective papers which gave them opportunities to reflect and internalize the learning experiences and a chance to extract appropriate NOS knowledge for the targeted aspects on NOS. These reflection papers were at specific points during instruction. Another experience
concerning NOS given to these students was the assignment to design science lessons of their choice including explicit/reflective address of NOS issues and a 30 minutes allocation to teach these designed lessons to their peers (microteaching).

This gave the researcher opportunities of multiple data points which included two responses to the VNOS-C survey and the accompanying interviews, reflection papers, designed lessons, and observation of microteaching. The Method I course was made up of NOS related inquiry activities addressing NOS in an explicit and reflective manner. Method II consisted of scientific inquiry experiences similar to what teacher candidates are expected to use during their teaching profession. They were again asked to reflect on NOS related issues and how they would plan to teach NOS explicitly and reflectively using the experiences they had acquired during the courses. All students were involved in Method I and II.

The POS (philosophy of science) course experiences were limited to the graduate students only. The students were treated to reading and reflecting on original works of philosophers of science. They were tasked to reflect on these works vis-à-vis their current understanding of NOS and then write their reflective papers. Aspects of NOS in these classes were explicitly and reflectively addressed in the context of the philosophical works in discussion. The students were also challenged to design lessons in which NOS was explicitly and reflectively addressed giving rationale for including those specific aspects of NOS. Like in the first courses, every student chose the subject and topic of their own interest to situate their lessons. However; the POS students were never accorded the chance to teach their lessons.
Analysis of results showed that there was a substantial improvement in the views of NOS in the pre-service teachers, although many still held to some uninformed (naïve) views. About 30-60% of the students were reported to have failed to develop a consistent, comprehensive understanding of the nature of the scientific enterprise as measured by the VNOS-C. In other words, the students failed to develop an overarching consistent cognitive picture of NOS. Their knowledge was best described as compartmentalized. For example, students would correctly affirm that science is tentative and give examples of scientific theory, but at the same time hold the view that laws are established facts in science that cannot change. Moreover, these students’ NOS views were supported with inadequate examples (examples not sourced from the history of practice of science). The ubiquitous example used by the students that is cited by the author was the change from a ‘flat to a round conception’ of the Earth.

On the other hand, the results showed that the graduate science teacher candidates who attended the POS and the other methods courses had changed their views of NOS. They internalized informed views of almost all targeted NOS. In his own words, Abd-El-Khalick (2005) reports that:

Their views were: (a) more articulate and indicative of deeper understandings of the issues involved, (b) supported with adequate examples from the history and practice of science (these examples included ones not discussed in the POS course), and (c) more consistent across the VNOS–C items and reflective of more coherent overarching frameworks for thinking about the scientific enterprise, and the generation and validation of scientific knowledge. (p. 17)
In this study, the pre-instruction survey of the students’ NOS knowledge showed that both the undergraduates and graduate students had the same NOS views. This review is then inclined to think that the manifested differences in the quality and coherence of NOS view between the methods only treatment group and the methods and POS treatment group is due to graduate students’ exposure to POS. Having NOS explicitly/reflectively taught to them in the POS context could have helped them to form such an integrated, well-composed understanding of NOS. Their ability to come up with examples outside of what was discussed in class and their increased confidence to plan and teach NOS was evidence of this new understanding.

Even with the success discussed in this review, it should be noted that results from studies using History-philosophy of Science (HPS) knowledge as a vehicle for NOS instruction be it to teacher candidates or science students are still a mixed package. Some have reported unsuccessful attempts to deliver NOS as an imbedded content and learning outcome in teaching and learning HPS. The example of Abd-El- Khalick and Lederman (2000) stands out. However, it should be added that in this course NOS aspects were not addressed explicitly. Other studies have reported some success including Lin and Chen (2002) who embedded NOS in history of chemistry as part of a chemistry course and successfully helped their students improve their views of NOS. So did (Irwin, 2000) who immersed NOS in the HPS of the atomic theory as a treatment in a quasi-experimental study of 14 year olds in United Kingdom. He reports that although there was no significant difference in scores of the control and experimental group on chemistry
content tests, the experimental group articulated better understanding of the relevant aspects of NOS covered by the chemistry topics on the periodic table.

Lastly, this study referenced studies focused on teachers’ NOS instructional intentions and personal perceptions concerning the position of NOS among other teaching related tasks. These are reported to play a valuable role in their choosing to teach or not to teach NOS. Unfortunately, these aspects of classroom practice have not been of great focus in NOS teaching research as evidenced in the following observation from, Lederman (1992):

The importance of teachers’ instructional intentions and students’ perceptions of classroom tasks has been virtually ignored in research on the nature of science. It is not adequate to simply observe a teacher and draw inferences without also investigating the teachers’ intentions and the reasons for instructional decisions. (p. 352)

Preferred Science Pedagogy (PSP)

This is covered by Teaching Standard B of the NSES below:

Teachers of science guide and facilitate learning. In doing this, teachers

- Focus and support inquiries while interacting with students
- Orchestrate discourse among students about scientific ideas
- Challenge students to accept and share responsibility for their own learning
- Recognize and respond to student diversity and encourage all students to participate fully in science learning
- Encourage and model the skills of scientific inquiry, as well as the curiosity, openness to new ideas and data, and skepticism that characterize science

- Coordinating people, ideas, materials, and the science classroom environment

(National Research Council [NRC]-NSES, 1996, p. 32)

The standards further stipulate that:

**LEARNING SCIENCE IS AN ACTIVE PROCESS.**

Learning science is something students do, not something that is done to them. In learning science, students describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others. In the *National Science Education Standards*, the term "active process" implies physical and mental activity. Hands-on activities are not enough—students also must have "minds-on" experiences. (National Research Council [NRC]-NSES, 1996, p.20)

This NSES guidance portrays views on preferred science pedagogy (PSP) that are clearly focused on teaching science as “science in the making” by orientation and student-centered by approach (Latour, 1987). In this perspective science teaching is conceived as the instructor allowing science learning to be a result of an active, natural, critical, liberal, and social knowledge construction process by the students and their instructors. There was a noticeable scarcity in literature of empirical studies on science teacher educators’ teaching practices in general. However, a few studies existed that
indicated that university professors had fair to good content knowledge on what teaching by inquiry entails (Goodnough, 2008; Hodges, 2006). Literature further purported that science teacher educators supported teaching by inquiry at the K-12 level because it involved active learning by students as opposed to passive reception of knowledge (Crawford, 2000; Keys & Kennedy, 1999).

Preferred Science Pedagogy Views in Science Education Reforms

*Definition*: Pedagogy is the science or art of teaching. Fenstermacher and Richardson (2005) provide a simplified outline of teaching as:

1. There is a person, T who possesses some
2. Content, C and who
3. Intends to convey or impart C to
4. A person, S who initially lacks C, such that
5. T and S engage in a relationship for the purpose of S acquiring C
6. S acquires C to some acceptable or appropriate level

(Fenstermacher & Richardson, 2005, p. 188)

This conceptualization of teaching or pedagogy insinuates that the act of teaching is both a task and an achievement. Science teacher educators must critically address the views that inform their teaching orientations and strategies as they come into a teaching context since teaching is diversely influenced by the instructors’ central values and beliefs (Tatto, 1998; Tattoo & Coupland, 2003). If teaching is considered a task, all that
science teacher educators do is engage the students in some form of learning activity (represented by the stages 1 to 5 in the outline) and the task would be accomplished. On the other hand, if teaching is conceptualized as an achievement, then the science teacher educators labor until the teacher candidates attain a satisfactory understanding of the lesson’s intended goals (represented by 1 to 6 above). This conceptualization of what it means to teach resembles that of Hirst (1971). His conceptualization of teaching was also based on the task-achievement dipole centered on the intentions of activities that pass for teaching (facilitating some form of learning).

Fenstermacher and Richardson (2005) also apply this task-achievement dipole argument to learning. They delineated quality teaching from successful or unsuccessful teaching. Successful teaching involves the instructor presenting content and the students demonstrating proper learning of that content. The opposite of this would be unsuccessful teaching. However, quality teaching involved more than students successfully demonstrating that they learned the material and included the nature and be-fittingness of the means of presentation of the lesson, age appropriateness of content, and linkage of pedagogical approach used to the learning objectives and national standards. In other words, quality teaching also meets professionally accepted norms about teaching (Fenstermacher & Richardson, 2005; Pestel 1988; Tatoo, 1998). The best way to think of effective quality teaching is to consider the amount of learning accrued from it since contemporary theorists on teaching advocate planning for learning instead of planning for teaching (Wiggins & McTighe, 2005).
This means that quality teaching by science teacher educators should be conceived as going beyond delivery of content to teacher candidates, to cover also the classroom learning environment that facilitates effective delivery of this content, and how this environment is monitored during the process of teaching.

**Brief history of science pedagogy in the USA.**

Although a thorough discussion on the developmental history of pedagogy cannot be featured here, this review covers how inquiry, the prevailing contemporary pedagogy and practice of teaching, is clearly rooted in the history and philosophy of science teaching in the USA. At the onset, this review acknowledged that pedagogical issues are generally immersed in an amalgam of social economic philosophies.

Dewey (1997) claims that there are two pedagogical philosophies: the traditional and the progressive. He elaborated that pedagogical practices based on traditional philosophy assume the transmission of knowledge from the past to the present. Accordingly, in transmission philosophy “…the subject matter of education consists of bodies of information and skills that worked out in the past; therefore, the chief business of the school is to transmit them to the new generation” Dewey (1997, p.17). Alberts (2005) commenting on university teaching of freshman science today, repeated this statement almost verbatim. He compares this pedagogy to that used during ancient civilizations which consisted of rabbinic lectures and preaching that the students (disciples) listened to and toiled to understand what the instructor was saying without questioning (Alberts, 2005). Their behavior in learning environments created by such
pedagogies, fits Dewey’s description of student behavior during traditional type of instruction as “… docility, receptivity, and obedience” (Dewey, 1997, p. 18).

In modern times, the textbook has become the chief representative of the wisdom of the past. Meanwhile teachers act as agents of the textbook; their role is to bring learners into contact with this textbook wisdom (Pestel, 1988). This perspective or philosophical worldview of teaching is also exhibited in large class lecture teaching, common in almost all post-secondary institutions of learning. Watching any one of these sessions one would witness what Pestel (1988) called “preaching” of the textbook wisdom.

The progressive philosophy of teaching, on the other hand, entails a pedagogy that aims at giving the learner a firm set of experiences from which to construct their own knowledge. Dewey alluded to this idea when he said “… the fundamental unity of the newer philosophy is found in the idea that there is an intimate and necessary relation between the processes of actual experiences and education” (Dewey, 1997 p. 20). Today, contemporary orientations or perspectives of teaching for example inquiry, conceptual change, project-based learning, process-based learning, and co-operative activity learning, among others, fit this description (Magnusson, Krajcik & Borko, 1999).

This study believes that the genesis of today’s guided inquiry approach to teaching is grounded in the progressive perspective or philosophy exhibited by Socrates. In his ancient institutions of learning, he moved away from telling as evident in rabbinic lectures to using questions as tools for aiding his students to construct knowledge (Hake, 1992; Nilson, 2003). Later in the early nineteenth century, Jean-Jacques Rousseau, and
later his student Pestalozzi, advanced the idea of guided inquiry by advocating for an education of the child that developed the child’s natural inborn capacities. This education was based on creating active life experiences for the learners as contexts for understanding the natural world (DeBoer, 1991). This study considers these efforts to be the genesis of open discovery learning or perspective on teaching.

The two models (guided inquiry and open discovery learning) have, in this era, been modified and renamed as the constructivist model of learning. Constructivism in all its forms is not a theory of teaching but a cognitive theory of knowledge and learning. The evolution of constructivism, on which teaching through inquiry is based, was made possible first by the works of cognitive psychologists Jean Paul Piaget in the 1950s and later in the 1960s by social psychology and pedagogical theorists such as Bruner (discovery learning), Schwab (enquiry into enquiry), Gagne (inquiry methods) and Ausubel (meaningful learning). Later, Vygotsky put together his social constructivism theory and Von Glasersfeld proposed his radical constructivism learning theory having critically learned from the contributions of Piaget, Brunner, and Ausubel (Mintzes & Wandersee, 2005a; Woolfolk, 2004).

Lastly, this study notes a need to address the aspect of a conceptual orientation for this to be a fair discussion on vital knowledge and research issues associated with pedagogical perspectives. Feiman-Nemser (1990) defined conceptual orientations in teacher education as “a cluster of ideas about the goals of teacher preparation and the means for achieving them” (p.1). Such programmatic orientations reflect a coherent
perspective on teaching, learning, and learning to teach that gives direction to the practical activities for educating teachers.

This study expects to determine conceptual orientations espoused by science teacher education programs in Uganda. Whatever conceptual orientations are espoused by science teacher education units, hopefully they support current reform based pedagogical approaches.

Science teacher educators and scholars in the developed economies like the USA endeavor to help their science teacher candidates and classroom science teachers to develop pro-reform pedagogies and classroom practices. The following study demonstrates their efforts:

Koballa, Dias, and Atkinson (2009) studied the image portraying hands-on sessions and classroom presentations by presenters (science teachers, scientists and science teacher educators) during a classroom inquiry teacher professional development conference. These professionals did not only lead the practical sessions but also gave argumentations for the particular experiences they emphasized as part of their effective inquiry teaching. This study gathered basic data on eight experts modeling classroom inquiry to science teachers through observations and interviews. Extra data was provided by curriculum artifacts collected during and after presentations. The study established that there were varying interpretations by the conference facilitators of what teaching using inquiry really means. Albeit, all the conference facilitators agreed that inquiry is a new approach to teaching and not just a new technique of teaching. The study results also showed that majority of the conference facilitators interpreted inquiry teaching as an
approach to teaching that is active and student centered. Others interpreted it as a teaching approach based on questioning and yet others interpreted it as a learning approach with many instructional models that serve a scaffolding function (Koballa et al., 2009).

Concerning inquiry teaching, the preferred reform based science pedagogy, effective science teacher educators should not only master what it is and what it is not but should be able to transform this knowledge and create inquiry learning experiences and environments that fulfill science teaching reform efforts (Rodger W. Bybee, 2006). This is in addition to taking care of a number of other constraining factors to teaching using inquiry which may include barriers (external factors) and dilemmas (internal factors) (Anderson, 2002). Anderson explains that constraints caused by these two factors may be of a technical, political, and or cultural dimension. For instance, failure to interpret what teaching by inquiry entails an internal constraint (dilemma) of a technical dimension. Dilemmas of a technical dimension manifest as limited ability to teach using inquiry, for example, presenting difficulties with handling group work and failure to cope with the challenges of new teacher roles and or student roles specific to inquiry teaching. Anderson suggests that dilemmas of a technical nature are mostly due to inadequate in-service education. Such technical shortcomings are common among science teacher educators may be because of the way they experienced teaching as students and their consequent conception of what effective science teaching should look like or observation apprenticeship (Berry & Loughran, 2012; Bullock, 2009). That is, personal academic experiences and professional life history are perceived as determinants of their success in
school and professional journeys. Dilemmas therefore, have a direct relationship to the quality and development of science teacher educators’ PCK for inquiry (Magnusson, Krajcik, & Borko, 1999).

Keys and Kennedy (1999) found that these barriers and dilemmas are not easy to overcome even with professional development experiences. For a solution, Hodges (2006) suggests a systematic approach that involves self-study activities (Berry & Loughran, 2012; Bullock, 2009). This study is not able to present an empirical research based description of science teacher educators’ PCK for inquiry. However, below it examines empirical studies on inquiry PCK for K-12 teachers and infers from them aspects of inquiry PCK required for effective science teacher educators.

PCK for inquiry teaching is a form of transformed knowledge assembled together from other knowledge domains to create and execute inquiry based curriculum experiences (Magnusson, Krajcik & Borko, 1999). These domains include science teaching orientation, science curriculum knowledge, knowledge of objective and goals of science, general knowledge of a student’s learning and understanding of science, assessment of science knowledge and classroom context knowledge, among others. PCK for inquiry teaching is the knowledge science teacher educators and classroom science teachers need in order to plan and enact learning experiences that are useful to the process of science knowledge construction and to teaching and learning science. Inquiry PCK may include but is not limited to knowledge and ability to perform the following professional tasks:
(1.) Use and direct science learning explorations using teacher candidates’ own questions. No matter what instruction model science teacher educators choose, their PCK should be biased to exploring students’ questions before using their own generated questions. Instruction models or strategies can

(i) Use questions to engage teacher candidates in Socratic dialogues during a lecture or laboratory session or

(ii) Create appropriate activities for teacher candidates to unveil their prior-knowledge, and then to assist them to construct new and better knowledge.

Keys and Kennedy (1999) case study of a middle school classroom science teacher established that the practice of allowing learners to explore their own question is vital for their undivided engagement. Kennedy, the middle school science teacher in the Keys and Kennedy (1999) study, is commended for his ability to use student-generated questions effectively to implement inquiry based teaching. Abell, Anderson, and Chezem (2006) also suggest that picking on the learners’ own questions engages the class in more constructive arguments that build a better understanding of the observations being made. For example, students who were exploring sound, were able to demonstrate mastery of the concept of sound generation (cognitive) by comfortably creating acceptable arguments to back up explanations for their observations (observed sounds).

(2.) Encourage independent procedurals and social skills useful for learning. This knowledge includes developing a teaching pathway or strategy that the classroom inquiry should take. This pathway could be

(i) Teacher candidates each working alone or
(ii) Working in groups as they inquire into authentic real life problems. Students choose what data or observations are important to the questions they are trying to answer and grapple with how to make meaning of their observations to answer their questions. This procedure varies depending on the inquiry level chosen for the task. Whichever strategy is chosen, teacher candidates should be encouraged to seek opinions from others on the quality of progress of their work. In doing this they develop collaborative stances to knowledge construction as stipulated by NSES standard B (NRC, 1996).

Kennedy, mentioned earlier, allowed his students to work on different aspects of the inquiry activity independently as individuals or groups and to report their findings to the whole class. As some students opened encyclopedias to find definitions and meaning of the word “dew,” others used computers to find out other aspects of weather. Yet still, some individuals were given homework to find out about other aspects of the inquiry and report to the class the next day. She gave these students opportunity to direct procedures and encouraged them to develop social skills as they worked together and negotiated meanings and explanations of dew and the dew point.

Effective science teacher educators like Kennedy possess the necessary PCK for their practice to facilitate inquiry experiences that encourage teacher candidates to develop independent inquiry procedural and at the same time foster social skills (group and individual collaborations). Whatever the desired model of instruction, whether, Problem Based Learning (PBL), or the Kaplus learning cycle (5E) Rodger W. Bybee (2009), or (7E) Eisenkraft (2003), it is necessary for science teacher educators to have
PCK for inquiry to assist them in giving their teacher candidates impetus to develop classroom practices similar to those of Kennedy in the study reviewed here.

(3.) Help teacher candidates to use inductive reasoning with data to build explanations. One of the major tenets of inquiry teaching is the opportunity to allow learners to suggest plausible explanations of the observations they make. Richard Lehrer, Carpenter, Schauble, and Putz (2006) was a case study involving Putz, a science teacher, and her class learning about the causes and explanations of decay as applied to an apple. Data was collected by in-class observations and use of semi-structured interviews. Putz allowed the students to explore the effects of light and heat on the apple and this led them to investigate what causes decay for a year. The scaffolding that led to the yearlong inquiry of decay was provided by the teacher’s knowledge of how to use observation and inscription. This helped students to construct explanations from their observations.

Kennedy in the Keys and Kennedy (1999) study used student observations and explanations to teach science content. All groups presented the results of their observations and explanations on charts in front of the class. Then she led them into a discussion to identify common patterns in their explanations. The capacities of Putz and Kennedy to help their students develop inductive reasoning (a cognitive tool for drawing general conclusions from observations) present a facet of PCK for inquiry teaching desirable for effective science teacher education.

(4.) Help teacher candidates to use deductive reasoning to apply concepts (explanations) to new observations. Teacher candidates should be assisted to accurately take knowledge of prior observations and their explanations and to apply them to explain
new observations (build conjectures, hypotheses and transfer knowledge from one inquiry experience to another). This deductive reasoning usually is encouraged and accompanied by argumentations and opportunities for think – pair and share based on observation (Brooks & Brooks, 1993a; Nilson, 2003; Ueckert & Gess-Newsome, 2006). Putz, mentioned earlier, had the class explore which Halloween pumpkin was bigger later in the year. The exploration ended with the explanation of the difference between rotting of a tomato and that of a pumpkin. The students used the observations and inscriptions based on tomato rot to explain the pumpkin rot.

Science education reform oriented science teacher educators, such as the teachers discussed in these studies, need to transform their teaching from didactic learning experiences (where they preach to students) to a consultancy format (Settlage & Southerland, 2007) where they act as the more knowledgeable others (MKO) available to help learners in their quest for knowledge. They guide and sharpen the students’ thinking skills based on the observations they make as they construct their own understanding of the content material they are trying to learn. They need the Putz-like PCK for inquiry that facilitates teacher candidates to transfer knowledge from one experience to another. However, Novak (2005) suggests that even in such consulting roles, it is a good practice for the instructor to know when to come up with a mini didactic teaching moment to facilitate further and better scaffolding.
**Perspectives on preferred science pedagogy.**

There are as many teaching perspectives as there are philosophies of good teaching and of being a good teacher. This study reviewed some empirical studies on the subject to highlight the common perspectives manifested currently in science classrooms in the USA and in some other countries around the world.

Pestel (1988) proposed that whereas pedagogical approaches can be perceived as (1) preaching, (2) training, or (3) facilitating learning, only the last one (facilitating learning) should be considered teaching because it is capable of achieving most standard mandated learning outcomes. This study agrees with Pestel and considers quality teaching by science teacher educators to be the effective facilitation of the knowledge construction process by science teacher candidates. Further review of literature accorded this study a better understanding on what perspectives on science pedagogy are common in post high school institutions of learning.

Kember (1997) reviewed thirteen empirical research studies on the subject of university lecturers’ conceptions of teaching. The studies originated from Australia, the United States, Hong Kong, China, Canada, the United Kingdom, and Singapore. These studies had used various research methods including case studies, surveys, interviews and observational methods. The findings of the sampled studies pointed to five different conversions of conceptions of teaching including the following:

1. Teaching as imparting information
2. Teaching as transmitting structured knowledge
3. Teaching as an interaction between the students and the teacher
4. Teaching as facilitating understanding on the part of the student

5. Teaching as bringing about conceptual change and intellectual development in the students (see also Richardson, 1996).

Further examination of these studies showed that conceptions of teaching at the university level vary among different disciplines because of the different beliefs held by the lecturers about the nature of the disciplines they teach. The studies showed that lecturers in different universities who teach the same discipline held relatively the same conception of teaching (Norton et al., 2005), also see (Richardson, 1996). This study believes that since these were university level instructors, these findings may be true about science teacher educators also. In another study, Kember and Kam-Porkwan (2000) investigated lecturers’ approaches to teaching and the relationship between these approaches and their conception of good teaching. Findings of the study show that the subjects had generally two conceptions or perspectives on teaching: (1.) Transmissive and (2) Facilitative. Lecturers with a transmissive perspective exhibited approaches to teaching that mainly were teacher-centered and content oriented. In contrast, those who had a facilitative perspective mainly exhibited teaching approaches, which were dominantly student – centered and learning oriented.

W. W Cobern, Schuster, Adams, and Skjold (2012), creators of the instrument Pedagogy Of Science Inquiry Teaching Test (POSTT), grouped the known common perspectives of science teaching approaches into two teaching orientations:
(1.) Teaching science as *already made* science orientation and (2) teaching orientation that treats classroom science as *science in the making*. These two viewpoints on approaches to science teaching or strategies are described in (Table 2.1).

**Table 1: Classification of Teaching Orientation**

<table>
<thead>
<tr>
<th>Perspective /Orientation Held</th>
<th>Approach (Orientation in practice)</th>
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</thead>
<tbody>
<tr>
<td><strong>Already made science</strong></td>
<td>Didactic Direct (DD)</td>
</tr>
<tr>
<td></td>
<td>Teacher presents and explains science content directly may illustrate with examples or demonstrations. There is no active participation by learner</td>
</tr>
<tr>
<td></td>
<td>Active Direct (AD)</td>
</tr>
<tr>
<td></td>
<td>Teacher presents and explains science content directly. Student participate in verification/confirmation activities</td>
</tr>
<tr>
<td><strong>Science in the making</strong></td>
<td>Guided Inquiry (GI)</td>
</tr>
<tr>
<td></td>
<td>Students explore actively phenomenon or idea with the teacher’s guidance towards desired science content understanding</td>
</tr>
<tr>
<td></td>
<td>Open Inquiry (OI)</td>
</tr>
<tr>
<td></td>
<td>Students actively explore phenomenon or idea as they choose. Teacher guides but does not prescribe</td>
</tr>
</tbody>
</table>

Adopted from Cobern et al., (2012)
The Didactic Direct (DD) and Active Direct (AD) approaches or strategies fit into the transmissive perspective while Guided Inquiry (GI) and Open Inquiry (OI) approaches or strategies fit into the facilitative perspective of the Kember and Kam-Porkwan (2000) study. According to Kember and Kam-Porkwan (2000), instructors or teachers who hold an ‘already made science’ perspective when presenting science content are most likely to exhibit a transmissive pedagogy in action which may manifest in class as direct, didactic or didactic active teaching by practice. Instructors with this perspective tend to think of themselves as the knowledge authorities and sources and their students as unknowledgeable; viewing them as perennial sinks for their knowledge. This opposes the relationship between learners and their instructors that reform documents recommend.

Equally true then, those who espouse the ‘science in the making’ perspective on presenting science content in theory are most likely to have a facilitative pedagogy in practice manifesting as guided inquiry or open discovery orientations during teaching (Latour & Woolgar, 1986). This is in line with reform requirements. These instructors view their students as coming into the learning context with functional knowledge of the concepts they intend to teach. They therefore, consider themselves as guides who help their students to construct scientifically acceptable conceptions of what they are learning.

This study seeks to understand where on this spectrum Uganda science teacher educators’ perspectives and orientations lie. It is safe to suggest from these studies that they, like other university lecturers, may hold one of these two approaches to teaching. However, do their espoused approaches support the educational reforms that Uganda has embraced?
Classroom Learning Environment (CLE)

Teaching Standard D

Teachers of science design and manage learning environments that provide students with the time, space, and resources needed for learning science. In doing this, teachers

- Structure the time available so that students are able to engage in extended investigations
- Create a setting for student work that is flexible and supportive of science inquiry
- Ensure a safe working environment
- Make the available science tools, materials, media, and technological resources accessible to students
- Identify and use resources outside the school
- Engage students in designing the learning environment (National Research Council [NRC]-NSES, 1996, p.43)

And

Teaching Standard E

Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers

- Display and demand respect for the diverse ideas, skills, and experiences of all students
- Enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community
• Nurture collaboration among students

• Structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse

• Model and emphasize the skills, attitudes, and values of scientific inquiry

(National Research Council [NRC]-NSES, 1996, pp. 45-46)

Of these two standards, standard E stipulates the science teaching and learning reform perspective on psycho-social academic environment that instructors have to create to be successful at enacting reform based science teaching. These standards have a goal of helping science instructors at all levels of science education, to create a learning environment supportive of free collaborative knowledge construction process. Taylor, Fraser, and Fisher (1997) have called such a learning-teaching environment a constructivist learning environment (CoLE).

Constructivist theorists understand learning as an active cognitive process in which the learners make sense of the physical world by meaningfully constructing knowledge about it based on what they perceive by their senses and what they already know. This process is at best social and it involves negotiations and consensus building (Mintzes & Wandersee, 2005a, 2005b; Novak, 2005).

Uganda recently made reforms to its science curriculum and moved to a thematic curriculum. With the new curriculum also came a move to a more conversational style of teaching that emphasizes active participation of the students and group work during science teaching (Altinyelken, 2010b; O’Sullivan, 2010). This study is curious to know if
science teacher educators in Uganda share the same perspectives on CLE as the theorists involved in the current USA science education reforms.

Classroom Learning Environment and Science Education Reforms

Definition: Barry J. Fraser (1994) defines the Learning Environment (LE) as the physical, emotional, social and intellectual environment in which learning takes place. This definition takes into account of the fact that a learning environment extends beyond the physical objects in the space in which leaning or teaching is taking place to include the interactions between the learner and teacher. This interaction can be social or psychological or both (psycho-social) in nature. Standard E of the NSES stipulates a natural learning environment. What does that mean?

Bain (2004) in a national study of effective university instructors in the United States defined a natural learning environment as:

“....students encounter the skills, habits, attitudes, and information they are trying to learn embedded in questions and tasks they find fascinating (authentic tasks) that arouse curiosity and become intrinsically interesting” (p. 99)

He further defined a critical learning environment as where

“….students learn to think critically, to reason from evidence, to examine the quality of their reasoning using a variety of intellectual standards, to make improvements while thinking, and to ask probing and insightful questions about the thinking of other people”. (p. 99)

Science education reform in the USA and other developed economies demands that science teacher educators and indeed all teachers create natural and critical learning
contexts. For science teacher educators, these environments are vital because they promote meaningful learning of the content material they teach. The contexts also act as models of appropriate reform-based teaching that science teacher candidates can emulate when they start their careers as science classroom teachers (Putnam & Borko, 2000).

In general terms, higher achievement on a number of learning outcomes measured in a variety of classroom science subjects has been associated with classroom learning environments perceived by students as orderly and well organized (Barry J. Fraser, 2002). Such classroom learning environments exhibit cohesion and clear directions of learning goals. Contemporary theories of learning and teaching argue for a constructivist learning environment which accords students the opportunity to actively participate in the process of knowledge construction. In constructivist learning environments, learners are encouraged to take ownership of the knowledge they construct through monitoring the process of knowledge construction (NRC, 1996; Dart et al., 1999; S. J. Magnusson & Palincsar, 1995)

Reform documents, for example, the National Science Education Standards (NSES) (NRC, 1996) and Science for All Americans (AAAS, 1990) have stipulated benchmarks for science literacy that emphasize creation of classroom learning environments that are based on human constructivist learning models (constructivist learning environments or CoLE). These learning contexts make science learning personally relevant, allow for sharing of control of the learning process between the learners and the instructor, display knowledge as ever changing, and encourage greater
social interaction during learning to facilitate deeper understanding of the subject matter (Dart et al., 1999; National Research Council [NRC], 1993).

This study subscribes to the philosophy that for Uganda science teacher educators to engender a deeper and better understanding of the required reforms, they should allow for CoLE during their teaching. Consequently, they should espouse a Human Constructivist perspective (Novak, 2005) about science teaching and learning. Such epistemology of science learning and teaching will enable them to model for the science teacher candidates’ classroom learning environments in which knowledge constructive conversational teaching can take place and group work easily realized. This may help alleviate the documented struggles to create such learning environments current science teachers have (O’Sullivan, 2006).

**History of classroom learning environment issues in the USA.**

Studies that deal with understanding the working environments are as old as institutionalized education. DeBoer (1991) reported that Europe was the first continent to launch efforts to understand formal constructivist teaching and the learning environments. The prominent educator in this field was a Swiss Johann Heinrich Pestalozzi, a former student of French educator, Jean-Jacques Rousseau. In the United States, Herbert Spencer is reported by DeBoer (1991) as being one of the first people to import and advocate Pestalozzi’s views on teaching and the learning environment.

Spencer trumpeted Pestalozzi’s perspective or philosophy that useful knowledge should not be learned dogmatically but it should be constructed in a spirit of discovery
and inquiry. He presented his views in four essays; the most well-known is titled “What Knowledge is of Most Worth?” (DeBoer, 1991). Spencer also envisioned changes in the way schooling was organized to mirror the changes that were occurring in the political and religious spheres. Changes that allowed more individual liberty to construct personal knowledge about life and the world one lived in without the dictates of someone else.

Currently, Fraser, Taylor, Walberg, Wubbel and Treagust are among the leading scholars in this field (Barry J. Fraser, 1994, 1998, 2002)

DeBoer (1991) further reports that in 1962 Joseph Schwab similarly advocated for learning environments in which discussions are vibrant. He reasoned that discussions are vital for deeper engagement of the students in knowledge construction and for development of critical reasoning. The report gave three reasons that Schwab used as the basis for supporting discussion in CLEs. First, discussion evokes more active involvement in the learning process. Second, discussion, being a group activity, easily generates desirable emotional reinforcers of learning as learners work as members of a team. Third and last, discussion affords teachers more opportunities for effective interpersonal interactions with students. There are more chances for teachers to interact with individual students or groups of students during discussions than in other learning situations, making open discussion the basis for the progressive learning environment (Dewey, 1997).

The questions that linger around such discussions are: Does this come naturally to classroom science teacher without any input by science teacher educators during professional education? Can a science teacher educator help his or her science teacher
candidates acquire these professional repertoires without exercising or modeling for them? Moreover, can a science teacher educator model these experiences for his or her class without the backing of a well-developed, coherent perspective to support his classroom professional dispositions? Answers to these questions lie in findings of studies designed to expose science teacher educators who are successfully enacting such learning environments.

The key word in Schwab’s arguments is “construction”. This word assumes a constructivist philosophy and its application to teaching and learning. The use of constructivism to organize learning environment was also advanced by social psychologists Bruner, Ausubel and Gagne. These theorists based their arguments largely on the contributions to learning and teaching by cognitive psychology, specifically, the revolutionary work of Jean Paul Piaget in 1964. DeBoer (1991) reports that constructivism at this time sought to dethrone behavior-based education theorists such as Thorndike, who had long influenced how teaching was organized and learning was explained.

In addition to constructivist influences, conceptions of learning environments or perspectives about learning environments have also been influenced by industrial and human performance management research on organizational climates. Fraser (1994) briefly lays out this foundation through the 1936 work of Lewin, and the Lewinian formula, $B = f(P, E)$ where behavior (B) is a function of personal characteristics (P) and the environment (E). Fraser (1994) reports that this work was further developed in 1938 by Murray, in 1958 by Pace and further in 1970 by Stern. These efforts formed the
foundations of the earlier work in the field of school climate and classroom climate by such scholars like Herbert Walberg and Rudolf Moos in the late 1960s.

There is a dearth of empirical research on science teacher educators’ conception and perception of their classroom environments let alone constructivists learning environments (CoLE) accepted as reform based classroom learning environments (CLE). This is a direct contrast to availability of research on teachers at K-12 level. Examples include: elementary level (Allen & Fraser, 2007), secondary school level (Wolf & Fraser, 2008), and high school level (B. J. Fraser, Aldridge, & Adolphe, 2010). This scarcity makes it apparent that science educators are not investigating and documenting their views on their own teaching environments. This current study conceives instructors’ perspectives on CLE as part of their PCK for inquiry teaching.

Developing content pedagogical knowledge (PCK) by nature involves a great deal of reflection on practice and in practice (Kane, Andretto, & Heath, 2004). This is because PCK for inquiry teaching is assembled from, among others, knowledge of (i) science subject to be taught, (ii) teacher candidates’ pedagogical roadblocks to understanding the subject, (iii) nature of science and (iv) science as an inquiry. Science teacher educators and science teachers have also to add knowledge of constructivism as a theory of learning and its application to teaching as well as knowledge of the social cultural values and theories on teaching. Lack of social cultural values and theories knowledge is the most pervasive factor against constructivist teaching. Lack of this knowledge rationalizes traditional teacher-centered teaching (Gess-Newsome et al., 2003; Taylor et al., 1997). This rationality presents itself in two primary cultural myths: (1) an objectivist view of
the nature of scientific and mathematical knowledge; and (2) a complementary technical controlling ethos that views the curriculum as a product to be delivered.

The objectivist perspective about scientific and mathematical knowledge is that this knowledge exists independently of learners’ (teacher candidates) mind, is static and unchanging over time, and is the embodiment of universal truths (Lorsbach & Tobin, 1992). With this conception of scientific knowledge, science teacher educators are entitled to adopt the role of experts who transmit to students (teacher candidates) accurate versions of this universal body of truth. The curriculum under this conception of nature of scientific knowledge is a container of immutable knowledge (curriculum as product) which teachers (science teacher educators) are obligated to deliver (Berry & Loughran, 2012; Bullock, 2009).

A qualitative research by Kane et al., (2004) used multiple data sources (stimulated recall interviews, classroom observation, repertory grids and document analysis) to investigate and document the general characteristics of 17 effective tertiary teachers. This study reported five dimensions to effective tertiary teaching. These dimensions are:

(1). Deep subject knowledge

In the Kane et al., (2004) study, subject knowledge refers to knowledge of the science subject or any subject that the tertiary teacher is to teach. For example, biology, chemistry or in the case of this study, knowledge of Human Constructivist theories of learning and the constructivist learning environment. This knowledge would be enhanced by a deep constructivist understanding of nature of science and scientific inquiry.
(NOS/NOSI). This study argues that an amalgamation of all these forms of knowledge is foundational to creating and sustaining a natural and yet critical constructivist learning environment (Bain, 2004).

As referenced earlier (see p. 63), Bain (2004) in a national study of effective university instructors in the United States defined a natural learning environment as follows: “….students encounter the skills, habits, attitudes, and information they are trying to learn embedded in questions and tasks they find fascinating-(authentic tasks) that arouse curiosity and become intrinsically interesting” (p. 99). He further defined a critical learning environment as where

….students learn to think critically, to reason from evidence, to examine the quality of their reasoning using a variety of intellectual standards, to make improvements while thinking, and to ask probing and insightful questions about the thinking of other people. (p. 99)

Although not at the higher education level, Jake (pseudonym) the high school biology teacher whose teaching was center in the (Crawford, 2000) study served as a perfect example for this study. Jake used his knowledge of science as inquiry and that of his students’ curiosity to identify what questions to ask and discuss about the community environment they were studying, what data to collect and then allowed them to grapple with the data analysis. He had deep knowledge of ecological science and knowledge of the local geographical setting of the school and its ecology. He also had a deep understanding of inquiry as a learning–teaching approach coupled with a fully developed
knowledge of nature of science and scientific inquiry. After experiencing this classroom environment, some of the students had this to say:

**Carla:** I liked the hands on work instead of book work, because I got more out of the class. I also tried harder because what we were doing was worthwhile and beneficial to society.

**Mike:** You present material in an interesting way, and use material in real life situations.

**Dawn:** I liked all the field work. I liked how I could see how the stuff we learned is awfully important. I liked even when you were in pain with your back, you still had a positive attitude and gave us your best. (Crawford, (2000), p.923)

**2. Skill**

In the Kane et al., (2004) study, skill dimension referred to techniques exhibited in teaching repertoires. These usually manifest as classroom behavior of the science teacher educators. In the case of constructivist learning environments effective science teacher educators should master certain characteristic skills. These may include:

(i). **Good communication:** Effective science teacher educators, in their efforts to create and sustain a constructivist learning environment, should make their expectations of the teacher candidates clearly known at the beginning of the course and at every inception of each class. They should give clear instructions and directions during classroom learning activities. Such communication is vital for creating a non-threatening, respectful and orderly classroom environment. Practices like writing due dates for assignments and agenda for the day on the board may help make teacher candidates’ mental activities focused and their thinking orderly (Bain, 2004; Schussler, 2009; Stronge, 2002). These
may not come easily. Learning to be a good communicator may require science teacher educators to reflect on their instructional beliefs and dispositions.

(ii). *Use of relevant learning experiences*: Science teacher educators should have skills for putting together natural (personally relevant) learning activities that display the uncertainty inherent in science knowledge and its construction. Such activities aim at increasing teacher candidates’ free participation in choosing explanations (theories) to their observations and presenting argumentations to defend their theory of choice. The science teacher educators should have skills to create learning communities within their classrooms to facilitate this free flow or exchange of ideas. Classroom learning environments that present these opportunities to learners are referred to by the NSES as ‘engaging’. In such environments the learners are not passive recipients of knowledge. Instead, they are engaged as co-constructors of knowledge in their learning communities (Bain, 2004; Chen, Lattuca, & Hamilton, 2008; Taylor et al., 1997).

(3). **Interpersonal relations**

Good interpersonal relations are vital for the existence of a constructivist learning environment in that teacher candidates find them legitimate and beneficial for their learning since they can question and participate fully in the pedagogical planning (critical voice and shared control dimensions of (CLES-II (20)). Science teacher educators should display open and conducive interpersonal relationships that do not hinder communication with teacher candidates. Instead, their interpersonal relations should encourage teacher candidates to share freely their insight about pedagogical issues and the learning environment they find themselves in (Alberts, 2005; Bain, 2004; Taylor et al., 1997).
This was observed about Jake the subject of Crawford (2000) case study. He had a great interpersonal relationship with his students and acted as a co-inquirer with them during pedagogy planning as indicated in the following quote, when he speaks to his class, lamps himself with them and does not give instructions but instead paints a picture of what they might deal with:

I don't really know what we're going to find out. It is really going to be interesting to get some data and to get some base line data for comparison, might give us some ideas for questions we might want to ask further, might give us some indications as to what kind of condition the river is in...I really have no idea. (Crawford, (2000), p. 923)

(4). Personality

Personality here just as it was in the model of Kane et al., (2004) refers to personal characteristics that are useful to sustaining a constructivist learning environment. These personality qualities should engender student negotiation and shared control of the learning environment between science teacher educators and teacher candidates. Effective science teacher educators have those personality traits that will not impede but instead facilitate teacher candidates to engage their teachers in discourse that bolster their epistemological positions. Enthusiasm about teaching, humor, being approachable, display of passion for the subject matter and the learning of this subject matter are some of the personality characteristics useful to designing and sustaining a constructivist learning environment (Bain, 2004; Brooks & Brooks, 1993b; Taylor et al., 1997).
(5). Research/Teaching nexus

Kane et al., (2004) found out that effective tertiary teachers always reflected on their own research to inform their teaching. This is true also for science teacher educators as they develop good pedagogical content knowledge for enacting and sustaining a constructivist learning environment. Science teacher educators who talk freely about their research experiences with teacher candidates and show them how the material they are learning is related to their research efforts, can make the learning environment relevant to them. Science teacher educators who choose to refer to their current research undertakings in a classroom learning environment may facilitate teacher candidates to understand the uncertainty that inquirers of any kind face. This may enable teacher candidates to channel their own curiosity into understanding better their learning material and they may also divulge tacit hindrances to learning if they believe that their teachers will help them to overcome these hindrances.

Science education reforms have been greatly influenced since the 1950s by the constructivist theories. Next this study reviewed literature on constructivism relevant to the purpose of the study.

Constructivism, Inquiry Movement and Science Education Reforms

The reforms examined in sections 2.5 to 2.7 were and are still influenced by the constructivist epistemology of science and science learning (Novak, 2005), more than any other epistemology of learning in science. Considered in the merits of constructivism, the three foundational areas of nature of science (NOS), preferred science pedagogy
(PSP) and classroom learning environment (CLE) are closely related and held together by a shared strong constructivist epistemology, especially the perception of the goals of science teaching and learning (Novak, 2005). Constructivism conceives scientific knowledge and its artifacts as not discovered but constructed (invented) through careful observations of nature, and critical thinking (imagination and creativity). Observations give scientists empirical artifacts with which to construct scientific evidences using their prior knowledge about nature, creativity and imagination, and agreed upon professional consensus procedures and values.

Contemporary science education reform efforts are aimed at giving learners of school science the same experiences that scientists enjoy during the process of creating scientific knowledge. Students are supposed to learn and view the scientific enterprise as run by human beings and driven by man’s quest for understanding how the physical environment around him behaves. The recent reform publication in the USA called this ‘science for all Americans’. It promotes the development of school science products that have capacities to be critical consumers of scientific products. These school products are supposed to be scientifically literate individuals who can fully participate in democratic decisions that involve science. Moreover, they are expected to hold those in authority who deal with scientific decisions accountable, for they are knowledgeable in science and its processes (see Science for all American Project 2061: AAAS, 1993).

This study argued that for the USA and indeed for Uganda to realize their current embraced educational goals, science teacher educators in both countries should allow for Human Constructivism based perspective on science and science education to inform the
designing of science learning experiences in schools. This includes the behaviors of the classroom science teachers and students during the teaching-learning process.

Human Constructivist perspectives should be extended to cover relevant research in this area. These Human Constructivist perspectives will demand that the tools used be heavily naturalistic in nature and by design. Examples include case studies, and qualitative measures of learning and understanding. This is clearly a move away from the use of psychometric tests as research tools towards tools like clinical interviews, concept mapping, and participant observations; a general movement in science education research away from psychological models toward anthropological models, nomothetic comparisons to idiographic descriptions. The movement is from, for example, complex multivariate analyses to simple data transformations. Some see this movement as more authentic and informative to science educators in general and classroom teachers in particular (DeBoer, 1991; Novak, 2005; Mintzes & Wandersee, 2005b).

**Brief History of Constructivism in Science Education**

The current study surmises that the single most influence on the current science education reforms in developed economies is the constructivist school of thought and its worldview of knowing, knowledge and learning. Understanding this constructivist worldview is crucial to appreciating the advocated for reforms. So this study aimed at highlighting a few salient features of constructivism and Human Constructivism in particular (Mintzes & Wandersee, 2005a, 2005b; Novak, 2005; Novak & Gowin, 1984).
Evolution of constructivism which gives base to modern inquiry teaching was made possible first by the works of cognitive psychologists Jean Paul Piaget in the 1950s and later in the 1960s by social psychology and pedagogical theorists such as Bruner (discovery learning), Schwab (enquiry into enquiry), Gagne (inquiry methods) and Ausubel (meaningful learning). Later, Vygotsky put together his social constructivism theory and Von Glasersfeld proposed his radical constructivism learning after they both critically learned from the contributions of Piaget, Brunner, and Ausubel (Mintzes & Wandersee, 2005b; Woolfolk, 2004). The break-through in cognitive and social psychology represented by the work of these scholars has greatly helped science teacher educators understand cognition, classroom social environment and their relationship to science teaching. Inquiry as a content pedagogical approach derives its strength from being rooted in cognitive science discoveries about learning and it is enhanced by social leaning activities.

Social constructivists (Vygotsky) believed that the learner’s culture (language) and context in which learning is occurring have a role to play in the process of constructing personal and shared interpretations of reality. This Vygotskyian outlook on learning makes knowledge a product of social interactions, learning a social process and accepted meanings as agreements shaped by social patterns and assumptions encapsulated in language (Brooks & Brooks, 1993b; Novak, 2005; Woolfolk, 2005).

Joseph Novak is one among many theorists who propagated another form of constructivism quite different from past forms. He called it Human Constructivism. Theorists like Joel Mintzes, James Wandersee subscribe to this theory. Novak’s Human
Constructivism is a new synthesis of learning based on Ausubel’s meaningful learning. It stresses the importance of prior knowledge and asserts that no two human beings construct precisely the same meaning even when presented with the same identical objects or events. To this group of learning theorists, learning is gradual and assimilative in nature (Mintzes & Wandersee, 2005b). Today Novak’s Human Constructivism forms the basis for the contemporary inquiry teaching or teaching that models Human Constructivist understanding of knowledge and learning (see also Science for all America Project 2061, AAAS, 1996). Its philosophical basis is that the natural world is real, independent of human thoughts, but understandable (post-positivism). Thus understanding the world around us is accomplished through careful and rigorous construction of our own knowledge about it through reason and observation (Brooks & Brooks, 1993b; Novak, 2005; Woolfolk, 2005).

One particular aspect of social constructivist-based theory of learning/teaching influential to inquiry as a content pedagogical approach is Vygotsky's Zone of Proximal Development (ZPD). The ZPD describes the difference between what a person can learn on his or her own, and what that person can learn when facilitated by someone with greater expertise, a more knowledgeable other (MKO). The idea of well-timed instructional interventions, operating within an individual's ZPD, has become a compelling idea of instruction especially in inquiry instruction where the teacher candidates are expected to be in free dialogue with the science teacher educators (MKOs). These MKOs act as facilitators in the teacher candidates’ knowledge construction process as they help them grapple with data or observations and push them
to use their creativity and inborn curiosity to create their own meaning of the material being learned. In other words they have to maximize ZPD time and help the student not just develop a relationship of trust with them but to develop a healthy relationship with the content they are learning (Berry & Loughran, 2012; Berry, 2009).

Ausubel contributed to this by insisting that teaching should help learners reason deductively, and not inductively, by giving them an opportunity to be exposed to the content being learned from the general forms to the specifics (Novak, 2005; Woolfolk, 2005). In so doing, learners are facilitated to construct understandings of complex material by effectively integrating the basic material (understandings) underlying them.

Human Constructivism as a theory has been greatly embraced by educators in the USA, other developed economies for example Japan and Finland, and some developing economies like Slovenia, Thailand and Morocco as evidenced by the similarities in their pursued educational reforms reflected in the TIMSS reports (Kastberg, Ferraro, Lemanski, Roey, & Jenkins, 2012).

Uganda, since 2006 embraced similar science education reforms, however, it is not known what perspective on foundational areas of reforming science learning and teaching Uganda science teacher educators hold. Nonetheless, they have to prepare classroom science teachers that will be teaching science education reforms very similar to what the USA. This study was designed to contribute to understanding of their perspectives especially on the three foundational areas of NOS, PSP and CLE. This study chose to focus on science teacher educators over other professional sub group in science education because of their unique roles described in the literature review below.
Science Teacher Educators’ Central Role in Science Education

Science teacher educators are teachers of teachers entrusted with the task of professionally and effectively preparing classroom science teachers for their teaching profession tasks. This makes science teacher educators major players in fomenting failure or orchestrating success in science education reform efforts in any nation. This is because science teacher educators are primarily tasked with the professional preparation of science classroom teachers, extend their influence in science education beyond classroom issues. Scholars have identified the following as functions of science teacher educators in the science education service industry:

1.) They are the gatekeepers to the science teaching profession. 2.) They lead inquiry efforts in the field of science education. 3.) They are tasked with stimulating professional development in the field. 4.) They are involved in curriculum development. 5.) They encourage reflective skills in teacher candidates and in service teachers. 6.) They are involved in corroborations with others outside the education sector on matters affecting science education (Korster et al., 1996 cited in Cochran-Smith, 2003). That is why Cochran-Smith (2003) being cognizant of their role, referred to them as the linchpin in science education reforms of all kinds. Despite this great role, little is empirically documented about their perspectives and competencies in the three areas of NOS, PSP and CLE; considered critical to enacting effectively reforms to science teaching, learning and research in science education (Koster et al., 2005; Murray & Male, 2005a).
The fore mentioned cardinal functions of science teacher educators make their held perspectives of influence in shaping success in reforming of science education. Their perspectives can color their epistemological commitments on science and science education as fields of study, their views on approaches to content delivery in classroom situations and appropriate progressive classroom learning environments supportive of reform based teaching and learning of science (Altinyelken, 2010; Bybee, 2009; O’Sullivan, 2006). So their held perspectives will affect classroom science teachers’ proper implementation of the desired science education reforms. Since studies have shown that classroom science teachers more often teach the way they experienced their own classroom science as students (Kagan, 1992; Kennedy, 1996; Rokeach, 1968). Other scholars have called this propensity to enact their best classroom science experiences observational apprenticeship (Berry & Loughran, 2012; Bullock, 2009). This revelation makes this study even more important for documenting Uganda science teacher educators’ perspective on NOS, PSP and CLE, since they do not have a documented long history of initiating or involvement in Uganda’s science education reforms.

It is disappointing that there is a dearth of research focused on science teacher educators as also observed by Murray and Male, (2005b). Koster et al., (2005) attribute the paucity of peer-reviewed literature on science teacher educators to two reasons: (1) Science teacher educators are too busy studying other teaching professionals that they have no time to study their own professional subgroup. (2) Policy makers consider science teacher educators as having a minor role to play and therefore of low status.
This dearth of empirical research literature on the science teacher educator as a professional subgroup left this study to construe from empirical literature on classroom science teachers the perspectives held by science teacher educators who taught them what and how to teach. This was in line with the central assumption of the study that classroom science teachers are a reflection of their science teacher educators. Next the study explains why it is interested in the three critical areas of NOS, PSP and CLE.

**Why NOS, PSP and CLE?**

Nature of Science (NOS), Preferred, Science Pedagogy (PSP), and Classroom Learning Environment (CLE) are three areas critical to effective teaching of science. These areas have the vital aspects needed for proper conception and presentation of knowledge on the scientific enterprise (scientific literacy) ([AAAS], 1990, 1993; NRC, 1996), and learning science in a manner that is close in experience to what scientists do when creating scientific knowledge. This study believes that the authors of the reform documents (reformers) envisioned a process of human transformation through a liberal science education to be more effective than some form of scientific indoctrination. They chose to leave indoctrination to religion and turned to teachers and specific pedagogical practices to unleash the power of human imagination and creativity through science classrooms experiences.

In so doing they advocated for a participatory, liberal science education that fosters knowledge constructed collaboratively in light of one’s prior knowledge or ideas.
To fulfill this, the current reformers have advocated for the following changes to classroom science experiences:

- Open discussion and learning about NOS and NOSI.
- Encourage learning science in a way that is critical of the textbook script, this is done by teaching science as an inquiry and through inquiry pedagogy.
- Encourage creation of a learning environment that allows students to be active participants in knowledge creation, interact as intellectuals, and co-share control of intellectual authority with their teachers/instructors ([AAAS], 1990, 1993; NRC, 1996)

Such a perspective on science and science teaching is seen as a tool good for developing scientific literacy. The above thoughts can be clearly seen in the following excerpt from the NSES:

> The new vision includes the “processes of science” and requires that students combine processes and scientific knowledge as they use scientific reasoning and critical thinking to develop their understanding of science. Engaging students in inquiry helps students develop

- Understanding of scientific concepts
- An appreciation of "how we know" what we know in science
- Understanding of the nature of science
- Skills necessary to become independent inquirers about the natural world
- The dispositions to use the skills, abilities, and attitudes associated with science.

Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including
asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (NRC 1996, p. 105)

This excerpt shows that indeed science education should encourage classroom science lessons to be planned with intentions to teach and assess the learners’ acquisition of NOS knowledge, learning the processes of science and construction of scientific knowledge complemented by the science textbooks. For a liberal science education the NSES has this about the classroom learning environment.

**TEACHING STANDARD E:**

Teachers of science develop communities of science learners that reflect the intellectual rigor of scientific inquiry and the attitudes and social values conducive to science learning. In doing this, teachers:

- Display and demand respect for the diverse ideas, skills, and experiences of all students.
- Enable students to have a significant voice in decisions about the content and context of their work and require students to take responsibility for the learning of all members of the community.
- Nurture collaboration among students.
- Structure and facilitate ongoing formal and informal discussion based on a shared understanding of rules of scientific discourse.
- Model and emphasize the skills, attitudes, and values of scientific inquiry (NRC, 2000, p 23)
This excerpt stipulated what a reform based classroom learning environment should look like and the preferred science pedagogy (PSP) in the USA. These two NSES guidelines together, show clearly the close relationship of the three areas of NOS, PSP and CLE. They show that for one to effectively teach using the preferred pedagogy in this case inquiry, one must possess a perspective on classroom learning environment that complements it. Inquiry as a teaching–learning approach would present contexts that would better facilitate collaborative knowledge construction among students as well as modeling and emphasizing the skills, attitudes, and values of science and scientific inquiry as stipulated by the standards. This relationship, intended to exist, between the preferred pedagogy and the resulting learning environment for the USA science learners has implications on science teacher educators’ teaching competences.

Science teacher educators in their science teaching methods lessons should teach the foundations, advantages and challenges of teaching using the preferred science pedagogy (PSP) which is inquiry. They should challenge and help teacher candidates overcome their observational apprenticeship by modelling for them that inquiry can be employed across the full spectrum of science teaching. This may help them not only develop the competences necessary for teaching using inquiry but it may help them develop the much needed supportive perspective that inquiry suits better the goals of reform based science education.

The Crawford (2007) study showed that the perspective of the mentor or what Vygosky and social constructivists call MKO (more knowledgeable other), has a lot of influence on the translation of learned experiences about teaching into actual enactment
of reform based science teaching and learning. This makes understandings of perspectives held by science teacher educators on critical reform aspects necessary for monitoring success of planned reforms.

This study conceived that the intrinsic relationship between preferred science pedagogy (inquiry) and the classroom learning environment (constructivist learning environment) appeals to NOS as a learned outcome in the manner here explained. Targeting aspects of NOS as learned outcomes is best served by inquiry teaching which gives the best contexts for students to experience (explicit/reflective) instruction in NOS. Moreover, the targeted NOS aspects are made “lived” experiences to the students by the classroom learning environment (CLE) which supports NOS related behaviors like student-scientist, argumentations, collaborations, brainstorming, etc. to occur naturally when teaching (Abell, Anderson, & Chezem, 2006; Akerson & Volrich, 2006).

An empirical study may provide evidence from literature helpful in understanding this relationship. In the study Crawford (2000) the beliefs and practices of a high school biology teacher (Jake) who successfully developed and sustained an inquiry-based classroom were examined. Data was collected through classroom participatory observation and semi-structured interviews. Jake fitted the description of qualified subjects and was selected. Jake’s knowledge and abilities in inquiry teaching was displayed by his ability to use authentic life problems to create inquiry environments in which the students learned their biology curriculum content. Jake created a supportive classroom environment (constructivist) by making his expectations from his students known to them, allowing them to be involved in planning the learning experiences and
suggesting how best to execute them, in addition to allowing for and encouraging collaborations between student-science groups.

This way he was able to engage and maintain their cognitive enthusiasm in the learning experiences. He held them accountable and encouraged them to own their learning experiences and modify them as they found fitting. As shown earlier, Jake’s students recognized the need to invest in their inquiry activities as suggested by these quotes from them:

**Carla:** I liked the hands on work instead of book work, because I got more out of the class. I also tried harder because what we were doing was worthwhile and beneficial to society.

**Mike:** You present material in an interesting way, and use material in real life situations.

(Crawford, 2000, p. 923)

Jake had 15 years of experience as a high school biology teacher and a Masters of Arts in teaching. His well-developed knowledge of inquiry based teaching encompassed encouraging his students to develop the following science learning habits that are target characteristics of inquiry based science teaching:

“1. Situating instruction in authentic problems
2. Allow students chance to grapple with data
3. Encourage collaboration among students and with the teacher
4. Make learning experiences connected with lived experiences in society
5. Teacher modeling behaviors of a scientist
6. Development of student “ownership” of knowledge (Crawford, 2000, p. 922)
When the study examined Jake’s teaching, it revealed that he allowed the close relationship between the preferred pedagogy, and learning of NOS to be visible in the learning environment he created for his students. He was effective in allowing the learning experiences and the learning environment he prepared for his class to model the behaviors of scientists which included experiences like: Unleashing creativity and imagination as they grapple with evidence and meaning making from data, owning one’s learning and collaboration among students as they solved or examined real life authentic issues. This may give an insight into Jake’s perspective on the two critical areas of PSP (guided inquiry) and CLE (constructivist) which lines up well with the efforts of reforming science education in the USA.

However, good as this study was, it is silent about NOS teaching and learning in Jake’s class. NOS learning and teaching recommended by the NSES was not at all referred in spite of classroom learning environment presenting terrific contexts for NOS learning. There is also need to remember Lederman (1992) multiple case study of five high school biology teachers. Results of this study indicated that teachers’ conceptions of science do not necessarily influence classroom practice. The above observation informed this study on its own focus on science teacher educators’ perspectives on NOS that; it should not depend solely on observing the subjects during their teaching to gain insights about their NOS perspectives. Instead the study should seek to know what NOS perspective is promoted if at all in syllabi and other teaching material, in addition to interviewing the subjects and having them responding to paper and pencil instruments.
Another observation made from the literature reviewed is that although these three critical areas are so closely related, it was hard to find studies that have examined the three areas together in a single study. Most studies focus on inquiry and teaching environment (Crawford, 2000; 2007) or inquiry and NOS (Abd-El-Khalick, Bell & Lederman, 1998; Gess-Newsome et al., 2003; Schwartz & Lederman, 2002). This current study examined all three together. This is because the study believed that examining all three together, accorded it a deeper understanding of how the study subjects related science, science teaching, and nature of science than if each area was studied singularly.

Geographical and Political Location of Uganda

Uganda is located on the eastern part of Africa. East Africa comprises of Uganda, Tanzania, Kenya, Rwanda, and Burundi. Uganda is one of the smaller countries in the region just a little bigger than Rwanda and Burundi that are almost the same size. Uganda lies between Latitudes 1.2\(^0\) South to 4\(^0\) North, Longitudes 30\(^0\) East to 34\(^0\) East, with the Equator cutting across it in the south (Figure 2.0). This geographical position gives Uganda an equatorial climate. Uganda’s population of approximately 30 million lives in communities scattered across the country. Kampala, the capital city, bursts with about 2 million people. The total area of Uganda is 236,040 km\(^2\) of which 199,710 km\(^2\) (approximately 85\%) is land and 36,330 km\(^2\) is water.

Uganda is home to the greater portion of Lake Victoria, the second largest fresh water body in the world which is also the source of River Nile, the longest river in the world. The only snowcapped mountain peak along the equator is on Uganda’s Rwenzori
Mountains whose highest peak Margherita (mountain of the moon) has an elevation of 5,109 m (16,763ft). Uganda is a land locked country with neighbors Sudan in the north, Kenya in the east, Tanzania in the south and the Democratic Republic of Congo in the west. It shares its south western border with Rwanda.

There are over 56 tribes in Uganda and just as many local languages but only a handful of regional languages. English is the currently the official language although Kiswahili is fast developing and has been recommended for upgrading to become the national and East Africa regional language.

Figure 1: Geo-Political Map of Uganda (courtesy of Google maps)
Brief Socio-Political History of Uganda

Before Uganda became a protectorate of the Queen of England, it comprised of fragmented kingdoms and chiefdoms (inter-lacustrine kingdoms of Africa) ruled by kings and chiefs. These included the Buganda Kingdom, Busoga Chiefdoms, and the Bunyoro, Toro, Rwenzururu and Bugisu Kingdoms which were Bantu language speaking kingdoms. Others were Luo language speaking kingdoms including the Acholi, Alur and Langi chiefdoms, the Iteso and Japadhola Kingdoms. Uganda also comprised of minority groups such as the forest pygmies or Batwas.

Uganda did not have formal organized religion as each tribe and kingdom worshiped the gods of their ancestors as instructed by their elders and or kings. Education was informal and especially given to teenage boys and girls to prepare them for adult life. It centered majorly on the traditions and norms of the tribes (and their enemies), plants and fruits suitable for food, and the weather; no numeracy or literacy. In some tribes it was taboo to count especially to count children (Ssekamwa, 1997).

Uganda became a British protectorate through the signing of the Buganda agreement of 1900 between the Buganda Kingdom and Her Majesty Queen Victoria, queen of England and the head of the Imperial British Empire. The British government quickly set up their administrative agency, the Imperial British East African Company (IBEAC), to administer the new protectorate. The IBEAC was headed by William Macknon and had been formed earlier in 1885 to run the Kenyan colony (Walker, 1917). It was the IBEAC and Christian missionaries that introduced the European style of
Education in Uganda

Brief history of education in Uganda.

Uganda was exposed to the Arabic world for many centuries before the coming of Europeans. The Arabs introduced counting and writing majorly to facilitate the then mostly barter trade. They brought cotton and woolen fabrics and clothes, cowrie shells, mirrors and guns. In exchange, they were given slaves, animals and animal products (ivory, Rhino horns, leopard skins, and hides), and salt.

Uganda was later introduced to the European world through the exploratory exploits of Dr. David Livingstone and his fellow Christian explorer Henry M. Stanley in 1873. Stanley, a Christian statesman and explorer like Livingstone, was more interested in stopping slave trade and spreading the Christian faith than in expanding the Imperial British Empire. Dr. Livingstone later arrived in Uganda on a second visit. It was during this second visit that the Kabaka (king) of Buganda, Mutesa 1, was converted to Christianity and asked Livingstone to write a letter to the Church Missionary Society (CMS) of the Church of England to ask for missionaries of that church to come to Uganda (Ssekamwa, 1997).

Anglican missionaries (Wangereza) led by Bishop Mackay in 1877 and French catholic missionaries (wafaranza) led by Father Lourdel (nicknamed Mapeera because he
introduced his name in French *je m’appele* (arrived and introduced formal education, as it was known in the Western Hemispheres. The church based education trained converts/catechists to read the Holy Scriptures and to do evangelism. So this education emphasized a lot of reading and writing. Mackay also introduced vocational training especially on working with timber for building and furniture. The local population was already advanced in clay craftsmanship and metal smelting.

When Uganda became a protectorate of the Queen of England in 1900 (Ssekamwa, 1997), this relationship introduced Uganda to the British culture that included formal education. The first schools in the new British protectorate were built by the religious groups. The schools at that time taught catechism, reading and writing starting at sub grade to grade 3. Later the IBEAC allowed them to teach up to sixth grade.

When the royal families (and their friends) wished to have British aristocratic type of education, the kings pushed for schools. Every region got a school to serve the local king’s desires. The kings worked closely with the religious groups to fulfill this. For example, Kings College Buddo built in 1906 served the Buganda royal family, Protestants and their friends. One Gayaza high school built in 1905 was for girls only. The Catholic Church had built St. Mary’s college, Kisubi (a boys-only school) in 1903 and later in 1942, St. Mary’s college, Namagunga (a girls-only school). In the eastern regions the Isebantu (king) of Busoga, a protestant, built Balangira college, Mwiri (later renamed Busoga college, Mwiri) in 1911 for boys only and Wanyange girls’ school in 1959. This phenomenon was replicated all over the protectorate with either protestant or catholic churches joining with an affiliated king to establish the institutions.

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This study notes that mass girl child education commenced later (in the 1940s) as initial efforts concentrated on the male child.

The system had progressed to 6 years of grade school, 2 years of junior secondary school and then tertiary education that consisted of working at the colonial government offices as clerks or mid-level managers. The subjects that were taught included English, Latin, mathematics, reading, Vernacular, science, and technical drawing. Each year, the king selected candidates to send to England for University education (Scanlon, 1964; Ssekamwa, 1997; Walker, 1917).

**Current education system in Uganda.**

Uganda’s education system has been in place since the 1960s. Over the years, since its independence in 1962, Uganda has made small steps away from its inherited colonial educational system. These changes however do not constitute true educational reforms except the reforms that were announced in 1996.

Currently, Uganda’s education system commences with seven years of primary education after which students have a wide range of options for both public and private education depending on aptitude, ambitions and resources. At the primary education level students are introduced to basic knowledge of the sciences and the primary tools of doing science especially observation. Primary education ends with sitting for the Primary Leaving Examination (P.L.E), a national examination qualifier for secondary education.

After primary school, students who qualify, pursue four years of secondary education also called Ordinary level (O-level) which ends with the sitting for the Uganda
Certificate of Education (U.C.E) examination, the national examination qualifier for high school. At O-level the sciences are compulsory and they include the disciplines of biology, chemistry, physics, and mathematics. Students are exposed to introductory knowledge in these fields and introduced to the so called scientific method as a model of scientific inquiry. On the other hand, there are Business Technical Vocational Education and Training (BTVET) institutions which take P.L.E. leavers who are unable to join secondary level education. These institutions give their students basic mental tools and skills in specific fields and a certificate of completion.

After secondary education, qualifying students attend two years of upper secondary education (high school) or the Advanced level (A-level) which ends with the sitting for the Uganda Advanced Certificate of Education (U.A.C.E) examinations. At A-level, students pursue and concentrate on three science subjects; their best three. For example, one may pursue a concentration in biology, chemistry, and physics, abbreviated as PCB. They are treated to relatively advanced knowledge of these disciplines and equally equipped with semi advanced investigative skills pertinent to the subject disciplines. However, if after completing secondary education, a student is not ready or does not qualify to join high school, there are a myriad public and private institutions similar to BTVETs which admit U.C.E. leavers. These equip them with relatively higher skills and mental tools in the relevant fields and an advanced course certificate at completion. Some U.C.E leavers opt to join Primary Teachers Colleges (PTC) to qualify as lower primary and kindergarten teachers.
After A-level, students can directly join university to pursue various fields of study for a minimum of three years. Uganda’s first University (Makerere University) was established ninety years ago in 1922 as a college of the University of London. Currently Uganda boasts of 32 Universities and the list is still growing. There are numerous other post-secondary tertiary institutions as evident in this quote from the Government of Uganda Investment Authority (UIA) website.

Currently, there are 32 universities in Uganda, all accounting for a student population of about 110,000 and 30,000 graduates annually. Makerere University alone accounts for over 30% of this total. There are also technical and commercial business colleges that enroll another 20,000 students studying various disciplines, some of which are of particular relevance to the needs and development of the private sector. For instance, Technical colleges enroll about 2,000 students and offer disciplines such as metal works/foundry, carpentry, ICT skills, hotel and tourism, agriculture, fisheries, forestry etc. There are efforts currently geared at fostering cooperation between the training institutions and the private sector which will ensure that courses and graduates are relevant to the needs of the private sector. (Uganda Investment Authority, 2011)

Of the 32 universities, five are public universities scattered across the regions of the country. They assume the role of regional universities. Makerere University (MUK) and Kyambogo University (KYU) are in central Uganda, the most populated region. Mbarara University of Science and Technology (MOST) is in the western region, Busitema University of Agriculture (BU) in the eastern, and Gulu University (GU) in northern Uganda.
In summary, the education system in Uganda consists of seven years of primary (elementary), followed by four years secondary education and two years of high school. Students can then undertake university studies for at least three years. Alternatively, alongside this direct path of formal education, students may join the BTVET system after P.L.E or U.C. E examinations. The BTVET training is usually satisfactorily completed in two years. Figure 2 below is a summary of this current education system.

**Science teacher education in Uganda.**

Only the five government or public universities mentioned above, notably, Makerere University, Kampala (MUK), Kyambogo University (KYU), Busitema University of Agriculture (BU), Mbarara University of Science and Technology (MUST), and Gulu University (GU) guarantee university degrees courses in science or science education. This is because of the high logistical and man power costs involved in science teaching. These institutions, acting as regional public universities, are mandated to offer the full spectrum of liberal Arts and Science education.
Kyambogo University, located in Kampala, is the lead university in teacher education and has a long history of involvement in teacher education. It is the quality controller of teacher education and the overall supervisor of Primary Teachers Colleges (PTC) and National Teachers Colleges (NTC); both two-year colleges of a lower tertiary education level mandated with teacher education (O’ Sullivan, 2006).

PTCs are the lowest level and admit students who have finished the four years of secondary education (that is, students who have a U.C.E certificate). These students opt for careers in primary (elementary) school teaching usually because they have not qualified for the next education level (high school). They however need to have passed
English language, Science and Mathematics in their Uganda Certificate of Education (U.C.E.) examinations to be admitted into PTCs. After two years of study, these Teacher candidates graduate with a Grade-three teacher certificate, the lowest entry level certification for the teaching profession. They are certified to teach all subjects but only at the primary school level.

The upper level NTCs admit students who have finished six years of formal secondary education and passed their U.A.C.E examinations with at least two principle passes and one subsidiary pass. Teacher candidates study for two years at these colleges and graduate with a Grade-five teacher diploma. These teacher candidates are prepared to teach two of their A-level principle subjects at the secondary school (S1-S4) level. Recently, provision has been made for teacher candidates to pursue a diploma in teacher education (DTE) to qualify as tutors or teacher educators at the PTC level. They graduate with a Grade-six teacher educator certificate.

On the other hand, University science teacher education programs admit highly qualified students graduating from the A-level. When admitted, teacher candidates study for three years and graduate with an undergraduate teaching degree. They are prepared to teach at least two principle subjects at A-level, as priority, but are allowed to teach at secondary (O-level) when needed.

Science teachers have opportunities to upgrade by studying relevant courses at either colleges or universities to achieve the next teacher certification. Also university undergraduates with degrees that are not related to education can study for one year at the
university level to attain a postgraduate diploma in teaching (PGDE). They then can teach at both A-level and O-level.

Whereas there are specific pathways to becoming a classroom science teacher (as described above), the professional pathway to becoming a teacher educator in Uganda is not clear. For example, undergraduate science teacher candidates who graduate with honors and high honors can be retained at the university as science teacher educators. These very candidates can get into graduate school, in the school of education, and become science teacher educators. Recently also, those with Grade-five teacher certificates can pursue a diploma in teacher education (DTE) and return to the PTCs and NTCs as tutors or science teacher educators. Due to the current reforms, DTE has been phased out to become a BTE (Bachelor of Teacher Education) and also a new degree program, Bachelor of Education (B.Ed), was started in 2003 (Hartwell et al., 2003; O’Sullivan, 2010).

**Education Reforms in Uganda**

In Uganda, education reforms, although now integrated into MDG policy, were originally a result of a political accident than a well-planned and thought out socio-economic policy. Briefly, in 1996 Uganda opened up again to multi-party politics after a decade of no open participatory democratic governance. In that year the political opponent to the incumbent president offered to abolish graduated tax and the president offered a new education policy that included free primary education or what is now called ‘Universal Primary Education’ or (UPE) as a counter policy offer in excess of the policy
promises offered by his opponent. In 1997 after the elections (the incumbent won) the government implemented UPE. This improved access to education. When UPE was started, primary school level enrollment tripled.

Government has since turned its focus onto the quality of education, arguing that education, especially science and technical education, is one of the central socio-political mechanisms for fighting poverty and achieving the Millennium Development Goals (Altinyelken, 2010a; Wood, 2008). Government also made another politically motivated pronouncement for Universal Secondary Education (USE) in 2007. In the same year the president announced that his focus was on science and technology development in the education field. He announced that 80% of post high school government scholarships and bursaries would be earmarked for students offering science disciplines at university and two year colleges (Munaabi, 2005; Tinkamanyire, 2010; Tukacungurwa et al., 2012). He also promised high wages for science and technology teachers, and more funding for research nationwide. Lastly, he announced the introduction of a new curriculum (the thematic curriculum) and teaching approaches (Altinyelken, 2010b; Ssebuyira, 2010).

In the classrooms, Uganda has embraced reforms in its science teaching practices. The reforms have introduced new curriculum for primary level education (since 2007), the advanced secondary level education and just recently government announced that the process to create a new curriculum for the ordinary level of education had begun. Reforms are also affecting science pedagogy. Classroom science teachers have been asked to drop their teacher-centered approaches to teaching and strive to adopt student-centered approaches. In Uganda, this new preferred science pedagogy has been labeled
the ‘conversational’ teaching approach. This new pedagogical approach encourages classroom science teachers to promote students’ learning in groups and to allow students some freedom to discuss among themselves. Moreover, with the new pedagogy, classroom science teachers have been asked to involve a higher level formative assessment and to reduce their reliance on summative assessment to measure student learning and achievements. Lastly, the reforms ask primary school classroom science teachers, especially those teaching students in primary one, two and three, to use the mother tongue as the language of instruction (Altinyelken, 2010b; Ssebuyira, 2010; Tukacungurwa et al., 2012).

This is not the first time that Uganda has tried to introduce pedagogical reforms to science education. In the early 1970s, the government tried to borrow from the Nuffield sciences in Britain to change the way sciences were taught then. This process culminated in the introduction of School Science Project (SSP) sciences. The goal was to develop critical and creative thinking and observational powers in the science students, and to abandon the dependence on textbooks which were considered sacred by science teachers and their students. Local district and tribal practices like iron smelting, charcoal burning, brick making, beer brewing, ethanol distillation, food fermentation, food preservations etc. were some of the activities that were used to create contexts in which science was to be learned (Haden, 1973; Whittle, 1971). The political turmoil that engulfed the country then, unfortunately, never allowed this process to mature, leaving a few secondary schools (that were used as pilot centers) stranded with the reform efforts. The rest of the country resorted back to the teaching of the textbook.
The new 2007 primary school education curriculum was to affect, first, science teaching in primary one to three (lower elementary). Then it would roll out successively as its products moved from one class to the next. By 2012, all primary school instruction was of the thematic curricular by nature and students starting secondary school this year (2014) will have a thematic curriculum for USE.

In summary, the introduction of the thematic curriculum that emphasizes science for all (SFA), the reforming of classroom science instruction that emphasizes student-centered pedagogies, and the promotion of formative assessments over emphasis on examination have been bold moves to reforming Uganda science education. In addition, reformed science education advocates for students’ classroom science experiences that mirror life outside of the classroom and the use of local language as the medium of instruction for the first three years of school experience (1-3) (Altinyelken, 2010a; O’ Sullivan, 2010). This study believes that reforms in Uganda’s science education will have an impact on the whole of East African since Uganda is a pioneer in higher education in this region.

A professional body, the Uganda National Academy for the Sciences (UNAS) was launched on 20th October 2000. It was the first eminent body of Uganda scientists and science educators. It brings together a diverse group of scientists from the physical, biological, and social/behavioral sciences to work together in an interdisciplinary and trans-disciplinary manner to further the studying, learning, researching and development of the sciences in the country (Ssebuyira, 2010). It is similar to the AAAS (American Association for the Advancement of Science) in the USA. In 2010 UNAS and science
teachers across the country announced that they had developed an inquiry-based approach to teaching. They insisted that the strategy was aimed at making learning easier for students right from primary school, through a hands-on based approach rather than the theory based approach which had been the practice. In his own words UNAS president, Professor Edward Mugambi said

Inquiry based science education is key to revamping learning delivery. Universities produce poor science graduates that they want to avert by training them to produce critical reasoning and innovative students. We have made inquiries into basic science education and would soon produce a report that will be tabled to the ministry of education in order to have policy changes in science education. (Ssebuyira, (2010), p. 2)

Formation of professional bodies such as UNAS and their research abilities may positively impact the future in that policies on science education may have a sizeable input from science teacher educators, scientists and philosophers of science. These will be better than the policies originating from political leaders as was the case in 2007.

On 26th February 2009, during the release of the Uganda Advanced Certificate of Education (U.A.C.E) results for 2008, the secretary to the Uganda National Examinations Board (UNEB) announced that the candidates had again performed poorly in mathematics, chemistry, biology, and physics. He elaborated that, science students did not use scientific terminologies correctly, failed to draw accurate specimen, and did not write, complete or balance chemical equations correctly. They were ignorant of correct symbols and formulae. He revealed that there was evidence that teachers had not
integrated practical and theory lessons as some students were unable to transfer the knowledge they acquired in one area to solve problems in another (Butagira & Natabaalo, 2009).

Butagira and Natabaalo (2009) reported that this disclosure by the UNEB secretary upset the line minister who presided over the occasion. She ordered the teachers to shift their teaching methods from giving students pamphlets based on tips for answering questions to methods that promote comprehensive learning to ignite critical thinking in young scholars. Although in the ministerial address, she was changing policy by ministerial order, without the required research that informs change in science pedagogy, nothing has changed. Despite this and other suggested reforms, some of which are already in implementation stages, year after year when the results of the national examinations, for any level, are released, there is an un-ending cry over poor performance in the sciences.

For example this year (2014) when releasing the Uganda Certificate of Education (U.C.E) or Ordinary level (O-level) results, the secretary to the national examination board lamented that “……more than 50 percent of the candidates were unable to demonstrate the basic competencies in science with chemistry being the most worrying” (Kasirye (2014), p. 2). The Daily Monitor Newspaper reported that the secretary explained that there is a consistent poor performance in the construction of graphs, solving of simultaneous equations, skills of geometrical construction, vectors, the set theory, fraction expressions and consumption of compound interests, handling of apparatus, recording observations and drawing conclusions. The UNEB secretary is
further reported to have lamented about students who found difficulty with questions requiring explanations, descriptions of experimental procedures, use of chemical symbols and formulae, writing of units and dealing with tasks that required practical experiences. He also added that candidates had difficulty in understanding the meaning of essential words used in questions and as such gave irrelevant answers (Kasirye, 2014; Tukacungurwa et al., 2012).

**Science Teacher Education and Science Education Reforms in Uganda**

The reforms alluded to in the previous section generated a lot of excitement in the general population and Uganda Newspapers frequently report new developments. However, only a few policy positions on science teacher education have been published.

Recent research reports show that even though teachers are embracing the new curriculum and teaching ideas with enthusiasm, they are failing to effectively implement the curricular reform mandates. One of the outstanding bottle-necks cited is poor preparation of classroom science teachers. Classroom science teachers have been reportedly wondering what to do because they were not given proper training to implement the reforms, and that the facilitators of professional development efforts are themselves not well versed with the new competences needed to enact the reforms (Altinyelken, 2010a, 2010b; O’Sullivan, 2010). This may be contributing to the problems discussed in the previous section (Katunzi, 2010).

Teacher Education across Sub-Saharan Africa (TESSA), a multi-national organization addressing science teacher education among African nations south of the
Sahara, has identified (through its research) that for reforms to take place, change has to begin with teacher educators (Stutchbury & Katabaro, 2011). TESSA has been seeking to understand science teacher educators in Uganda and how to help them prepare classroom science teachers to implement the reforms initiated by the government. Their efforts enabled the Uganda government to unveil the new inquiry based science teacher education curriculum for the National and Primary teachers colleges (NPTC) in 2012.

This current study argues that empirical data on the views of Uganda science teacher educators on foundational aspects of science education for all (SFA) such as NOS, PSP and CLE will benefit the science education community.
CHAPTER III

METHODOLOGY

Definition

A review of literature showed that in countries like the USA, United Kingdom and Canada, classroom science teachers’ and science teacher candidates’ perspectives on Nature of science (NOS), Preferred Science Pedagogy (PSP), and Classroom Learning Environment (CLE) are well known. The literature also showed that studies leading to this knowledge employed various research methodologies. For example, researchers used qualitative methods to study teacher candidates’ views of NOS (Brickhouse, 1990; Moss, 2001) and science teacher educators conception of inquiry teaching (Abell et al., 2006; Koballa et al., 2009) On the other hand, quantitative methods were used to study classroom science teachers views on classroom learning environments (Barry J. Fraser, 2007). This however, is not the case with science teacher educators whose perspectives or knowledge in the three areas of NOS, PSP and CLE ranges from scantily documented to non-existent altogether. One such study by Koballa, Dias and Atkinson (2009) used qualitative methods to capture college science teachers (including science teacher educators) beliefs about science (NOS) and how these beliefs are depicted in their classroom curriculum enactment.

The fact that little is known so far about science teacher educators’ perspectives on NOS, PSP, and CLE may be acceptable and considered functional in the developed
world like the USA where science education policies are highly informed by research done by science teacher educators. It would not be considered naïve to assume that science education policies or goals concerning NOS, PSP and CLE in countries like the USA are in some ways a reflection of the science teacher educators’ epistemological commitments in these areas. This assumption, however, cannot be extended to Uganda where science education policies are less likely the result of research by science teacher educators and are more likely statements made by political leaders. Science education policies in Uganda are not a reflection of STE’s perspectives on NOS, PSP, and CLE and many other educational policies as such. So the most reliable means of knowing or establishing Uganda STE’s perspectives on NOS, PSP, and CLE is by way of empirical studies. This study undertook the task of understanding and documenting Uganda science teacher educators’ perspectives on NOS, PSP, and CLE by using five research questions, stated in the next section.

**Review of Research Questions and Overview of Methodology**

The questions that guided this study were:

1.) What do Uganda science teacher educators understand regarding nature of science?

2.) According to Uganda science teacher educators, what are the preferred science pedagogical approaches?

3.) What are Uganda science teacher educators’ perceptions of their classroom learning environment?
4.) How are Uganda science teacher educators’ views on nature of science, preferred science pedagogy and classroom learning environment correlated, if at all?

5.) How are views of Uganda science teacher educators’ on nature of science, preferred science pedagogy and classroom learning environment evident in their science methods course syllabi?

This study, in its quest to generate useful empirical data to answer these questions, adopted a multiple data, mixed method methodology, situated in the pragmatic paradigm (Tashakkori & Teddlie, 1998). In the pragmatic research worldview, the question trumps the paradigm, meaning that the research question or problem determines the research approach to be used and not the worldview of the researcher. This worldview concurs that there is no exclusivity of approaches to answering researchable problems by qualitative (constructivist paradigm) researchers and quantitative (post-positivist) researchers. Instead both approaches can be applied for a thorough understanding and answering of a research problem or question. Thus pragmatists advocate for mixed methodology (Daley & Onwuegbuzie, 2004; Tashakkori & Teddlie, 1998).

The study design was therefore, an exploratory, triangulation-concurrent mixed methods approach to educational research (John. Creswell, 2009; John Creswell & Plano-Clark, 2007; J. W. Creswell & Garrett, 2008). The study employed both quantitative and qualitative approaches to search, to find and document Uganda science teacher educators’ current perspectives on NOS, PSP, and CLE. Operating from within the pragmatic paradigm, the study used quantitative and qualitative data triangulation and complementarity to interpretively build empirical portraits of Uganda science teacher
educators’ mindsets or views about these three areas of science education reform. The study used both parametric and non-parametric descriptive statistics and tests, and interpretively built qualitative codes and categories of participants’ responses as analytical tools. These were used as lenses for understanding and documenting the perspectives of the participating science teacher educators (John Creswell & Plano-Clark, 2007; Yin, 2006).

Table 2: Data Collection and Instrumentation

<table>
<thead>
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Data collection procedures consisted of paper and pencil survey instruments that included: VNOS 270-B, SUSSI, POSTT II, and CLES-II-(20). Other data collection methods included document analysis, and telephone interviews (see Table 2). The study
subjects were individuals selected from universities and two-year Primary Teachers Colleges (PTCs), and National Teachers Colleges (NTCs) in Uganda. This study denotes the last two forms of institutions together as (NPTC). This, across the board, sampling was crucial for the study to capture instructors’ perspectives at all levels of science teacher candidates’ professional education.

The mixed method notation QUAN + QUAL (Figure 3) was given to the study’s design following Creswell and Plano-Clark (2009). The reason being that in this study both qualitative and quantitative data are of the same status. Onwuegbuzie and Leech (2006) would otherwise give this study design an “F1” notation (also see Daley & Onwuegbuzie, 2004). It is an F1 design because mixed methods approaches were applied throughout the study research procedure starting from the formulation of the problem and research questions, through data collection, and data analysis, to data interpretation and reporting of results. Accordingly, this study was a fully mixed, concurrent, equal status mixed methods F1 study (Onwuegbuzie & Leech, 2006).

Adopted with modification from Tashakkori and Teddlie, (1998)

**Figure 3: Visual Depiction of the Research Methodology**
During data analysis, Quantitative (QUAN) and qualitative (QUAL) data were first treated separately. Later the two data sets were combined or integrated for further analysis. This process was necessary to create convergence of data for maximization of mixed methodology approach to the study (Creswell & Plano-Clark, 2007; Creswell, 2009; Daley & Onwuegbuzie, 2004; Tashakkori & Teddlie, 1998). The study collected and examined both the QUAN and QUAL data to ascertain all its subjects’ perspectives on the three science education areas of NOS, PSP, CLE were represented and if any available interrelationships existed between them. The interrelationships that the study sought for included those that existed between the views of subjects from University level and those from NPTC level as well as correlations between subjects’ views on each of the three areas of science education.

Justification of Paradigm and Methodology

A mixed methods design research methodology was used. This design assumes that neither quantitative nor qualitative designs alone give a full picture of the problem and its analysis, hence the need to combine both (Tashakkori & Teddlie, 1998). A concurrent mixed methods design was selected to ensure that both quantitative and qualitative data had the same status, triangulated and complemented each other (Creswell & Plano-Clark, 2009).

The following statement by O’Cathain, Murphy, and Nicholl (2007), stating that “Mixed methods studies can access knowledge or insights unavailable to a qualitative-study and a quantitative study undertaken independently (p 147)” embodies the central
reason why a mixed study methodology was proposed. “Yield” is what these authors called the extra insight into a study provided by mixing methods. This study was interested in this “yield” advantage, and therefore the choice of the pragmatic paradigm. This study was also informed by the knowledge that pragmatism evolved from reflections by scholars on the quantitative-qualitative (QUANS-QUALS) research wars between the empiricists and the constructivists (Tashakkori & Teddlie, 1998). Moreover, a mixed methods design suited the study because of the very nature of the social-cognitive phenomenon of personal perspectives which the study focused on.

The Webster dictionary gives the following words as synonyms to perspective: outlook, view, mind-set, perception, persuasion, belief and opinion. These synonyms by themselves suggest how messy the phenomenon of perspectives is thus warranting pragmatic approach to its investigation using a mixed methods design (Pajares, 1992). Moreover, there is a tendency of knowledge of NOS, PSP and CLE issues to be varied and personal. Meaning that, the use of only one traditional research approach may not give the real picture of the prevailing views of the subjects (Brooks & Brooks, 1993a; Kember & Kam-Porkwan, 2000; Koballa, Dias, & Atkinson 2009; Lederman, 1992; Haney & McArthur, 2002).

Quantitative data mostly addressed research questions one to four. This coarse grained data granted the study a broader and general understanding of Uganda science teacher educators’ views about NOS, PSP and CLE including any trends and relationships visible in their perspectives. On the other hand, fine grained qualitative data addressed all five research questions. The qualitative tools enabled the study to decipher
trends and relationships in depth, gain a deeper descriptive though narrower understanding of the participants’ views by providing fine grained data. For example, using the subjects’ own words to describe their perspectives granted the study a deeper understanding of science teacher educators’ views concerning the three areas (Creswell & Garrett, 2008).

Mixed methods and the pragmatic paradigm also allowed the study to use multiple quantitative tools to investigate NOS perspectives. In other words, if a facet of the subjects’ NOS perspectives was not captured by one investigative tool, the study had inbuilt mechanisms for it to be captured successfully by another. This was in keeping with the pragmatic ideal which propagates the idea of choosing “the right tool for the right job” (Saldana) 2009, p. 2). Daley and Onwuegbuzie (2004) study of “Attributions towards Violence of Male Juvenile Delinquents: A Concurrent Mixed Methodological Analysis” is within this pragmatic paradigm and is very similar to this current study.

Accessing the Participants and Data Collection Procedures

In this section the study briefly reports the process of getting to the participants, gaining their consent to participate in the study and collecting the desired data from them.

Accessing the subjects.

Science teacher educators were made aware of this study by notice board announcements, researcher promotion visits to staff rooms and by heads of departments in the universities
and NPTCs who promoted and recommend the study to their faculty. The recruitment process started with the researcher introducing the study and explaining in detail to potential subjects the purpose and requirements of the study from potential subjects. The researcher explained the roles participants would have in the study and the cost of participation. The researcher explained the consent process and invited potential participants to ask any clarification questions to which he responded succinctly. Then science teacher educators were invited to consider becoming subjects in the study. Every consenting participant (consented by signing the consent form) was given one week to consider and evaluate their decision to participate.

After a week every subject who decided to continue with the study was officially welcomed and each filled a personal biographical-data form. The bio-data collected included name of participant, highest academic credential and year of attainment of the credential, years of experience as a science teacher educator, courses commonly taught, courses they were teaching at the time of participating in the study and information on whether they had been formally exposed to history and philosophy of science. Lastly, subjects were asked to provide information on any professional development exercises they had been undertaken in the past two years.

**Quantitative data collection procedure.**

Quantitative data collection in the study was by subjects’ responses to three survey instruments. The instruments were SUSSI for perspectives on the nature of science (NOS), POSTT-II for perspectives on preferred science pedagogy (PSP), and CLES II-
(20) for perspectives on classroom learning environment (CLE). The QUAN data collected was used to answer the first four research questions which included:

1.) What do Ugandan science teacher educators understand regarding nature of science?
2.) According to Uganda science teacher educators, what are the preferred science pedagogical approaches to science teaching?
3.) What are Uganda science teacher educators’ perceptions of their classroom learning environment?
4.) How are Uganda science teacher educators’ views on the nature of science, preferred science pedagogy and classroom learning environment correlated in any ways?

All subjects recruited were given a large Khaki envelope that contained the following documents: a written reminder and introduction of the study, and the three surveys (SUSSI, CLES (20) II, and the POSTT). The directions of returning the envelopes were given at the back of each envelope. These surveys were collected back as they trickled into the designated return office. Each envelope that was received back was labeled. The label denoted the study site location and the order of reception of subjects’ envelope. The names of the respondents were blotted out on each survey. For example, KYU-001 was designated to the first participant to return their surveys at the Kyambogo University study site. The code KYU was later adopted for all participants. A list of names and corresponding code numbers was securely locked in a lock and key drawer, different from the one containing the scripts themselves.
Quantitative data collection instrumentation.

In this section the study expounds about the paper and pencil instruments used for data collection. These were: SUSSI, POSTT-II and CLES II-(20) survey instruments. The SUSSI and CLES-(20) II instruments have been used in international studies to document science teacher perspectives about the nature of science and classroom learning environments respectively (Khishfe & Abd-El-Khalick, 2002; Liang et al., 2008). This utilization history convinced this study that these instruments were suitable for the task of studying Uganda science teacher educators’ perspectives. Although the POSTT-II had not yet been used in any published study, its development involved an international consortium of expertise that would benefit this study. These survey instruments also presented an added advantage because the data collected by these instruments could easily be combined with qualitative data. Lastly, survey-type of instruments were judged as best suited for collecting data to answer the “what?” type of questions of the study and they also can be used to collect a large amount of data quickly.

Description of quantitative survey instruments.

As mentioned in the previous section, three different instruments were used for collecting quantitative data. These were (1) SUSSI, (2) POSTT-II, and (3) CLES II-(20).

The SUSSI survey

This is a mixed methods instrument developed by Liang et al. (2008). It is useful in gathering data on six aspects of NOS:

(1). Understanding of what in science is an observation and what is an inference
(2) Understanding of scientific claims being robust but tentative. In other words the understanding that science does not establish truths about the behavior of nature

(3) Understanding about scientific theories having an explanatory value of why and how nature behaves the way it behaves and laws being descriptive in nature, in that they describe what is observed about nature under prescribed conditions

(4) Views or understanding of the reality that science and scientific knowledge reflect the values of those who practice it and it is embedded in the general social cultural norms of the people that fund and advocate for it

(5) Understanding that human creativity and imagination are ubiquitous in the practice of science and may be the single most valuable human attribute to science and its practice

(6) Understanding that there is no single scientific method but that scientists approach the problems they are studying in systematic ways but without prescribed steps or order.

The study was interested in these particular aspects because of their relationship to K-12 science education and the goal of scientific literacy for all. Moreover, science education scholars, philosophers and historians of science hold meaningful consensus on these aspects of nature of science (Abd-El-Khalick, 2005).

The SUSSI has a blend of Likert-type items and related open-ended questions. The items are arranged in six scales of: Nature of observation and inference in science, Nature of scientific theories, Scientific laws and theories, Role of creativity and imagination in science, Influence of society and culture on development of science, and Nature of scientific methodology. Each scale has a battery of four items with a five Likert score scale ranging from “Strongly disagree” to “Disagree” through to “Undecided” to
“Agree” and ending with “Strongly Agree”. The open-ended response is a write in opinion backing the answer choices the respondent makes on the battery of the four statements. The SUSSI version used was reported to have a Cronbach reliability alpha of 0.68 with a China sample, 0.66 with a Turkey sample, and 0.61 with an American sample. This study noted that these SUSSI reliability alpha scores although acceptable, were low. This is something the study kept in consideration as data gathered by SUSSI was interrogated during analysis. The study also took care of improving the rather low reliability score of the instrument by including questions based directly on the SUSSI in the interview protocol. The study also sought and established reliability measures of the SUSSI as an instrument for the specific sample of respondents involved in this study and for each battery of items in each scale of the SUSSI instrument.

The POSTT-II survey

The instrument Pedagogy of Science Teaching Test (POSTT-II) by Cobern et al. (2012) was used to collect data on subjects’ perspectives or views on their preferred science pedagogy (PSP). This instrument is composed of 16 spectrum Multiple Choice Questions (MCQ) items based on teaching scenarios of K-8 science subject disciplines. Each POSTT item consists of a teaching vignette or scenario accompanied by a question that demands the respondent to give a personalized response. Responses are chosen from four multiple choices that represent the full spectrum of the most common teaching orientations.

Each spectrum of multiple choice responses has on one end representative teaching orientations of teaching science as “Ready-made-science.” At such end the
response choices are “Didactic Direct” and “Active Direct” approaches to teaching science. A Didactic Direct approach manifests when the instructor is active during the learning-teaching experience as an expositor of scientific knowledge and the learners are involved as passive recipients of that knowledge. The Direct active is an improvement of the Direct didactic, improved by the instructor allowing limited active participation of the learner at very low level cognitive tasks and answering of rhetorical, procedural questions.

On the other end of the multiple choice spectrum are choices of teaching approaches representative of orientation to teaching science as “Science in the Making”. This orientation to science teaching usually manifest as “Guided Inquiry” or “Open (unguided) Inquiry” approaches to science teaching (Cobern et al., 2012). Guided inquiry is modeling science in the making where the instructor facilitates the inquiry activity by contributing some of the inquiry task inputs. In doing so the instructor can vary the levels of difficulty of the inquiry task by choosing what aspect of the task he or she chooses to contribute (R W. Bybee, 2000).

Open or unguided inquiry puts the learner into a context that allows them to make all possible observations and manipulations on their own without the help of the instructor and to make sense of those observations (construct knowledge) about the encountered phenomenon.
This instrument has not yet been mass tested and therefore it does not have established reliability measures as yet. This was the first time the POSTT-II survey was deployed for mass administration outside of the classrooms. However, the instrument has been used successfully on trial basis on teacher candidates at the beginning and near the end of their career professional training. The POSTT-II spectrum MCQ has been found insightful into teacher teaching orientations and for writing respondents’ teaching profiles.

The CLES –II (20) survey

The Constructivist Learning Environment Survey II (20) or CLES-II (20) instrument was designed to solicit respondents’ perspectives or conception on what the classroom learning environment should look like when their preferred science pedagogy is taking place. The CLES-II (20) was developed by B. Johnson and McClure (2000) by revising the first CLES instrument (now referred to as CLES I) developed by Taylor, Fraser & Fisher (1997). The revised form consists of 20 items, with four items in each of

### Figure 4: Possible Response Choices to a Typical POSTT Vignette

| A. Didactic Direct.                  |
| B. Active Direct.                   |
| Science as produced through inquiry ('Science-in-the-making’) |
| C. Guided Inquiry                  |
| D. Open (unguided) Inquiry         |

Science presented as a known product ('Ready-made-science’)

A. Didactic Direct.

B. Active Direct.

Science presented as a known product ('Ready-made-science’)

A. Didactic Direct.

B. Active Direct.

Science as produced through inquiry ('Science-in-the-making’)  

C. Guided Inquiry  

D. Open (unguided) Inquiry
the five scales: personal relevance, uncertainty, critical voice, shared control, and student negotiation.

Each item has responses on a five-point Likert scale with the alternatives of “Almost Never”, “Seldom”, “Sometimes”, “Often” and “Almost Often”. CLES (20) II has an internal consistency Cronbach alpha reliability of 0.85. Its process of validation report shows that the process consisted of a sample of 464 secondary school teachers.

Study sample.

The study used a non-probabilistic, purposeful sampling (Creswell & Plano-Clark, 2007) to recruit respondents for the surveys. This type of sampling was preferred over random sampling because of the logistical difficulties that the study met. These difficulties included difficulty in knowing or even estimating the population of potential participants and logistical difficulty in reaching subjects in the limited time that was available to the study. Moreover, purposeful non-probabilistic sampling also was in keeping with fully mixing the study at each stage so that it remained a single study and not become two parallel ones (Yin, 2006). Institutions from which the study sample was recruited were also chosen non-randomly.

The study chose its participants from four established, long serving and well recognized public universities in Uganda: Makerere University (MUK) in central Uganda, Mbarara University of Science and Technology (MUST) in western Uganda, Kyambogo University (KYU) in central Uganda and Gulu University (GU) in northern Uganda. Also subjects were admitted to the study from two well known, long serving
public National teachers colleges (NTC) namely, Kaliro NTC in eastern Uganda and Unyama NTC in Northern Uganda. This criterion was extended to choosing subjects from four public Primary teachers colleges (PTC) namely, Ggabba National PTC, Buloba PTC, Kibuli PTC and Shimoni National PTC, all from central Uganda. A total of ten institutions were involved in the study.

The sample size targeted was a maximum of 90 and a minimum of 60 science teacher educators. The realized sample for the study was 63 subjects who satisfactorily completed the surveys. The study sought after a good mix of responses for the study’s data. Respondents in this study were individuals with diverse age, years of teaching experience, and academic qualification.

The study targeted one hundred percent participation completion by the study subjects. As a measure against participant attrition, honorariums in form of cash gift cards were given to those who completed, successfully, each section of the study.

Description of the subjects.

This study recruited participants from the three levels of science teacher education in Uganda. From the university, the study had 36 participants of which 31 were males and five were females. From the National Teachers Colleges (NTC) level the study had 13 participants of which 11 were males and two were females. Lastly, from the Primary Teachers College (PTC) level the study had 15 science teacher educators; ten males and five females. The total number of participants was sixty four of which 12 were females and 52 were males. One participant did not respond to all three surveys, hence was dropped from the study, reducing the total number of participants to 63.
All study participants were science teacher educators but some were also heads of departments, curriculum developers and long serving educators. It was not easy to access these individuals either due to their busy schedules or simply a low drive to participate. Their areas of science specialization and years of experience as science teacher educators varied widely. Participants specialized in life science (biology), physical science (chemistry and physics), vocational sciences (agriculture, home economics and nutrition, and sports), and mathematics (see Table 4.1 below for numerical details).

Table 3: Participants’ Credentials, Level of Teaching and Area of Specialization

<table>
<thead>
<tr>
<th>Credential</th>
<th>Teacher Education</th>
<th>Distribution of Participants by Science Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Level</td>
</tr>
<tr>
<td>Ph.D. (12)</td>
<td>University (12)</td>
<td></td>
</tr>
<tr>
<td>Masters (28)</td>
<td>University (22)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NTC (03)</td>
<td>03</td>
</tr>
<tr>
<td></td>
<td>PTC (03)</td>
<td>01</td>
</tr>
<tr>
<td>Bachelors (18)</td>
<td>University (02)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NTC (06)</td>
<td>02</td>
</tr>
<tr>
<td></td>
<td>PTC (10)</td>
<td>05</td>
</tr>
<tr>
<td>Higher-Diploma</td>
<td>University (00)</td>
<td></td>
</tr>
<tr>
<td>(05)</td>
<td>NTC (03)</td>
<td>01</td>
</tr>
<tr>
<td></td>
<td>PTC (02)</td>
<td>01</td>
</tr>
</tbody>
</table>

n= (63)
Biographical data also showed that only two participants were teaching assistants (TAs) and had less than three years of experience while the rest had five or more years of service as science teacher educators with an overwhelming majority indicating service in excess of 10 years.

The study asked its subjects to indicate what form of professional development (PD) they had been involved in during the last five years and if they had acquired formal instruction in the history of science and philosophy of science. All participants reported that they had had some form of PD in the last five years. Their PD centered mostly on general science pedagogy, development of curriculum materials, adoption of regionally developed materials, writing of examination items, and application of computers to teaching and student mentoring. However, biographical data also revealed that 28 (44%) of the participants had never been formally exposed to the philosophy of science (POS) nor the history of science (HOS). Twenty five (40%) had been exposed formally to only one of them and only seven (11%) reported to have been exposed formally to both POS and HOS. Three (5%) participants did not report their professional development or exposure to POS and HOS.

**Description of study context.**

The four universities and six teacher training colleges from which study subjects were recruited are well known in Uganda and the East African region. These public institutions were established by acts of the Uganda protectorate government or the independent Uganda parliament. They have handled science teacher education for more than 20 years.
and they are recognized regional centers for science teacher education development. One of the institutions, Kyambogo University, is in charge of all syllabi generation, final examinations and eventual teacher certification for all NTCs and PTCs teacher candidates in the country. It is the nation’s epicenter for teacher education and development.

Two universities and all PTCs involved in the study are based in the central region which is most populated and has better access to educational resources. The central region serves teacher candidates from the whole East African community (Uganda, Kenya, Tanzania, Rwanda, and Burundi). One university and one NTC are based in Northern Uganda and one NTC in the Eastern region. The Northern and Eastern regions are the poorest and least populated regions of the country. For two decades, the northern region has been plagued with rebel insurgency that incapacitated delivery of educational services, among other social services. The Northern institutions also serve teacher candidates from the youngest nation of the world, the nation of Southern Sudan. Eastern Uganda has been plagued by decades of poor medical facilities, landslides and outbreaks of jigger infestations resulting in temporal but repeated school closures. Institutions in this region also serve teacher candidates from Western Kenya.

Participants were also recruited from a university in the Western region. This region is the wealthiest in terms of infra-structure for educational purposes. It is well connected by road networks and has better social services compared to the rest of the country. The institutions of this region also serve teacher candidates from Rwanda and the Democratic Republic of Congo (DRC).
The study intentionally recruited participants from various regions to include variety, that is, science teacher educators serving in urban and rural settings, poor and wealthy settings, and from densely populated and sparsely populated settings.

**Qualitative data collection.**

In addition to the quantitative surveys, qualitative data on the nature of science (NOS), preferred science pedagogy (PSP) and classroom learning environment (CLE) perspectives were solicited from the subjects. They were interviewed and they also responded to an open-ended NOS survey the VNOS-270B. More qualitative data was collected by applying techniques of Document analysis to the science teaching methods syllabi used in the departments. The resulting qualitative data was useful for answering all the research questions. Qualitative data in form of participants’ own words uncovered: (1) a deeper understanding of the subjects’ perspectives in the three areas and the reasons/motivations underlying the held views (2) Prevalent trends in thoughts and opinions of the subjects about the three areas of focus of the study (Creswell, 2009; Yin, 2006). This qualitative data was specifically suited in assisting the study answer the “How?” research questions which were:

**Research question (4):** How are Uganda science teacher educators’ views on nature of science, preferred science pedagogy and classroom learning environment correlated, if at all?
**Research question (5):** How are Uganda science teacher educators’ views on nature of science, preferred science pedagogy and classroom environment evident in their science methods course syllabi?

**Qualitative instrumentation.**

Qualitative data collection tools included: (1.) An open-ended questionnaire (VNOS 270-B), (2.) document analysis and (3) semi-structured in-depth telephone interviews. The open-ended questionnaire *Views of Nature of Science Questionnaire (VNOS 270-B)* was administered alone two months after quantitative surveys were collected. The VNOS 270-B was another instrument used to obtain subjects’ views on NOS. It was administered only to those subjects (11) who were selected for interviews. In the next section the study expounds on the qualitative instrumentation.

**The Views of Nature of Science Questionnaire (VNOS version 270B)**

VNOS-270B is a modified version of the original VNOS version C by Lederman et al. (2002). VNOS-C mostly solicited science teacher educator’s perspectives on the following aspects of the nature of science: (1) methodology in science, (2) understanding of theories and laws and their differences, (3) the creative and imaginative nature of science, (4) social and cultural influences on science and its progress, (5) tentativeness of scientific knowledge or products and (6) general conception of what science is when compared to art. This instrument is composed of eight open-ended questions that ask the respondent to divulge as much conception about the nature of science as possible and it is used with follow up interviews.
The VNOS is possibly the most highly used instrument in the recent past, for qualitative nature of science survey studies (Liang et al., 2008). It consists of open-ended questions used in conjunction with follow up interviews. The VNOS and its derivatives are modeled on salient aspects of history and philosophy of science and on a conception of science as a way of knowing based on a constructivist paradigm as saddled in the consensus view of NOS teachable to K-12 science learners (Abd-El-Khalick, 2005; Lederman & Lederman, 2004).

Construct validity of VNOS-B was ascertained by Bell in 1999 using nine expert (individuals with doctoral degrees in science and science education) and nine non-expert (individuals with doctoral degrees in literature and language arts) responses to the instrument (Lederman et al., 2002). It is worth noting that although it is one of the most recently used NOS surveys in science education, its reported validation process does not include pertinent participation and contributions from scientists and philosophers of science.

Abd-El-Khalick revised and re-established the validity of the VNOS-C by systematically comparing and contrasting participants’ NOS profiles that were independently generated from separate analyses of the questionnaires and corresponding interview transcripts. Comparisons indicated that interpretations of participants’ NOS views as elucidated in the VNOS-C were congruent to those expressed by participants during individual interviews (Abd-El-Khalick et al., 1998; Lederman et al., 2002).

Like other VNOS derivatives, the VNOS 270-B focuses on less-controversial and generally agreed upon aspects of NOS teachable to K-12 level students. These aspects
include: Scientific knowledge is tentative, empirical, theory-laden, partly the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects are the distinction between observation and inference, the lack of a single recipe-like method for doing science, and the functions of and relationships between scientific theories and laws that are attested to by the reform documents (Abd-El-Khalick, 2005).

**Telephone Interviews**

More qualitative data were collected by way of interviews. These were one hour to an hour and a half long. The interviews questions were semi structured and open ended. Interview data was useful in triangulation of information gathered by the four instruments (SUSSI, VNOS 270-B, POSTT II, CLES II (20), clarification of meaning of words used in the SUSSI and VNOS 270-B free responses, and for acquiring more pertinent data that could have been missed by these surveys and the other qualitative procedure (document analysis).

Most lead interview questions were based on the surveys (SUSSI, VNOS-C (270B), POSTT-II, and CLES II (20)) with appropriate follow up questions generated as the interview progressed. Closed-ended targeted questions were used to address specific data needs. Subjects were given an opportunity to use their VNOS 270-B survey written responses and to use these earlier responses to provide expanded verbal responses or clarify earlier answers during interviews.

These interviews were conducted over long distance international telephone calls. The researcher acquired a secure phone over which the interviews were conducted and
recorded. The researcher, using a research assistant, made two appointments with each of the interview subjects.

The first one was a meeting between the research assistant and the subject to ask the subject to consider setting time for the interview. In this first contact, duration, content, required documents, actual local time for the interview were discussed and agreed upon.

The second one was the actual interview call. The interviews were as informal as possible, non-threatening, and carried no prior professional expectations from the subjects. The subjects were encouraged to be engaged in open candid conversations about their perspectives on nature of science, preferred science pedagogy and classroom learning environment. They were also encouraged to share their professional and general experiences as science students and now science teacher educators. Subjects were assured at the beginning of the interview and during the course of the interview that there were no wrong or right answers. They were reminded of their consent to participate, rights and freedoms before the interview. They were also assured that a soft verbatim transcript of the interview would be sent to them for their perusal for clarification and authentication before the interview information was used in the final document. They would have a chance to decide what information could be used and which to be left out in the final data analysis.

**Document Analysis**

More qualitative data was collected through the content analysis of the science teaching methods syllabi. The data from document analysis helped the study to get
evidence of the held perspectives as demonstrated in the syllabi. The language used to offer emphasis on particular aspects of the syllabi offered the study insights on what are the held perspectives by the framers of the curriculum (Creswell, 2009; Creswell & Plano-Clark, 2007). The study used the document analysis method to source qualitative data that would be used to answer all questions but particularly to address the study’s fifth research question stated below.

**Research question (5):** How are Uganda science teacher educators’ views on nature of science, preferred science pedagogy and classroom environment evident in their science methods course syllabi?

The major documents that were analyzed were science teaching methods syllabus for the represented institutions and departments in Universities. Qualitative text analysis paid attention to, presence or absence of text about the sought after area (NOS, PSP, and CLE) perspectives, and the quantity of texts (words) that are used to introduce and elucidate pertinent concepts about the sought perspectives. This analysis also sought after the use of words to describe or emphasize importance placed on the perceived perspectives by the syllabi text.

Lastly, concerning science teacher educators’ preferred science pedagogy, document analysis of the manner in which the available points (marks) were distributed among the learning activities in the course syllabus was used to make judgment on the anticipated predominant approach to teaching the course.
Using different colored high-lighters, the text was color coded for the three perspectives of NOS, PSP and CLE. That is, the text was color coded for language and its use to promote perspectives on nature of science, preferred science pedagogy and classroom learning environment. The color coded text was examined for meaning, ideas and indications and promotions of held perspectives.

**Qualitative survey sample.**

The subjects were selected from the sampled quantitative survey participants. Male and female subjects were purposefully selected as non-probabilistic sample (Creswell & Plano-Clark, 2007). They were selected in such ways that qualities like differences in age, years of science, difference in academic credentials, differences in level of service were not compromised. They were asked to respond to the VNOS-270B, and later interviewed after two-three months of responding to the VNOS-270B and five to six months of responding to SUSSI, POSTT-II, and CLES-II (20). The interview process was carried out until data reached saturation. At the point of saturation the study had interviewed four female and seven male participants; four (4) from the university level and seven (7) from PTCs. They had been purposefully chosen from the pool of participants to keep in the research theme of representation by level of deployment and level of academic qualification (Onwuegbuzie & Leech, 2006).
Establishing face validity of surveys for Uganda.

Validity refers to the degree to which a study accurately measures, reflects or assesses the specific concept that the researcher is attempting to measure or establish (Creswell & Plano-Clark, 2007; Tashakkori & Teddlie, 1998). For the current study, face validity of the instruments was crucial since the instruments originally targeted non-African science education communities. Establishing face validity of the instruments (SUSSI, CLES-II (20), and POSTT II) for the Uganda science teacher educator community was important.

To achieve face validity, electronic copies of the instruments were sent to four science teacher educators, two at the university level and two at national teachers’ college level in Uganda. These individuals were PhDs in their respective areas of teaching. They were well conversant with the science teacher education program in Uganda. Also copies of the surveys were sent to three high school science teachers. These individuals had master’s degrees in their specific science areas of teaching, a thorough understanding of the Uganda’s elementary to high school science curriculum, and are national examiners in their subjects of specialization. Lastly, copies of the surveys were given to three science teacher education doctoral students coming from Anglo-phone African countries (Uganda, Kenya and Malawi). Kenya and Malawi have a science curriculum very similar to that of Uganda.

These individuals were asked to study the items of each instrument and make comments on the suitability of the items for the Uganda science educator community. They were asked to comment on items that they deemed not suitable for the purposes of the study and to suggest changes or provide suitable substitutes. All the comments
provided were examined by the researcher and consciously considered on suitability. Only survey items that received unanimous acceptance by the reviewers as suitable were accepted without amendment. General modifications to the items suggested by reviewers were only incorporated after further consultation with the dissertation committee members and the originators or authors of the instruments. This was the case only for the POSTT-II where there was consensus that the names of the instructors used in the vignettes and the class levels be changed to mirror local Ugandan names and class levels. In the case of the VNOS-270B survey, the study believed that instrument items were to be appropriately validated by means of the follow up interviews (Abd-El-Khalick et al., 1998).

**Data Analysis**

… data analysis means organizing and interrogating the data in such a way that allows researchers to see patterns, identify themes, discover relationship, develop explanations, make interpretations, mount critiques, or generate theories. It often involves synthesis, evaluation, interpretation, categorization, hypothesizing, comparison, and pattern finding. (Hatch (2002); p. 148).

This perspective of data analysis was allowed to guide all data analyses in this study, meaning that, this view of data analysis was applied during quantitative, qualitative and any mixed data analysis.
Quantitative data analysis.

This started by organizing and cleaning up the responses gathered using the instruments SUSSI, POSTT II, and CLES (20) II. The surveys were checked for clarity of response choices (shadings) and judgment criterion of what is an acceptable response and what is not completeness of responses. Decisions were made on what was acceptable as contribution to data and what to exclude. Attention was paid to identification codes given to the subjects ensuring that names of subjects written on the surveys were not readable. The personal information or bio-data sheets were compounded and tabulated. All the surveys were coded as KYU and also arranged in ascending order (i.e. KYU-001 to KYU-063).

The quantitative data that the study collected was generated by Likert scales so it is ordinal in nature (SUSSI and CLES II (20)). The same is true for the multiple choice questions (MCQs) of the (POSTT). So naturally the next stage was to:

(1) Find if the data would fit the use of parametric descriptive statistical analyses or not. This was settled by subjecting the data sets (SUSSI, POSTT-II and CLES (20) II) full instrument, data sets in each scales of every instrument with scales, and lastly data sets separately grouped as University or NPTC to the one sample Kolmogorov-Smirnov test for normality using SPSS software.

(2.) Establish the reliability of the data sets (SUSSI, CLES-II (20)). Cronbach’s reliability alpha of the SUSSI and the CLES (20) II for whole instruments and for each of their constituent individual scales were established. This was done using SPSS statistical software. The POSTT data needed not to have this test.
(3) Find if the data had some regular patterns useful in describing the perspectives or the knowledge of the study subjects in the three areas of Nature of science (NOS), Preferred science pedagogy (PSP) and Classroom learning environment (CLE). This data interrogation was done using Pearson’s (r) correlation analysis and Independent sample Student t-test treatment using SPSS (Brown, 2011; Carifio & Perla, 2007).

Lastly, the study described, explained, and presented the patterns of the data and their meanings using pie-charts and bar graphs. In doing this the study was able to create portraits or profiles of the study subjects’ perspectives in the three areas center to its investigations.

Qualitative data analysis.

The process of qualitative data analysis employed by the study is represented by Figure 5 below, that is Creswell’s (2007, 2009) approach to qualitative data analysis. Although the flow looks linear, the process was not always linear and some of the stages are not clearly demarcated. However, the chart is a visual of the logical path that qualitative data analysis took.

(1) There was organizing and preparing the data. This included verbatim transcription of interviews, re-writing out field notes, examination of accuracy of the color codes of the coded texts of the science methods syllabi (document analysis), and generally organizing data as according to its original sources to make it ready for the analyst to interrogate it.
(2) Reading through all the data. This perusal gave the analyst a general sense of the data and a rough overall meaning of the data as he labored to judge the ideas in the data and data credibility.

(3) The detailed analysis began with the coding process. The coding was done with the help of a computer program, HyperResearch. In vivo and descriptive codes were developed by quantitative data transformations (qualitizing) and assigned to the appropriate data portions (Saldana, 2009).
To guard against personal biases by the analyst, inter-coder reliability was sought. Three different coders familiar with the study and with advanced knowledge in qualitative data analysis were used to establish acceptable coding criteria. Inter-coder reliability of at least >85% agreement was sought and established among coders that

Figure 5: Flow Chart of the Qualitative Data Analysis Process

Adopted from Creswell, (2009; p.186)
included the principle investigator. This process involved the three coders coding the same data and comparing their results. If they were less than 85% in agreement, they hashed out their differences and coded again the same portion of data.

This process was repeated until all coders were at least >85% in agreement. The study obtained a kappa measure of inter-rater reliability using Rela2, a web based software. Then typological descriptive, interpretive narratives were written on these themes to interpretively describe the subjects’ perspectives based on the typologies developed during qualitizing of quantitative survey data. These narratives constituted the qualitative data analytical memo of the study.

The themes developed in the qualitative data analysis process outlined were used in the final mixed data analysis only after authentication by the subjects. As a means to guard the credibility of the data, the written analytical memo and the verbatim transcription of the interviews were shared by way of email correspondence with all interviewees. They were requested to carefully read through and comment on the authenticity and accuracy of the data transcripts and the subsequent themes. They were also asked to provide pertinent corrections to any misrepresentation of their views and to provide any changes to the views they already provided citing reasons for the changes. While the study recognized the rights of subjects to authenticate the views expressed in the analytical memo, it assumed that the subjects were in agreement with the contents of the memo if they did not respond within two weeks of request of authentication. The study did not request authentication again until final narratives were written after executing mixed method data analysis.
Mixed methods data analysis.

This stage of data analysis involved integrating and converging both quantitative and qualitative data in an attempt to construct better and comprehensives perspectives profiles of the subjects. The profiles of subjects’ perspectives on NOS, PSP and CLE based on mixed methods data were expected to be closer to actual than either presented by one type of data by itself.

The intention of converging the two sets of data extended beyond the mere need to triangulate one set of data by the other. Instead the study was drawn to the possibilities that integrating both data enabled it to gain better understanding of the patterns invisible, if each data set is treated singularly. At this level of mixing, the study searched for grounds to get confirmation of already established patterns, complementarity between data sets, opportunity and to extend data to create yield and crystallization of the findings (O'Cathain, Murphy & Nicholl, 2007; Onwuegbuzie & Leech, 2006).

Mixed data analysis included cross-over strategies. For example visual integrated data display of qualitative data and coding of the SUSSI quantitative data in light of the qualitative SUSSI data (Yin, 2006). Data transformation was performed on SUSSI and CLE (II) 20 responses. Qualitizing these quantitative responses generated qualitative descriptive categories that were used as lenses to typologically interpret qualitative data codes for the classification of qualitative data responses. This afforded the study better powers to compare and integrate the qualitative themes generated from the qualitative data, so as to build better crystalized participants’ perspective profiles (Driscoll, Afua-Appiah, Salib, & Douglas, 2007; Spillane et al., 2010).
The mixed methods notation for this data analysis was QUAN + QUAL. This data analysis process was as seen in the scheme (Figure 6). In this scheme, this stage of mixing analyses is shown as comparing and integrating data (Creswell, 2009). The study used some data presentation strategies that included: tables, pie-charts, bar-graphs, and text.

![Mixed Methods Data Analysis Scheme Chart](image)

Adopted from Creswell (2009); p. 210

**Figure 6: Mixed Methods Data Analysis Scheme Chart**

**Data interpretation.**

Data interpretation followed analysis, and involved examining data to see how they converge, diverge and disagree (data discrepancy). Furthermore, both data sets were examined to see if they confirm, complement each other or how both crystallize the study issues or otherwise.
Data were validated by cross-examining emerging themes of interpretation against the raw data from which these interpretations emanate. It is at this stage that the study was able to make greater meaning of the data and assess the added value of mixing methods. Also at this stage the study decided what to do with discrepant data, if any (Creswell, 2009; O’Cathain, Murphy & Nicholl, 2007; Onwuegbuzie & Leech, 2006).

Validity Approaches in both Qualitative and Quantitative Procedure

Throughout the study legitimization of results in mixed methods research (Onwuegbuzie & Johnson, 2006), or validity in mono-methodology research was keenly observed. In this case internal validity as opposed to external validity was the greater target. This is because the study did not seek to generalize its findings on the whole population of Uganda science teacher educators. Instead its aim was to guard as much as possible the procedure of the study so that the findings were generalizable on the participants or subjects of the study.

Instrumental validity on the quantitative data collection instruments (SUSSI, POSTT-II and CLES-II (20)) was addressed as already noted in the foregone section. The (VNOS-270-B) was validated by the follow up telephone interviews. This in addition to the fact that some of these instruments (VNOS-270-B, CLES-II (20), and SUSSI) had already been used extensively in published works ensured an acceptable validity and reliability. Nonetheless, the study established the reliability of the SUSSI and CLES II (20) instruments based on its specific sample.
The validity concern with qualitative data was guarded by allowing the subjects to verify the contents of the qualitative and mixed analytical memo before the final write up. Also cross comparison of interview and survey data for the interviewed subjects helped to guard data validity. This was further guarded by verbatim transcription of interviews and allowing subjects to cross check and authenticate the transcript contents.

Meanwhile reliability concerns about qualitative data were addressed by way of observing and establishing inter-coder reliability. This process involved three different coders/raters. This vigilance ensured that data credibility was secured. Furthermore, the investigator kept a personal diary and field notes to help with reflexivity. These records were used to check how the researcher’s personal knowledge of the research context and close proximity with the profession and Uganda may have affected the study and its findings. Moreover, self-reflection on the side of the researcher and regular open dialogue with the Principal Investigator (PI) guarded against concurrent bias in data (Creswell & Plano-Clark, 2007; Tashakkori & Teddlie, 1998; Yin, 2006)

**Potential Ethical Issues and Other Problems**

Potential ethical issues in this concurrent mixed methods survey study were those common in studies that involve human subjects. In this study the potential incidences included, breaching of confidentiality agreement between the study and the subjects. The study used pseudo names and assigned numerical identifiers to subjects. This ensured that their identity information was taken off from all of the scripts and any study document that carried the subjects’ identification information. Moreover, all the scripts and
documents were kept in a lock and key drawer in the researcher’s office. Other potential ethical issues included the possibility of heads of department forcing their subordinates to participate or using the study to exploit them in any ways. The study made it clear that voluntary participation was key to subject recruitment. This was emphasized at the introduction of the study, during the consent agreement signing, and all the time throughout the study by reminding the subjects that they were free to withdraw their participation at any time without any damage to their professions or personal reputations (Creswell, 2007, 2009). The other potential ethical incident for a study like this is that subjects could misunderstand the honorarium token of thank you for participating promised to them as cash for better information or more information. The study assured all its subjects that there was no right or wrong answer and that no one would get a higher honorarium because of their responses to the surveys or interviews. They were constantly reminded that the greatest reward (to them) was that by participating, they were contributing to the expansion of knowledge. The token of gratitude for their participation (honorarium) was given only to those who successfully completed the qualitative and quantitative sections.

The following set of pointers to ethical practices as assembled by Terrell (2011) helped guide the study on ethical issues.

- Participants must participate voluntarily
- Participants must understand purpose and procedures of the study
- Participants must understand that they have the right to a copy of the results
- Participants must understand the potential benefits of the study and that their privacy will be respected
- Researchers must understand the impact of their presence at research sites and ensure that these sites are left undisturbed at the end of the study
- Care must be taken to identify and nullify any actual or perceived issues where power between the researcher and participant could be abused
- Anonymity must be maintained during data analysis and data kept for a reasonable period of time
- Ensure that writing is not biased towards any group (e.g. age, ethnicity, sexual orientation, race, gender etc.)
- The details of the study must be carefully explained within the actual report so as to allow readers the opportunity to judge the ethical quality of the study for themselves (Terrell, 2011, p. 276)
CHAPTER IV

RESULTS

Introduction

It is difficult to conduct research in Uganda because Uganda does not have well
developed communication systems such as broad band internet and land line phone
services. Telephone communication is almost completely by expensive cellphone
networks. The road network is also poor making road travel unreliable. Moreover, the
researcher found out that there is little desire among scholars to engage in efforts geared
towards creating knowledge and discovery. The situation is exacerbated by the many
international and inter-governmental research agencies that have introduced a culture of
‘buying’ information from research subjects by giving them exorbitant honoraria. These
agencies bus participants across the country to the cities for day seminars during which
they collect data from them. They then give huge cash reimbursements to the participants
to cover their expenses for the day, a form of incentive. This arrangement was popular
among scholars and professionals. This study fears that the practice may bias data
collection since participants may give information which is tailored to the aims of the
study or influenced by their experiences in the one day seminar.

These circumstances made the process of creating knowledge more difficult for
the student researcher. However, this study prevailed by exercising patience and going to
every work site of its respondents thereby reducing possible excessive expectations and their influence on the study.

The study results reported here are products of a slow and closely monitored process of data collection and interaction with the study subjects in situ, in pursuit of scholarship and knowledge creation. In the next section, the study presents the findings of this study regarding participating Uganda science teacher educators’ views on Nature of Science (NOS), Preferred Science Pedagogy (PSP), and Classroom Learning Environment (CLE).

**Participants’ Perspectives on Nature of Science (NOS)**

The first research question of the study was what do Uganda science teacher educators understand regarding nature of science? To answer this question the study asked its participants to explicitly share their views on the nature of science. The study sought their views on six aspects of NOS:

- Nature of scientific observations and inferences, denoted as OBSINF.
- Nature of scientific theories, denoted as NOSTH
- Comparison of nature of scientific laws and theories, denoted as LAW Vs TH
- Role of human creativity and imagination in science denoted as CREIMA
- Role of social and cultural values in science denoted as SOSCUL
- Methodology in science denoted as METHOD in this study.
Sixty-three Uganda science teacher educators responded to the NOS survey instrument, the Student Understanding of Science and Scientific Inquiry (SUSSI). Their responses were subjected to quantitative and qualitative analysis to identify salient characteristics useful for building profiles of participants’ NOS views. The study desired to use parametric descriptive and inferential statistics in the building of participants’ profiles; thus the SUSSI data was tested for normality (D'agostino, Belanger, & Ralph B. D'agostino, 1990). The normality test returned a Kolmogorov-Smirnov-Z (KS-Z) score of 0.949 with $p = 0.328$, for the full data set, KS-Z score of 0.700 with $P = 0.711$ for the NPTC (NTCs plus PTCs) subgroup, and KS-Z score of .895, with $p = 0.399$ for the university subgroup. This test confirmed that the data sets were normally distributed.

The small number of participants (63) did not allow the study to carry out a meaningful factor analysis for the data since it would have required at least 120 participants to satisfy the minimum ground of 5 participants: 1 item (The SUSSI has six scales each with four statements giving it 24 statements or items). Reliability of the SUSSI survey instrument to capture data on Uganda science teacher educators was also tested (the instrument had been developed outside of Uganda). Reliability tests returned an acceptable Cronbach’s Alpha of 0.776 for the instrument as a whole indicating that useful meaning could be made out of the data (McCroskey & Young, 2006).

Table 4 below shows the reliability measures for each scale of the SUSSI survey. Two scales, Scientific Laws and scientific theories, and Methodology in science were dropped because they had very low reliability measures and dropping them did not significantly affect the overall reliability of the survey. The nature of scientific theories
scale was retained although it had a low reliability measure because dropping it affected the overall reliability measure of the survey significantly.

The quantitative data that is reported in this section, therefore, is based on four scales of: OBSINF, NOSTH, SOSCUL, and CREIMA.

Table 4: SUSSI Scales Reliability Measures

<table>
<thead>
<tr>
<th>SUSSI scale</th>
<th>Cronbach’s Alpha</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBSINF</td>
<td>0.729**</td>
<td>acceptable</td>
</tr>
<tr>
<td>NOSTH</td>
<td>0.447</td>
<td>Unacceptable***</td>
</tr>
<tr>
<td>SOSCUL</td>
<td>0.759**</td>
<td>acceptable</td>
</tr>
<tr>
<td>CREIMA</td>
<td>0.870**</td>
<td>acceptable</td>
</tr>
<tr>
<td>Laws and Theories</td>
<td>0.258</td>
<td>unacceptable</td>
</tr>
<tr>
<td>Methodology</td>
<td>0.361</td>
<td>unacceptable</td>
</tr>
</tbody>
</table>

Mixed method data analysis involved transforming the Likert scale responses for each SUSSI scale into a single descriptive category score. This process referred to as qualitizing, was as follows: The responses of each participant on the scale of the SUSSI survey were grouped. Then each group of responses was categorized as either Naïve (denoted by 1), Transitional (denoted by 2), or Informed (denoted by 3) using the following rules:

**Category 1 (Naïve):** All four responses in the battery/scale consist of only lower Likert scale scores (1s and 2s) and undecided (3s). For example, (1, 2, 2, 1) or (2, 3, 3, 3).
Category 2 (Transitional): At least one of the scores in the battery was an upper Likert scale score (4s or 5s). For example (4, 2, 1, 3) or the battery responses are a mixture of all Likert scale scores.

Category 3 (Informed): All four responses in the battery consist of only upper Likert scale scores (4s and 5s). For example, (4, 5, 5, 5).

These categories represent the quality of the views inherent in SUSSI scale quantitative responses. The data generated from these transformations was used as representative numerical values (frequencies) for the statistical manipulation of data. The transformation also allowed the study to use all 63 participants’ responses on each SUSSI scale to generate typologies or lenses for interpreting the qualitative data from free SUSSI responses, VNOS-270B survey, interviews and document analysis.

Guarding reliability of SUSSI transformed results

The study assured consistency of this data transformation process by establishing inter-rater and intra-rater reliabilities of Cohen’s Kappa of more than 85%. Inter-coder reliability for the SUSSI scoring was established by having two individuals (a graduate student and a professor) both well familiar with the study and the SUSSI to code three different scripts of the SUSSI responses. Their outcomes were compared until there was not less than 80.0% inter-coder agreement. This exercise reported an inter-coder reliability of 80% (Cohen’s Kappa = 0.727). On the other hand, intra-rater reliability was reached by the student researcher coding all responses at least twice a week for three consecutive weeks until a consistence of above 80% was achieved with this process.
Data transformation that consisted of (1s, 2s 3s) was tested for normality and it returned KS-Z of 1.073, with p = 0.20, meaning that this data set also was normally distributed and thus suitable for applying parametric statistical treatments.

Participants’ OBSINF scale responses.

Quantitative Data Analysis Results:

The results reported here are the raw data on participants’ responses on the SUSSI scale of OBSINF (Figure 7). The results are presented as whole group responses in the form of frequencies and percentages.

![Figure 7: SUSSI Responses on OBSINF Scale](image)

Figure 7 shows that participants’ responses were varied and covered the full Likert scale of the survey. Only 10 responses (4%) were ‘undecided’ (3s). Ninety-three responses
(37%) were on the lower side of the scale (1s and 2s) and a majority 149 responses (59%) were on the upper side (4s and 5s). On this aspect, science teacher educators’ responses were by majority on the upper scales.

Mixed Method Data Analysis Results:

Each participant’s responses on the OBSINF scale of the SUSSI survey was transformed into either the category (profile) of Naïve, or Transitional or Informed. The distribution of all 63 participants’ categorical responses by frequencies and percentages is as shown in Figure 8.

![Figure 8: Participants’ Views on OBSINF](image)

This figure shows that majority 37 (59%) of the quantitative responses on the OBSINF scale reflect a Transitional view on the nature of scientific observations and inferences. A minority 7 (11%) responses reflect a Naive conception of this NOS aspect by the participants.
Qualitative Data Analysis Results:

Qualitative data consisting of free responses on this scale on the SUSSI and from the VNOS-270B surveys, and responses gathered through telephone interviews were interpreted as fitting all three categories (Naïve, Transitional and Informed). The study then used participants’ own words to label their views in each of the profiles as follows:

**Naïve views**

Views profiled as *Naïve* were labeled ‘*Same reality, same observation always*’. These views reflect the perspective that scientific observations are objective and not affected by the scientific observer. Below are four excerpts that are exemplars in this profile:

> “Scientists’ observations and interpretations are the same in the biological and physical sciences. E.g. using a pendulum to determine acceleration should produce the same result by different scientists”. (KYU – 027 SUSSI response)

> “Scientific observations such as in chemistry (i.e. reactions) depend on facts of such reaction pathways. There is no way any other observation apart from what is meant to take place for this chemical reaction even can happen” (KYU – 030 SUSSI response).

Scientists’ observations and interpretations are the same when for example the objective is the same and the procedure or process of arriving at or conducting the experiment is the same, with other variables, being constant other than the one being investigated. Physical observations do not
differ for different objects hence facts about such observations remain the same (KYU – 045 Interview script).

“Scientists’ observations and interpretations are the same if the observations made are accurate. E.g. when a body is seen to be moving faster and faster as time goes, then it is concluded that the body is undergoing acceleration” (KYU – 036 SUSSI response)

**Transitional Views**

Participants with views described by this profile were the majority 37 (59%). The views profiled as transitional were labeled ‘Always same observation, but sometimes different interpretation’. Participants’ responses reflect that they correctly perceive the possibility for different scientists to observe the same natural phenomenon and yet to come to different conclusions and interpretations. However, they do not accept the same view concerning scientific observations. The following excerpts are exemplars of this perception:

“The observations are always the same but the interpretations will depend on the level of expertise and the assumptions under consideration” (KYU – 016 SUSSI response).

“Different scientists make the same observations and interpret them differently, e.g. when medical doctors diagnose diseases in patients, they may have the same observations but,
make different interpretations of the signs of diseases observed” (KYU – 054 SUSSI response).

**Informed Views**

Views profiled as *Informed* were described by the label ‘**Prior knowledge and skills color observations and their interpretation**’. Nineteen (30%) participants’ responses were categorized as Informed (Figure 4.2). Below are two excerpts from participants’ responses that confirm this perception.

“**Both observations and interpretations are influenced substantially by previous experiences of the subject doing the observation. If there is no such experience, observations may not mean much let alone the interpretation of the observed subject**” (KYU – 019 SUSSI free written response).

Scientists’ observations/interpretations may be different because of subjectivity brought about by one’s prior experience. People observe/interpret objects through their lens of prior knowledge on the often, hard scientists observation and interpretation may be the same because they follow standard methods and procedures (KYU – 022, interview transcript).

In summary, concerning the OBSINF aspect of NOS, the results show that although a total of 149 (59%) responses of 252 responses were on the upper scales of the SUSSI Likert scale. When transformed, they yielded only 19 (30%) views profiled as *Informed*. The majority of 37 (59%) views qualified as *Transitional*, as seen in Figure 8.
Participants’ NOSTH scale responses.

Quantitative Data Analysis Results:

The results in Figure 9 are raw data on participants’ responses on the SUSSI scale of NOSTH presented as frequencies and percentages.

![Figure 9: SUSSI Responses on NOSTH Scale](image)

The results reveal that participants had responses at all levels of the SUSSI Likert scale. However, a majority of responses 169 (67%) were on the upper scales (4s and 5s) and only 64 (26%) on the lower scales (1s and 2s). Nineteen responses (7%) were on the undecided scale point (3). So majority responses were high scale score responses.

Mixed Methods Data Analysis Results

The quantitative data (Likert scale responses) were evaluated and transformed into qualitative categories of Naïve, Transitional, or Informed (Figure 10). In this case
transformation of the data yielded no *Naïve* category leaving all participants’ responses to be categorized as either *Transitional* (81%) or *Informed* (19%).

![Pie chart showing 51% transitional and 12% informed](image)

**Figure 10: Participants’ Views on NOSTH**

Qualitative Data Analysis Results:

Typological interpretation of the analysis of SUSSI free responses, VNOS-270B responses and interview data on this aspect of NOS also reveals an absence of *Naïve* views on this aspect of NOS. The qualitative data shows that participants view scientific theories as explanations and predictions while scientific laws are viewed as being descriptive in nature. Views in the *Transitional* profile were labeled as, ‘*Grounded theories never change*’. Exemplars of this view include:

“*Grounded theories such as those of evolution and inheritance cannot change with time*” (KYU – 042 SUSSI response).

“*Scientific theories do not change over time if there is concrete experimental evidence to support them e.g. Huygens’s wave theory of light was proposed and confirmed after*
sometimes through experiments. Experiments also showed that Einstein’s theory was true and still true.” Participant KYU – 036 Interview transcript).

Additionally, responses in this profile revealed that some of the participants held the view that scientific theories may change but they insinuate an ontological perspective that they do this because they are not yet scientific laws or principles. For example, participant KYU – 032 said that, “Theories change because they are not principles e.g. The theory of geocentricism (the earth is at the center of the universe). Another participant, KYU – 059, shared that “Theories are not laws therefore they may be based on several assumptions and are subject to review.”

A minority (19%) of the participants had responses which revealed conceptions of NOSTH that were classified as Informed views (Figure 4.4). Views profiled as Informed were labeled as, ‘Theories are products of human cognitive activity so may change’ Responses in this profile reveal that participants understand theories as artifacts of human cognitive activities. They even suggest that scientific theories are tentative because of two major possibilities:

New evidence
Some participants attributed change of scientific theories to new evidence. For example participant KYU – 047 shared that:

Science as a body of knowledge is dynamic and ever changing being a human activity. Scientific theories change over time as a result of on-going experimentation hence they may be revised e.g theories about the transmission of some diseases keep changing as more knowledge is gained through the scientific process (KYU – 047, Interview transcript).  

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Another participant, KYU – 033, who considers scientific theories changing due to new evidence shared that, “Theories change depending on new observations arising e.g. with improved technology. For instance atomic theory has changed over time; “an atom” which meant “cannot be split” is now known to contain sub-atomic particles.”

New technology

Other participants suggested the tentativeness of scientific theories is due to man inventing advanced technology which enables him to make better observations of nature. For example participant KYU – 004 shared that “observations change with accuracy of instruments used, hence also interpretations will change and therefore theories will be put to test.”. Another participant, KYU – 015, shared that “depending on the tools used, modern tools may possibly reveal some information which was not easily observable. If this is the case then a theory may change”

In summary, there were only two levels of understanding of NOSTH revealed by the results. Majority, 51 (81%) participants held a Transitional conception and 12 (19%) participants held the Informed conception of nature of scientific theories.

Participants’ SOSCUL scale responses.

Quantitative data Analysis Results:

On the role of society and cultural values in the creation of scientific knowledge, participants responded to four statements by indicating on a Likert scale their level of agreement or disagreement with the statements. Figure 11 below presents the distribution
of the 252 responses from the participants on the five–point SUSSI Likert scale as frequencies and percentages.

Twenty-five (10%) responses indicated indecision. The remaining responses were almost equally distributed between the lower scale scores (1s and 2s) (45.6%) and upper scale scores (4s and 5s) (45%). This result clearly reveals that this group of participants did not have a clear cut conception of the SOSCUL aspect of NOS.

Figure 11: SUSSI Responses on SOSCUL Scale

Mixed Methods data Analysis Results:

The quantitative responses on SOSCUL were subjected to data transformation to generate categorical scores of Naïve, Transitional and Informed. The results of this treatment are as shown in Figure 12. This typological classification of each individual’s responses on the SOSCUL SUSSI scale returned majority 34 (54%) participants’
responses as being *Transitional views*. Seventeen (27%) responses were classified as *Naïve* and 12 (19%) as *Informed views*.

**Figure 12: Participants’ Views on SOSCUL**

Qualitative Data Analysis Results:

The typologies of responses (*Naïve, Transitional, and Informed*) were again used to interpret qualitative data from free response on the SUSSI, VNOS-270B and from interviews during qualitative data analysis. The procedure returned responses that fitted into all the three categories or typologies.

Some responses profiled as a *Transitional* were labeled as ‘*Society and Culture affect “Taught science” not “Discovery” efforts*.’ For example,

Society plays an important role on how and what science is taught at school because they are involved in aims and objectives for reading and learning science that is, Man power requirements … so cultural beliefs may influence what science is taught but not how it is developed.

(KYU - 018 Interview transcript)
Others were labeled as ‘Society and Culture affects the “Advancement” of science but not the “Process”’. For example,

“Culture may influence scientific development but not process of research” (KYU – 003 SUSSI response).

“It’s just a matter of ethnics. I doubt society and culture can affect scientific research if the ethical issues are all observed during the research process. Besides, if it is entirely lab work controlled and developed using objectivity” (KYU – 020 SUSSI response).

Some participants’ SOSCUL responses profiled as Naïve (Figure 4.6) were labeled as ‘Matter has no culture’. For example,

“A molecule is a molecule and can be specifically tested for in the same ways whether in Uganda or UK in Canada” (KYU – 006 SUSSI response).

“Research on light will give the same results whatever society and culture carries it out”. (KYU – 056 SUSSI response).

Others were labeled as ‘Science is objective’. For example,

“Society and culture do not affect scientific research and scientific laws because the scientific research is conducted objectively pure and unbiased” (KYU – 013 SUSSI response).

“Scientific research or investigations is a kind of problem solving process. This problem solving process has definite steps. If these steps are followed, they should eliminate the
biases and pre-conceived ideas inherent in cultural beliefs in any society” (KYU-064 SUSSI response).

Qualitative responses on the SOSCUL aspect of NOS that were profiled as Informed were labeled as ‘Society and science are inseparable’ For example,

Scientific research, and society and culture are inseparable. The needs of the society will always influence what scientific research is to be conducted e.g. In the famine stricken countries, scientists would focus so much to improve on increasing food production other than nuclear bomb production. Likewise scientific research will also rely on the culture. (KYU – 029 Interview transcript)

Also reflected in the views in this profile was the view that society and its culture choose what specific questions to ask. For example, participant KYU – 027 had this to share, that: “Society and culture do affect scientific research particularly in the biological sciences. For example, research on producing test tube babies may be unacceptable in a developing economy or in a deeply catholic religious society.” Participant KYU – 022 added that “many research agendas in science are influenced by human activities. For example, environmental science is focused on pollution and environmental degradation which are partly caused by societies and their cultural values.”

Furthermore, in this profile is the understanding that societies and their cultural values guide future expectations in scientific knowledge creation. For example,
The culture norm and expectation will guide what the future expectation to be scientific research will help its achievement. This is true of production science of from traditional approach through industrial revolution to internet connectivity where information and advance technology is used for faster results. (KYU – 028, Interview transcript)

Last in this profile were responses that presented the understanding that society and cultural values determine the participants in scientific studies, Participant KYU – 031 shared this concept by saying “you cannot carry out research using human beings as guinea pigs without their consent. You cannot excavate Mary’s (the Mother of Jesus) bones to establish their age, DNA; the Roman Catholics will not allow such.

In summary, although there was almost equal distribution of the low and high Likert scale score responses, when categorized, these scores translated into only 12 (19%) and 34 (54%) Informed and Transitional views, respectively.

Participants’ CREIMA responses.

Quantitative Data Analysis Results:

Section five of the SUSSI was comprised of four statements about the role of creativity and imagination in the process of creating scientific knowledge. All 63 participants responded to these statements by indicating on a Likert scale their level of agreement or disagreement with the statements. The distribution of the 252 responses on the SUSSI Likert scale are presented in Figure 13. Sixteen (6%) responses were indecisive responses (3s) about this aspect of nature of science. The majority of responses
162 (64%) were upper scale scores (4s and 5s) and 74 (30%) responses were on the lower scale (1s and 2s).

Figure 13: SUSSI Responses on CREIMA Scale

Mixed Methods Data Analysis Results:

The Likert scale responses were subjected to data transformation. The response were evaluated and classified into *Naïve, Transitional* and *Informed* categories as shown in Figure 14 below.
Figure 14: Participants’ Views on CREIMA

Figure 4.8 shows that out of 63 participants, 28 (45%) participants responded with 

**Informed** views on the creativity/imagination aspect of NOS, 21 (33%) had responses that were **Transitional** views and 14 (22%) had responses that were categorized as **Naive**.

Qualitative Data Analysis Results:

Typologically analysis and interpretation of the qualitative data from free SUSSI responses, VNOS-270B response and interviews resulted into views fitting all three profiles as follows:

**Informed Views**

These were labeled as ‘*Creativity and imagination are the heart and soul of science*’.

For example the following excerpts:

“*Science is a human activity; therefore use of imagination and creativity is of paramount importance for the success of the scientific method*” (KYU - 046 SUSSI response).

“*Scientists have to design scientific research tools, collect data, choose the best method to present data ( ie percentages, graphs, charts etc) to enable them analyze and interpret*
A scientist must be imaginative and creative in order to advance the frontier of science...but their observations and interpretations must be objective, e.g. In developing the law of gravitation by watching an apple fall Newton had to be imaginative and creative so that he could objectively interpret the phenomena. (KYU - 047 Interview transcript)

This participant has *Informed* views on one aspect (CREIMA) and *Naïve* views that present science as an objective knowledge creating process.

**Transitional Views**

Transitional views of the creativity and imagination were labeled as ‘*Selective use of either creativity or imagination but never both*’. For example,

“Imagination and creativity in scientific investigations can produce fuzziness in data interpretation and collection. Empirical scientific inventions should not be imagined, whereas creativity such as improvisation is crucial in many scientific process skills” (KYU – 029 SUSSI response).

“Creativity is very important in logical reasoning, I think. So long as they are not supposed to use imagination during data collection; they should embrace creativity during the data analysis” (KYU - 020 SUSSI response).

Other participants suggested that when both are applied, they are applied at selected stages of the creative process but not on the entire process. For example,
In designing instruments for data collection, theories, imagination and creativity are utilized by scientists. And also in data analysis for them to identify analogues etc. but they need to be objective enough in reporting and sample selection to avoid bias so they do not use it here”.

(KYU - 034 SUSSI response)

Scientists use their imagination and creativity when they observe phenomenon which has never been observed before. This helps scientists to make meaning of the observed phenomenon. They do no use imagination and creativity if what they are dealing with has been observed and has been reported in literature. (KYU – 022 Interview script)

Yet still other participants conceived that these human attributes are called to play in the creative process in certain rare and difficult circumstances. For example, participant KYU – 035 shared with the study that “Scientists use imagination where the instruments for data collection or the situation being investigated grossly deviates from the reality which calls for creativity of the scientists to arrive at a conclusion.” And another participant, KYU – 015, in the same vein shared that “experimental investigation may require some form of creativity especially where appropriate tools are not available”.

Lastly, Figure 14 shows that some participants’ responses 14 (22%) revealed Naïve views on this aspect of NOS. The study labeled these Naïve responses as ‘Creativity and imagination interfere with reality’

Examplers for these views include the following:
“...scientists do not use imagination and creativity simply because these may never give you the exact truth about a phenomena” (KYU - 058 SUSSI response).

“Imagination and creativity are very likely to influence conclusions made after observation of facts and events. It is best if the scientists stands aside and looks at the situation independently in order to allow him/her to conclude objectively” (KYU – 019, SUSSI response).

“I think they do not use creativity because it may contradict the logical reasoning. Imagination may interfere with the observation and therefore the objectivity of the findings” (KYU – 051 SUSSI response).

In summary, results on this aspect of NOS show that although 64% responses were high SUSSI Likert scale scores, only 28 (45%) of the overall responses were classified as Informed, 14 (22%) were Naïve and 21 (33%) were Transitional.

The overall performance by this group of 63 participants on the four aspects of NOS, are as shown in Figure.15 below. The mean score for the group on the SUSSI survey was 3.4 on the five point scale. The result shows that overall; this group of participants scored below the upper score of “4” on all aspects of NOS. Their highest mean score was 3.7 (NOSTH) and their lowest was 3.0 (SOSCUL). When analysis of variance ANOVA with a Post hoc (Tukeys test) was applied to SUSSI scale average scores to discern if the observed differences in these means were not due to chance, ANOVA returned a significant test F (3, 248) = 5.843,. $p = 0.001$. This meant that at least one of the observed differences between the average scores was statistically significant and not due to chance. Post hoc comparisons using the Tukey HSD test indicated that the
The mean score for NOSTH aspect (M = 3.7, SD = 0.68) was significantly different from that of SOSCUL (M = 3.0, SD = 1.1). In addition, SOSCUL (M = 3.0, SD = 1.1) was significantly different from that of CREIMA (M = 3.5, SD = 1.2).

Figure 15: Participants’ Mean Scores on the Four Aspects of NOS (n=63)

Summary on Overall Quality of Participants’ NOS Views:

The study profiled all participants’ views on NOS (measured by the four scales of OBSINF, NOSTH, SOSCUL, and CREIMA). The results show that all three categories of Informed, Transitional, and Naïve views were realized on all the aspects except NOSTH which did not return any Naïve category. Each of these categories had a percentage contribution to the overall quality of participants’ views as shown in Table 5.
Table 5: Classification of Participants’ Views on the Aspects of NOS

<table>
<thead>
<tr>
<th>Aspect of NOS</th>
<th>Informed</th>
<th>Transitional</th>
<th>Naïve/Untutored</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBSINF</td>
<td>30</td>
<td>59</td>
<td>11</td>
</tr>
<tr>
<td>NOSTH</td>
<td>19</td>
<td>81</td>
<td>0</td>
</tr>
<tr>
<td>SOSCUL</td>
<td>19</td>
<td>54</td>
<td>27</td>
</tr>
<tr>
<td>CREIMA</td>
<td>45</td>
<td>33</td>
<td>22</td>
</tr>
</tbody>
</table>

The Informed view category was consistently a low percentage frequency score across the aspects. Even its highest frequency score of 45% (CREIMA) was not a majority’s view. The Transitional view category had the highest percentage on three aspects (OBSINF, NOSTH, and SOSCUL). Lastly, inspection of transformed raw data revealed that only three participants (KYU, 018, 021 032) were evaluated as having overall Informed views on all four aspects of NOS investigated and therefore NOS in general. No participant was evaluated to be overall Naïve, and 60 (95%) were evaluated as possessing Transitional views of NOS.

Inter–associations between the four scales

The study sought also to establish if there existed any form of inter-associations among the views of the participants as measured by the scales of the SUSSI survey. The study calculated each participant’s average score on every scale and then used (64 by 4) averages to run a measure of correlation between the four different scales score.
(OBSINF, NOSTH, CREIMA, and SOSCUL) on the SUSSI survey. This Pearson’s correlation coefficient (r) test returned results shown in Table 6.

**Table 6: Correlations within the Views on the Four Aspects of NOS**

<table>
<thead>
<tr>
<th>Correlations</th>
<th>OBSINF</th>
<th>NOSTH</th>
<th>SOSCUL</th>
<th>CREIMA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OBSINF</strong></td>
<td>r</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>1</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td><strong>NOSTH</strong></td>
<td>r</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>1</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td><strong>SOSCUL</strong></td>
<td>r</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>1</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td><strong>CREIMA</strong></td>
<td>r</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>1</td>
<td>63</td>
<td>63</td>
<td>63</td>
</tr>
</tbody>
</table>

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

From Table 6, results show that there is a strong significant correlation between participants’ views on the role of society and cultural values in science (SOSCUL) and their views on the role of creativity and imagination in science (CREIMA) aspects of NOS (r =0.326, p = 009). This was also true for their views on the role of society and cultural values in science (SOSCUL) and their views on scientific observations and inferences (OBSINF) aspects (r = 0.505, p = 000). Also observable was a significant correlation between OBSINF views and their views on nature of scientific theories (NOSTH) aspects of NOS (r = 0.309, p = 0.014).
University Vs NPTC participants’ views on NOS

To build a comprehensive profile of the participants’ views of NOS, the study extended the analytical treatment to understanding their views when treated as two separate professional subgroups on these four aspects of NOS. That is, subgroups of University science teacher educators and NPTC science teacher educators. Then it used each individual mean score from the raw scores to compare the performances of the two subgroups on the four aspects of OBSINF, NOSTH, SOSCUL, and CREIMA. The comparison of raw mean scores of the two subgroups is shown in Figure 16.

In general comparison, the independent t test returned a non significant difference (University: M = 3.2, and SD = 0.51; NPTC: M = 3.0, and SD = 0.54, p = 0.14) at alpha level (0.05). This means that the mean difference observed between the two subgroups was due to chance. When the same test was done for between scales, the test results returned showed that the mean difference in mean scores of the two subgroups on the first scale: (OBSINF) was significant (p =0.003) at alpha level (0.05). This means that the observed differences in the mean scores of the two subgroups on the OBSINF scale are not due to chance. However, all other mean score differences between the two subgroups on the scales (NOSTH, SOSCUL, and CREIMA) were shown to be statistically non-significant and as being due to chance.
As seen in Figure 16, means from the University subgroup on the four aspects of NOS range from 3.7 to 3.1 and the NPTC subgroup means range from 3.6 to 2.8. The University subgroup had their highest inferential mean on CREIMA and NOSTH; both having the same mean score (m = 3.7). Their lowest mean was on SOSCUL with (m = 3.1). Meanwhile, the NPTC had theirs highest on views on NOSTH with a mean (m = 3.6) and lowest on SOSCUL with a mean (m = 2.8). The overall calculated mean score for the University subgroup was 3.5 points and that of the NPTC one was 3.2 points.

Syllabi Content Analysis: Nature of Science Views

In its quest to find out how Uganda science teacher educators’ views on nature of science are evident in their science methods course syllabi, the study carried out content analysis on ten syllabi that were being used by the participants. Of the ten one was from a
PTC, one from a physics education department of a NTC and the rest were university syllabi from the departments of biology, physics, home economics and nutrition, sports science, mathematics, and agriculture education, science and teacher education, and the department of science and technical education.

**Views on NOS in the syllabi.**

Analysis of the contents of the syllabi revealed that four syllabi mentioned NOS: the University physics education syllabus, the NTC physics education syllabus, the University biology department methods syllabus and the methods syllabus from the University science and teacher education department. They all mentioned NOS only once. The physics syllabi mentioned nature of physics as a science and the biology education methods syllabi nature of biology. There was no detail of what these subtopics entailed for teaching purposes. When the text was inspected for any language that implies teaching approach, knowledge, skills and values related to NOS, there was none. One university syllabus indicated time allocated to NOS learning as two hours for the entire semester. The study could not find significant evidence of participants’ views of NOS in the science teaching methods syllabi analyzed.

**Participants’ Perspectives on Preferred Science Pedagogy (PSP)**

The study’s second question asked, “What are the preferred pedagogical approaches to science teaching among Uganda science teacher educators”? The study
sought answers to this question first by asking Uganda science teacher educators to respond to the POSTT-II instrument.

Quantitative results.

The responses from the 63 participants to the 16 items on the POSTT-II survey resulted in 1008 responses. These responses constituted the data used to quantitatively answer question two of the study. A normality test to ascertain if parametric tests could be used on the data was done, the test returned a Kolmogorov – Smirnov Z value of (7.859) at (p = 0.000). Meaning that the data was normally distributed and parametric tests could be applied to it. Descriptive and inferential statistics were used to describe and explain any observable patterns in the quantitative data respectively. The frequency distributions of responses on preferences of each pedagogical orientation, that is, Didactic Direct (DD), Active Direct (AD), Guided Inquiry (GI), and Open Inquiry (OI) were presented as a bar-graph (Figure 17). This was accomplished using MS excel and SPSS software. These frequencies were also presented as percentages for better use as descriptors and for comparison purposes within and across levels of teaching.

Figure 17:  POSTT-II Responses as Frequencies and Percentages
From Figure 17, it is clear that participants’ pedagogical preferences covered the full spectrum provided. Guided Inquiry (GI) had the highest frequency of preference by 420 responses (42%). It was followed by the Open Inquiry (OI) with 295 (29%) responses out of the 1008 responses collected. Next in order of preference was the Active Direct (AD) orientation. It received 202 (20%) responses of the 1008 total responses collected. Didactic Direct (DD) received the least preference. It was selected only 91 times (9%) out of a total of 1008 possibilities.

Mixed Methods Analysis Results:

Profiling of the pedagogical preferences of the 63 participants was impossible with the results in Figure 17. In order for the study to establish each individual participant’s most preferred pedagogy, mixed methods data analysis was used. Each multiple choice questions (MCQ) response of the POSTT-II, was considered a descriptive category (typology) on its own. So each choice was given a numerical descriptor (quantization) as follows: Didactic Direct (DD was denoted as 1), Active Direct (AD was denoted as 2), Guided Inquiry (GI was denoted as 3) and Open Inquiry (OI was denoted as 4).

Each participant’s responses were then statistically scrutinized to find out not only the spread of pedagogical preferences as per the POSTT-II response scale, but indeed to zero on that one pedagogical orientation reported as most preferred or the modal orientation for participants. As an example, participant KYU-001 had responses that indicated that AD was the modal pedagogical orientation preference with a frequency of seven, representing almost 44% of all KYU-001’s 16 responses on the POSTT-II survey. This
was done for every participant and counts of participants in each modal choice tallied as frequencies and percentages for the total 63 participants (see Figure 18).

None of the participants returned responses that had more than one mode, and most of the participants returned preferences that included at least three of the four choices provided.

Figure 18 shows that a majority 37 (59%) of the 63 participants indicated that their most preferred pedagogical orientation was GI. Only one science teacher educator indicated that DD was their most preferred science pedagogical orientation. Ten (16%) participants and 15 (24%) participants indicated AD and OI respectively as their most preferred science pedagogical orientation.

Figure 18: Participants’ Most Preferred Science Pedagogy

Qualitative results.

The categories of the MCQ (DD, AD, GI, and OI) were used as typologies or lenses to interpret qualitative data from the interviews and document analysis. As shown in Figure 18, the majority of participants 37 of 63 (59%) indicated that their most
preferred pedagogical orientation was (GI). Indeed when interview responses were
analyzed, majority of those interviewed talked of this orientation as their number one
choice of teaching preference. These GI enthusiasts’ PSP views were profiled under the
umbrella heading the **Pedagogists**. Views in this profile included for example this from
participant KYU – 013.

Pedagogy teaching is where the learner is involved all the time. It is the learner who handles most
of the learning process…….in pedagogy the students are encouraged to look for explanations
themselves …. I put the students into groups and they discuss that information then I ask them
questions to answer using that information. I may not give all the detailed information which is
required, so they will also have to look for more information by getting it from friends……….my
questions will guide them to achieve a certain objective which I want……. then the different
groups present. Now during the presentations the students add whatever information they think the
other have that they do not have. That is how I move with my teaching. (KYU – 013,
interview transcript)

Another participant KYU – 022 said this about GI as the most preferred pedagogical orientation

For me, I believe in mainly knowing what the learners know about what I am going to teach and
that forms the basis for what I present. That means it is always a two way dialogue, where I ask
them questions, present issues ask what I present what does it mean to them. I make it free for
them to say what they believe in and that way I feel comfortable when we interact. I teach old
people and I believe they know a lot, so I think it is important to share experience, my experience
with them and theirs with me. I do not believe the entire force of what I teach depends on me, so
my learners come with knowledge and what is important to help them put this knowledge into context. (KYU – 022, interviews transcript)

This perspective was also shared by participant KYU – 057 who shared that

…..I use the hands on methodology ...... also I teach skills of how to add and adapt information from other areas. Like if you are bringing materials in class, you can add more by teaching them how it is made, say a skeleton, you can get local materials to make it so you do it as the students are looking, like a demonstration, after demonstrating, you can group them , after grouping them you ask them to do what they can, then they display, after displaying you do a gallery walk, you appreciate their work and they ... audibly, let them correct their work, and where they did not get it, that is when you come in as supervisor or moderator. (KYU – 057, interview transcript)

Also according to Figure 18, ten (16%) participants indicated that AD is their most preferred science teaching orientation. Qualitative data analysis confirmed that some of the participants actually preferred this orientation. These participants’ PSP views were profiled under the heading the Traditionalist. This example from participant KYU – 005 fitted in this profile.

In the traditional way, for example you teach, you ask questions, you demonstrate you do that as a way to involve the learners..... You do not only listen but you make the learners all of them participate also It is not direct teaching like say hammering the points but you accept all answers from all the learners as they contribute and you bring all those points together other than you coming and saying you must do that and that and that. (KYU – 005, interview transcript)
Figure 18 also shows that 15 (24%) participants indicated OI was their most preferred science pedagogical orientation. This preference did not clearly show up in the qualitative data. However, there were some hints. Participants’ PSP views in this category were profiled under the heading the *Vocationalist*. Examples included the views of participant KYU – 014:

Yes it is research based. You will find that most of it is very practical and we want the students to discover on their own some of the challenges that surround them in the environment and how great they can improve the environment……. We want it to be more of research so that the students are able to discover a number of things and a number of challenges and how they can overcome those challenges to make the environment a much better place to live in. (KYU – 014, interview transcript)

Lastly, only one science teacher educator reported that DD was their most preferred science pedagogical orientation. Unfortunately, the qualitative data collected failed to capture this particular participant’s views expressed in his or her own words.

**Overall participants’ views on PSP.**

Results on PSP views clearly reveal that although every participant’s teaching orientation choices spurned more than one pedagogical preference, GI was the overall most preferred science pedagogical orientation, followed by OI. The least preferred was
Only one participant had choices that presented DD as the most preferred PSP (Figure. 18).

The Pedagogists trumpet active participation by all students all the time. The Vocationalists prefer a science teaching orientation that is hands on and experimental for their students. Meanwhile the Traditionalists love teaching orientations that allow students to chip in some times and do not let the instructor to do all the talking most of the time.

University Vs NPTC science teacher educators views on PSP.

The study further investigated if there were any differences in views on preferences of science pedagogical orientations between the higher level (University) science teacher educators and their lower level (NPTC) counter-parts. The results are presented in Figure 19 below.

**Figure 19:** University Vs NPTC Participants Most Preferred Pedagogy
The Figure 19 shows that the majority of university level 16 (46%) and NPTC level 20 (71%) (See also Table 7 below) science teacher educators indicated that GI is their most preferred science teaching orientation from all the preferences presented by the POSTT-II. Seven university participants (20%) indicated AD and other 12 university participants (34%) indicated OI as their most PSP orientations. For the NPTC four participants (14%) indicated AD and three participants (11%) indicated OI respectively as their most preferred science teaching orientation. One NPTC participant (4%) indicated DD.

Table 7: University and NPTC PSP Preferences

<table>
<thead>
<tr>
<th>Level of Teaching</th>
<th>Pedagogical Preference (%)</th>
<th>Didactic Direct (DD)</th>
<th>Active Direct (AD)</th>
<th>Guided Inquiry (GI)</th>
<th>Open Inquiry (OD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td></td>
<td>0</td>
<td>20</td>
<td>46</td>
<td>34</td>
</tr>
<tr>
<td>N/PTC</td>
<td></td>
<td>4</td>
<td>14</td>
<td>71</td>
<td>11</td>
</tr>
</tbody>
</table>

Syllabi Content Analysis: Preferred Science Pedagogy Views

Results of the analysis of ten syllabi for views on preferred science pedagogy are presented below.

PSP views in the syllabi.

All the university syllabi provided qualitative descriptors on preferred science pedagogy that only mentioned the approaches to be used. They mentioned that lecture, discussion,
individual and group work/assignments were the pedagogical strategies for the course but without elaboration. Therefore, University participants’ views on preferred science pedagogy were not clearly evident in their science methods syllabi.

On the other hand, the NPTC integrated science education syllabus was very specific on the science pedagogy of choice. It named it explicitly as Guided Inquiry (GI). The syllabi used phrases like, Students brainstorm and discuss, tutor guides students in groups or as individually, in group discussion, through library and internet search students will find out, in groups students display, in groups students prepare and demonstrate, as a project students carry out… These were used to describe and articulate the pedagogical orientations to be followed. The syllabus overtly stated that educators target to assist the students to develop the following skills: Creative thinking, critical thinking, problem solving, and effective communication. This language is ubiquitous in the NPTC syllabi.

Participants’ Views on Classroom Learning Environment (CLE)

Next, in this section results are presented to answer question three of the study, “According to Uganda science teacher educators, what does a classroom environment look like when preferred science teaching is taking place?”

The study solicited responses from its participants in two ways. One, they were asked to respond to a standard classroom environment survey, the Constructivist Classroom Survey version II (CLES-II (20)) (Johnson & McClure, 2000). This particular
survey was modified specifically for use with science teachers and the study found it appropriate for use on science teacher educators also.

The CLES-II (20) data was tested to find out if it was normally distributed (D'agostino et al., 1990; Lilliefors, 1967). The normality test returned a Kolmogorov-Smirnov-Z (KS-Z) score of 1.104 with p = 0.174, for the full data set, KS-Z score of 0.895 with P = 0.399 for the NPTC subgroup data set, and KS-Z score of 0.700, with p = 0.711 for the university subgroup data set. These tests confirmed that the data sets were normally distributed and the appropriate parametric statistical tests could be used. The study recognized the fact that there is some disagreement about whether it is appropriate to use parametric statistics with Likert scale data. The study was convinced by the work of Carifio and Perla (2007) and Brown (2011) that Likert scale data can be analyzed using parametric statistical approaches and measures. Furthermore, Norman (2010) provides empirical demonstrations that show that using parametric statistics on Likert scale data does not affect the “Robustness” of the statistics whatsoever.

The small number of participants (63) did not allow the study to carry out a meaningful factor analysis for the data. This is because the study needed at least 100 participants to satisfy the minimum ground for meaningful factor analysis of at least a ratio of five participants to every item (5:1). Since the original reliability studies of the CLES-II (20) were done outside Uganda, this study needed to establish its reliability for use in Uganda. Reliability tests returned a Cronbach’s Alpha of 0.792 for the instrument as a whole which is acceptable (McCroskey & Young, 2006).
Table 8: CLES-II (20) Scales Reliability Measures

<table>
<thead>
<tr>
<th>CLES II-20 scale</th>
<th>Cronbach’s Alpha</th>
<th>Evaluation/Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-relev</td>
<td>0.563*</td>
<td>acceptable</td>
</tr>
<tr>
<td>Uncert</td>
<td>0.595*</td>
<td>acceptable</td>
</tr>
<tr>
<td>C-voice</td>
<td>0.403</td>
<td>unacceptable</td>
</tr>
<tr>
<td>S-cont</td>
<td>0.812**</td>
<td>acceptable</td>
</tr>
<tr>
<td>S-nego</td>
<td>0.849**</td>
<td>acceptable</td>
</tr>
</tbody>
</table>

The study was faced with choosing to keep or drop the scale (C-voice) which returned an unacceptable reliability (Table 8). When C-voice was dropped, the model as a whole returned a reliability measure of Cronbach’s Alpha = 0.768. This is acceptable but less than when the C-voice scale is included. So judgment of retaining the C-voice scale was made since it seemed to be a good contributor to the obtained reliability (Cronbach’s Alpha = 0792) of the survey (McCroskey & Young, 2006). The data reported in this section is based on all five scales of Personal-relevance, Uncertainty, Critical-voice, Shared-control, and Student-Negotiation. These are participants’ responses to the four CLES-II (20) statements in each of the five scales as frequency distributions and as percentages.

Responses on the Personal relevance scale.

This scale solicited participants’ views on how intentional they are about making the classroom learning experiences in their rooms relevant to their students’ futures as teachers and to their lives outside the classroom.
Quantitative Data Analysis Results:

Figure 20 below shows participants’ responses on the (P-relev) scale. These are measures of their intention to create a personal-relevant CLE as measured by the Likert scale of the survey. Participants’ responses to the survey spurned the full Likert scale.

Figure 20: Participants’ Responses on Personal Relevance Scale

A total of 252 responses were collected on the scale. Four responses (1.4%) were on the lower score end of the Likert scale. Of the remainder, the majority were in the upper most two scales of the Likert spectrum: Often, 100 (40%) responses and Almost always 96 (37.6%) responses. However, there were 52 (21%) responses at the “Sometime” scale score level.
Mixed Methods Data Analysis Results:

The quantitative data from the survey could not appropriately help the study to decipher the views of the participants on PSP. So these data were transformed to qualitative categories.

The rationale of this data transformation which is inherent in the pragmatic research worldview was done to enable the study to make categorical qualitative judgments on collected quantitative responses and to generate typologies useful in the interpretation of the qualitative data (Driscoll et al., 2007; Spillane et al., 2010). The qualitizing was as follows:

The responses on each survey scale were inspected and evaluated as a group/battery. They were then categorized as follows:

**Category 1 (Struggler):** All four responses in the battery/scale consisted of only lower Likert scale scores (1s and 2s). For example, (1, 2, 2, 1).

**Category 2 (Transitional):** All four responses on the battery/scale were only 3s (3, 3, 3, 3) or included at least one upper Likert scale score (4s or 5s), for example, (4, 2, 1, 1).

**Category 3 (Performer):** All four responses in the battery/scale consisted of only upper Likert scale scores (4s and 5s), for example, (4, 5, 5, 5).

Therefore, qualitizing of quantitative responses data on the scale of Personal relevance (P-relev) revealed the qualitative categories inherent in the responses and their abundances as shown in Figure 21 below.
Figure 21: Participants’ Views on Personal Relevance

From Figure 21 the results show that majority 38 (60%) participants’ views were categorized as *Transitional* and the rest of the views, 25 (40%), as *Performer*.

Qualitative Data Analysis Results:

When the two categories generated by mixed methods data transformation were used as lenses to categorize and interpret the interview response during interview data analysis, it was evident that the interview responses fitted these typologies. For example, participant KYU – 005 had this to say on the aspect of P-relev.

… Class science will still need to be triangulated into life. Science should not remain in class because it will not be useful the ideas in class must be translated into real life. like when they do field excursions when they go out and explore…… the tendencies is for the teachers to teach soil erosion, theoretically, they say they do not have time to take the students where the soil erosion occurs e.g. in the gardens , or the sides of the roads, e.g. these murram roads to see and that it ..you know many students drop out and they should be able to use what we teach them to either solve their day to day problems or earn a living. (KYU – 064 interview script)
This participant had a positive belief that creating a CLE with personal relevance to life outside of the classroom can help ‘vocationalize’ science learning experiences. This belief was also shared by participant KYU – 013 whose views on the Personal-relevance aspect of a CLE is evidenced in this excerpt from participant KYU – 013 transcripts.

They should use the knowledge to practice in the community. Like the nutrition students what I teach them in class, is supposed to be practically usable in the community for example; students are supposed to describe diets, they are supposed to understand conditions like fever, they are trained to be dietitians, so if somebody has a fever, a student is to give recommendations of the right foods so now when you are training them in class you do it in such a way that they know when to use the knowledge which they have to recommend the right foods to different conditions.

(KYU – 013 interview script)

The views expressed in these excerpts convinced the study to label these participants as *Performer Exemplars*

The qualitative data also revealed participants views on CLE that were *Transitional* in nature. For example this excerpt from participant KYU -048 interview transcripts that, “...when you teach you get time to tell the students the implication and the life skills they get outside class and how they can integrate the concept that I have taught in their day to day living”. Responses of this kind that represented what the teacher does and not what the learners actively experienced were taken to be suggestive of *Transitional* views on this aspect of the CLE. This was evident in the following excerpt where the participant acknowledged that it still a challenging to make classroom science experiences relevant to students’ life outside the classroom. Participant KYU –
062 shared this with the study on this aspect of personal relevance of the classroom learning environment.

That one is a challenge….., because like we say the curriculum must serve the society as society serves it. Integrating student experiences with curriculum content needs an extra mile. Like since many of us were not taught that way, we try to break away from that way, otherwise basically it is just teacher and talk. Now the attitude of these students towards the subjects and towards the tutor will really depend on how you integrate what is in the curriculum and what is familiar to them. Interpreting this curriculum into applications and daily activities will be the order of the day.

(KYU – 062 interview script)

**Responses on the Uncertainty scale.**

The Uncertainty scale collected views on participants’ presentation of school science that correctly portrays science as evolving, not having all answers to all problems, and culturally and socially determined. Figure 22 below shows the distribution of all the 252 responses on the Uncertainty scale on the Likert scale of scores.

![Figure 22: Participants’ Responses on Uncertainty Scale](image)
The results in the above figure indicate that most responses 33% (83 of the 252) were in the middle of the Likert scale (Sometimes). The upper scales of Often and Almost always had 49 and 40 responses each respectively that is a combined 35% of the 252 responses, and on the lower Likert scales of Seldom (51 responses) and Almost never (29 responses) which was a combined total of 32% of all the scores.

Mixed Methods Data Analysis Results:

For the study to categorize these responses into descriptive typologies and to ascertain their abundances the quantitative responses were qualitized and the frequencies of the resulting categories obtained as shown in Figure 23 below.

Figure 23: Participants’ Views on Uncertainty

As shown in Figure 23, qualitizing participants’ survey responses on the Uncertainty scale yielded three categories of views: Struggler views 1 (2%), Performer views 4 (6%) and the majority views as Transitional views 58 (92%).

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Qualitative Data Analysis Results:

The interview data revealed some responses that fit the Struggler category or typology. These responses were not very elaborate but were indicative of a failure to identify aspects of the instructor’s practices that fitted the requirements of the aspect of the CLE. For example responses in this exchange between the interviewer and participant KYU – 051

**Interviewer:** If you are in science do you allow all the students to know that science does not have all the answers to all human problems?

**KYU 051:** I do not know? Depending on the questions they ask, yes there are some questions you cannot answer scientifically

**Interviewer:** As you teach do you allow them to be comfortable that actually science is not the absolute answer to every problem that we may face

**KYU 051:** I do not know what I would do

**Interviewer:** I mean what you do as you teach about diet. Do you allow that uncertainty to continue?

**KYU 051:** no at least I have not got that experience before of something that I cannot scientifically address as far as nutrition is concerned. I have not

These none elaborate and scanty responses showed that participants do not actively or vibrantly allowing for students to encounter uncertainty in science.
The *Transitional* profile included responses representing the majority views (see Figure 23). A good exemplar for responses profiled as *Transitional* is the following excerpt from participant KYU – 014:

Yes, we do that is why we have the induction training we take them to those areas where our services are wanted and when they reach there they register what challenges they meet and they try to use scientific approaches towards solving those challenges. In case they get stuck they consult with us and we help them to sort out the challenges. (Participant KYU – 014 interview transcripts)

This excerpt is a good illustration on an instructor that is lacking the confidence to allow for uncertainty in a science learning environment.

On the other hand the *Performer* profile included responses representing only four (6%) of the views. However these were the participants with views that resonate with the requirements of the aspect of Uncertainty in a CLE. A good exemplar was this excerpt from participant (KYU – 013)

It can happen several times when something comes up may be somebody has read further and a student asks a question and nobody knows the answer. Normally what I do is refer everybody to find out about that information. Then the following time it is what is used to introduce the new lesson, with that discussion of what have you found out sometimes you may fix them to deal with unknowns answers in science. (KYU – 013 interview transcript)
This participant though not hinting on particular aspects of CLE believes that it is ok for learners to leave the classroom with unsolved epistemological issue in science.

**Responses on the Shared control scale.**

The Shared control scale surveyed participants’ views on how they make sure their students have opportunities to explain and justify their ideas, and to test the viability of their own and other students’ ideas during their teaching. Results of distributing the 252 responses from the 63 participants among the survey Likert scale scores are shown in Figure 24 below.

![Image of the Likert Scale Score](image.png)

**Figure 24: Participants’ Responses on Shared Control**

The results show that the majority of responses 135 (54%) were Almost always. The response of Often was selected 58 times (23%); giving the upper scale scores a combined total of 77% of the scores. Seldom and Almost Never were chosen 13 and 2
times, respectively, which when combined is only 6% of the responses. The middle
ground response “Sometimes” received 44 (18%) of the responses.

Mixed Methods Data Analysis Results:

In order to categorically describe participants’ views on this aspect of the CLE,
their quantitative responses were qualitized. This data transformation yielded two
categories as shown in Figure 25 below. The categories also were used as typologies in
interpreting qualitative data from interviews.

![Figure 25: Participants’ Views on Shared Control](image)

Data transformation revealed that none of the participants’ views could be
described as Struggler. Therefore, all 63 participants views were either in the **Performer**
category 22 (35%) or in the majority **Transitional** 41 (65%) category.

Qualitative Data Analysis Results:

Typological qualitative data analysis of interviews using categories generated by data
transformation produced support of mixed methods results. For example, participant
KYU – 013 had this to share as their effort to allow for argumentation, a form of shared control in the CLE.

You may use some questions, you do not directly give them the answer but you ask questions around it to try to make them understand where the problem is so that you get more people joining the argument I mean more people agreeing on the right answer. So my work is to ask questions such that I seek improvement in their understanding of the content presented by the problem so that from there they can now deduce the answer and agree and accept that that is the right answer.

(KYU – 013, interview transcript)

Another participant KYU – 005, had this to share:

……I accept all answers from all the learners as they contribute and I bring all those points together other than I coming and saying you must do that and that and that. They learn to respect each other’s answers, they learn to listen to one another, they learn what is right and from their judgments they can come up with conclusions and say this answer is better than the other, and they learn and do not forget. There is that freedom of expression and also these students become confident, assertive and able to express themselves. (KYU – 005 interview transcripts)

These two excerpts are example of responses carrying views the study labeled argumentation promoters. These were profiled as Performer category.

Following is an excerpt from a conversation of the study with a participant. In this discourse the participant reveals that allowing for Shared control is not one of the strengths of the CLE created. Such responses were profiled as Transitional. In this
interview exchange, shared control of the learning environment was discussed and the role of the instructor and the learners in this process revealed.

**Interviewer:** Ok imagine that in that kind of environment you end up having a student or a group of students or two students disputing or disagreeing over something e.g the material you are teaching or it could be the way you are teaching the material, and they go into an argument about it and you are in the class how would you handle such a situation?

**KYU - 057:** “If it is a group of course I have to call for their attention, then I ask them what the matter is then I come in to correct them and show them the right way to go”

**Interviewer:** What else do you think you can do to address the situation?

**KYU - 057:** Yes alternatively I can get another group which is not arguing and it has done the work as I wanted, to work together with the other one (arguing group) so that they do child to child or teacher to teacher .....I think it can work best, whichever so that the other group cannot remain in darkness.”

**Responses on the Critical voice scale.**

The Critical voice scale measured the participants’ views on how they allow their students to feel free and empowered to question their pedagogical plans and methods. The distribution of the 252 responses from the 63 participants on the Likert scale scores are shown in Figure 26. These results show an almost normal distribution with a mode of Sometimes 84 (33%). The rest of the responses are distributed as 52 (21%) combined
responses on the lower score side of the Likert scale and 116 (46%) combined responses on the upper score side of the scale.

**Figure 26: Participants’ Responses on Critical Voice**

Mixed Methods Results:

Quantitative data transformation yielded three descriptive categories with corresponding abundances as shown in Figure 27 below.

**Figure 27: Participants’ Views on Critical Voice**
Data transformation showed that participants’ responses fitted in all three categories with abundances as shown in Figure 27. The category *Struggler* consisted of 2 (3%) of the participants’ views. That of *Performer* consisted of 5 (8%) participants’ views. The majority 56 (89%) participants’ views were of the *Transitional* category.

Qualitative Data Analysis Results:

When typological qualitative data analysis of interview responses was done using the data transformation categories, it was awash with responses in support of mixed methods generated categories. For example, participant KYU – 022 who fitted the *Transitional* category had this to say about allowing for critical voice “… the students are mature, they will demand it like in my department, and they will say you have not done practicals in this and that area”

Another excerpt that shows how the critical voice aspect plays out in the classroom environments created by the participants is depicted in this exchange between the study and participant KYU – 051 who the study also considers to fit the *Transitional* profile.

**Interviewer:** Do you allow them to question how or what they are learning?

**KYU 051:** They do not question how but what they are learning. How is this going to help us? How does it improve our teaching?

**Interviewer:** But you do not allow them to question how you are teaching

**KYU 051:** Not that I do not allow them to, but they rarely question how I teach
Interviewer: Would you want them to ask you how you are teaching?

KYU 051: I would not mind e.g. madam why are you teaching us this way? Why are you telling to do research?

Interviewer: So do you encourage them to ask you why you do the things you do

KYU 051: Yes actually we encourage them to ask us and also encourage them to state whether they are comfortable with those methods or not. That is especially for the diploma level.

These responses represent the notion that it depends on students for critical voice to manifest. It is not a result of deliberate efforts by the instructor.

The notion of allowing students a free rein to question instructors’ pedagogical and procedural decisions in the CLE was shared positively by almost all the participants that were interviewed. The following excerpts are examples of those that fitted the Performer profile:

Science has no room for such ... a teacher with that attitude of I am the master of knowledge' because knowledge has no limits especially now when new frontiers of knowledge are being discovered. a student on the internet can get the latest information on an item so that student can challenge you and you cannot say no you have to put yourself in a position of someone ready to learn from a learner, they will see you as a person who is resourceful. (KYU – 064)

Learning does not end as you said some students are sharper, some of them even read more than me. Even some of the ideas they may come up with you don’t know but you do not have to show them that you do not know but deep in your heart you know that it is a new idea to you don’t
reject it. There is a way you bring it in and you incorporate it into the work that you are giving.

(KYU – 005, interview transcript)

Another Performer exemplar excerpt is this interview exchange between the study and participant KYU – 014.

KYU - 014: That is ok. It is healthy for them to critic my teaching and may be bring out ways in which they would go about the same content and that is ok

Interviewer: So in your learning environment they are free to critically speak about what is going on

KYU - 014: Exactly, they are and that is what we love. it is very healthy for them to comment on how you are teaching, the method you are teaching with, the content you are teaching how you have handled a content whether it is from complex to easy or easy to complex that is very healthy...

For the profile Struggler, the following exchange between the study and participant KYU – 048 is a good exemplar.

Interviewer: so would you say you are the type that readily welcomes being criticized by your students?

KYU – 048: no..., yeah but it has to be a positive criticism.in a way that is geared towards the students learning.

In this interview exchange the participant evidently showed a struggling posture with the idea of Critical voice in the CLE.
Responses on the Student negotiation scale.

The Student negotiation scale surveyed participants’ views on how they ensure that the students have opportunity to contribute to the design and management of learning activities, criteria of assessment, and social norms of the classroom. Like all the other scales of the CLES II-20, there were 252 responses to this scale distributed on the Likert scale scores as shown in Figure 28. The mode response is Sometimes with 91 (36%) responses. Meanwhile, 21 responses (9%) were on the lower score side of the scale and 140 (55%) were on the upper side.

Figure 28: Participants’ Responses on Student Negotiation

Mixed Methods Data Analysis Results:

Mixed methods data analysis transformed quantitative data into categories usable in qualitative data analysis as typologies. Data transformation also assisted in providing
categories for describing participants responses to expose the inherent views about this aspect of CLE. Qualitizing yielded two categories with various abundances as shown in Figure 29 below.

![Pie chart showing percentages of participants' views]

**Figure 29:** Participants’ Views on Student Negotiation

Figure 29 shows that majority 42 (67%) of the participants had views on the aspect of Student negotiation in a CLE classifiable as *Transitional* and the rest 21 (33%) participants’ views as *Performers*.

Qualitative Data Analysis Results:

When the mixed methods typologies were used as lenses to interpret interview data, results supported the results in Figure. 29. The following interview exchange between the study and participant KYU – 057 is a good exemplar of responses indicative of views profiled as *Transitional*:

**Interviewer:** Do you ever ask your students to help you plan the content?

**KYU - 057:** yes, yes yes I use them
Interviewer: How do you do that?

KYU - 057: “Especially when I have a lot of work, I pick a certain group of students then I give them to research it in their groups, they bring what I had asked them to do then I use it for teaching”

Interviewer: In that way they get involved in planning the experiences you will be using?

KYU - 057: “Yes and I think they enjoy it because by the time I stand confidently teaching them, I know I will have some participation among the learners”

Also a Transitional view of ‘yes and no’ is expressed in this excerpt from participant KYU – 048 in interview exchange with the study.

Interviewer: Do the students contribute to plan what you are going to teach?

KYU - 048: No necessarily help me to plan but I would also say that it is yes or no because why I am saying yes is that when planning what to teach it depends on the level of these students understanding. In other words you cannot plan without you putting in mind the level of their understanding.

Interviewer: So, much as they will not be there physically you will be thinking of them

KYU - 048: Exactly

Interviewer: So they will be passively influencing you and your plan.

KYU - 048: My planning?

Interviewer: Do they help you decide which activities you use best for them?

KYU - 048: Oh no, no no no
As for the *Performer* profile on this aspect of a constructivist learning environment (CoLE), the following interview exchange between the study and participant KYU – 061 is a good exemplar.

**Interviewer:** Do you allow your students to get involved in deciding which activities you should work best with?

**KYU - 061:** *Yeah there is a situation where you can ask them to decide what work is best to use and they come up with their ideas.*

**Interviewer:** but most cases?

**KYU - 061:** *In most cases we are the ones who decide for them the activities but once in a while you may leave them the liberty to select their own way of study.*

**Participants’ overall responses on the CLES-II (20).**

Overall, the performance of these science teacher educators on the CLE-II (20) was as shown in Figure 30 and their views were categorized as seen in Table 9 below. These participants had an overall 63 (100%) Transitional views on CLE. The group performed best on the Personal relevance and Shared control scales with averages scores of 4.1 and 4.2, respectively. They performed second best on the Critical voice and Student negotiations scales with average scores of 3.1 and 3.7, respectively. They performed least on the Uncertainty scale with a mean scale score of (2.5).
Table 9: Classification of Participants’ Views on Aspects of CLE

<table>
<thead>
<tr>
<th>Aspect of CLE</th>
<th>Classification of Views (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performer</td>
</tr>
<tr>
<td>Personal Relevance</td>
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</tr>
<tr>
<td>Uncertainty</td>
<td>6</td>
</tr>
<tr>
<td>Critical Voice</td>
<td>8</td>
</tr>
<tr>
<td>Shared Control</td>
<td>35</td>
</tr>
<tr>
<td>Student Negotiation</td>
<td>33</td>
</tr>
</tbody>
</table>

To find out if the observed differences (Figure 30) on the mean scale scores were statistically significant, analysis of variance ANOVA with a Post hoc (Tukeys test) was used. ANOVA returned a significant test $F (4, 310) = 83.0, p = 0.000$. This meant that at least one of the observed differences in the mean scale scores was real (statistically significant and not due to chance). Post hoc comparisons using the Tukey HSD test indicated that only the mean score for P-relev ($M = 4.1, SD = 0.53$) was not significantly different from that of S-cont ($M = 4.2, SD = 0.52$). Otherwise the rest of the means for the other scales were significantly different.
Figure 30: Participants’ Mean Scores on CLES-II (20) (n=63)

Table 10: Correlations between CLES-II (20) Responses

<table>
<thead>
<tr>
<th></th>
<th>P-relev</th>
<th>Uncert</th>
<th>Sh-cont</th>
<th>C-voice</th>
<th>S-nego</th>
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</thead>
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<tr>
<td>P-relev</td>
<td>r</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<td>.333**</td>
<td>.322*</td>
<td>.283*</td>
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<td>N</td>
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<td>63</td>
<td>63</td>
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<td></td>
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<td>63</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Sh-Cont</td>
<td>r</td>
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<td></td>
<td>Sig.</td>
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<td>63</td>
<td>63</td>
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<td></td>
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<tr>
<td>C-voice</td>
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<td>Sig.</td>
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<td>N</td>
<td>63</td>
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</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Inter-associations between the five scales.

The study also wanted to know if there existed any form of inter-associations among the views of respondents as measured by the scales of the CLES II-20 survey instruments. The study calculated each participant’s mean score on each scale. These mean scores (63 scores for each scale) were used to run a correlation test between the different scales of the survey using SPSS software and the results were as shown in the Table 10 above.

University Vs NPTC participants’ scores on the CLES-II (20)

Further, the study sought to establish if there is a difference in the CLES-II (20) scores between the university science teacher educators (who comprise the upper level cadres of this professional sub group) and their lower level NPTC counter parts, who teach at the National teachers colleges (NTC) and Primary teachers colleges (PTC). Average scores on each scale for each subgroup were compared as shown in Figure 31 below.

Figure 31: University vs NPTC Mean Scores on CLES-II (20)(n=63)
From figure 31 it is shown that both groups had their lowest mean scores on the Uncertainty scale (3.3/University and 2.8/NPTC). The highest mean score was on the Shared control scale (4.3/University and 4.1/NPTC). These scores were statistically the same to the scores on the P-relev scale (4.2 University and 4.0 NPTC).

The averages for Student negotiation were remarkably close to higher (3.8/university and the 3.6/N/PTC). It is only on the scales of Personal-relevance and Shared control that both subgroups averaged above a 4.0. When an independent T-test was done to establish if the observed differences were significant, results showed that only the differences between the subgroup scores on the Uncertainty and Shared control scales, Uncertainty and Personal relevance are statistically significant (p = 0.18) and (p = 0.17), respectively.

**Syllabi Content Analysis: Classroom Learning Environment Views**

Analysis of the ten syllabi revealed the following about espoused views on classroom learning environment.

**CLE views in the syllabi.**

University syllabi did not provide any qualitative descriptors useful to infer depiction of envisaged classroom learning environment. All they did was to state proposed methods of content delivery as described in the previous section. Therefore, the study reports here that the university participant’ views on classroom learning environment are not evident
in the science methods syllabi they use. However, the NPTC syllabi state overtly that the desirable values the teacher candidates should develop include values like care, togetherness, concern for others cooperation, patience, sharing, and appreciation. These values are possible to develop when the teacher candidates experience the kind of pedagogy preferred as was shown on NPTC pedagogical stipulations. The classroom learning environment that can allow for their development should allow for: Discussion, free interaction in groups or individually, allowance to research materials, argumentations and presenting before the class. These activities are overtly suggested in the syllabi.

**Correlation between Views on NOS, PSP and CLE**

Question four of the study was an inquiry on correlations between the participants’ views on the three areas of NOS, PSP, and CLE. The question, “How are Uganda science teacher educators’ views on nature of science, preferred science pedagogy, and classroom learning environment correlated, if at all?” was answered stepwise. First, the study computed the average scores on all the three surveys (SUSSI, POSTT, and CLES II-20) for each participant. Then a correlation analysis involving this set of three average scores was run. The results are as shown in Table 11 below. The results show that there are no significant correlations whatsoever between any of the participants’ views on the three foundational areas to science education reforms investigated.
Table 11: Correlations between Scores on SUSSI, POSTT-II, CLES-II (20) (n=63)

<table>
<thead>
<tr>
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<th>CLES-II (20)</th>
<th>SUSSI</th>
<th>POSTT-II</th>
</tr>
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<tbody>
<tr>
<td><strong>CLES-II (20)</strong></td>
<td>r</td>
<td>1</td>
<td>-.180</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.228</td>
<td>.020</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>63</td>
<td>48</td>
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<tr>
<td><strong>SUSSI</strong></td>
<td>r</td>
<td>.228</td>
<td>1</td>
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<td></td>
<td>Sig. (2-tailed)</td>
<td>.072</td>
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<td>63</td>
<td>48</td>
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<tr>
<td><strong>POSTT-II</strong></td>
<td>r</td>
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<td>Sig. (2-tailed)</td>
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<td>.891</td>
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CHAPTER V

ANALYSIS AND DISCUSSION OF RESULTS

Introduction

This study used a mixed concurrent method to investigate Uganda science teacher educators’ perspectives on three areas foundational to science education reform namely Nature of science (NOS), Preferred science pedagogy (PSP), and Classroom learning environment (CLE).

Purposeful non-random sampling was used to select 63 science teacher educators at universities, National teachers’ colleges and Primary teachers’ colleges. Two NOS surveys, one PSP survey, and one CLE survey were administered to this sample. Following these surveys, a purposeful non random sample of 11 science teacher educators (from the original sample of 63) was selected for in-depth semi-structured telephone interviews. Lastly, the science teaching methods syllabi used by the participants of the study were analyzed for content related to teaching and learning NOS, PSP and CLE.

The multiple data sources used in the study provided complementary data that were triangulated with each other. The analysis of data employed quantitative, mixed methods and qualitative approaches. A mixed methods data analysis technique of data transformation enabled the study to categorize the data for easy description and also to use the categories as typologies during qualitative data analysis and interpretation. In the
In this section, the study presents the analysis and discussion of the results provided in Chapter Four in light of the research questions, raw data and reviewed literature. The presentation in Chapter Four follows the sequence of the five research questions. This analysis and discussion draws from salient features of quantitative, qualitative and mixed methods results to build meaningful and relevant answers to the five questions of this study.

Uganda Science Teacher Educators’ Perspectives on NOS

This study’s first research question was ‘What do Uganda science teacher educators understand regarding nature of science’? To answer this question, study participants responded to questions on four aspects of NOS: nature of scientific observation and inference (OBSINF), nature of scientific theories (NOSTH), and the roles of society and cultural values (SOSCUL) and creativity and imagination (CREIMA) in creating scientific knowledge. The study also analyzed their science methods syllabi for NOS relevant information.

For every aspect of NOS investigated, the study identified and profiled participants’ views into three categories of Informed, Transitional, and Naïve views, as determined by the mixed method analysis. Overall, the majority, 60 (95%) participants have a Transitional view of NOS. Only three (5%) participants (KYU 018, KYU 021 and KYU 032) were evaluated as having Informed views on all four aspects. None of the
participants have overall Naïve views on NOS. There is no significant difference between
the overall NOS views of University and NPTC science teacher educators although the
conceptions of University science teacher educators on one specific aspect (nature of
scientific observations and inferences) is statistically significant from that of the NPTC
Instructors.

On the SUSSI scales the participants’ mean score was 3.4 on a 5.0 point scale.
The highest mean score (3.7) was on NOSTH with no Naïve views reported on this
aspect. Their lowest mean score (3.0) was on SOSCUL.

The study asserts that an Objectivist or Purists view of nature of science was the
main hindrance to perceiving the acceptable consensus views of nature of science; the
subjectivity, tentativeness, influences of society and cultural values and beliefs, and the
role of creativity and imagination in science. These participants failed to understand that
the scientist is a ‘data collection tool’ and the main source of subjectivity in science; that.
creativity and imagination of the scientist is used ubiquitously in science. Instead,
majority participants accepted creativity as having a part to play in science and rejected
the role of human imagination. The study argues that the objectivist view of science
blinded them from perceiving how the role of imagination goes hand in hand with that of
creativity. They considered human imagination as a carrier of human subjectivity because
of their empiricist view point but they never perceived this with human creativity. To
them, creativity is more objective than imagination.

This study determined (based on participants’ biographical data) that the majority
of the participants had a limited formal exposure to history and philosophy of science.
The study believes that this was another contributory factor to the reported overall development of these participants’ NOS views. Biographical data revealed that 28 (44%) participants had never been formally instructed in either history or philosophy of science, 25 (40%) participants had been exposed to at least one of them, and only seven (11%) had been formally exposed to both of them. These science teacher educators had also reported more than five years of professional experience and some were heads of science departments. Scholars suggest that learning history and philosophy of science, is one of the best ways to be introduced to and to get exposure to matters concerning NOS (Matthews, 1994; Rudge & Howe, 2004, 2009). The study believes that professional development (for these participants) involving a sizeable NOS content would ameliorate this situation. Conversely, science teacher education methods syllabi could involve experiences that expose teacher candidates to the history and philosophy of science (Abd-El-Khalick, 2005).

These study results implicate professional science teacher education for the failure (noted in the statement of the study problem) by classroom science teachers to articulate knowledge matters concerning NOS and to make science learning interesting and humanized. At the least, they are a reflection of what NOS knowledge science teacher candidates get during their professional training. Moreover, the absence of a significant difference between the NOS views of university level participants (majority reported having doctorates and master degrees) and NPTC participants (majority of whom reported having only bachelor’s degrees) could be intriguing. This intrigue dissipates immediately when one realizes that most of the NPTC participants were former students
at the university departments where the university participants are currently educators. This scenario could also explain the poor NOS knowledge among classroom science teachers.

The participants’ understanding of NOS, revealed in this study, may be applied to strategic planning and development of successful promotions of ‘science for all’ such as school science curriculum revisions and implementations that effectively humanize classroom science and create enabling classroom learning environments.

The study, in the next section, discusses the participants’ understanding of each of the four (OBSINF, NOSTH, SOSCUL, CREIMA) aspects of NOS.

**Participants’ views on OBSINF.**

The group of 63 science teacher educators had an average score of 3.3 on this aspect on the SUSSI scale (Figure 4.9) meaning that they had a fair understanding of this aspect of NOS. However, the university subgroup scored a higher mean of 3.5 compared to the NPTC subgroup that had a mean of 3.0 (Figure 4.10). This was a statistically significant difference (p =0.003) at alpha level (0.05) on their conception of the nature of scientific observation and inferences (OBSINF). This study postulates that since most of the university participants had undertaken graduate studies and were involved in more research activities, these factors may have contributed to the better conception of the subjectivity of scientific observations and inferences.

Study results further demonstrated that the majority 37 (59%) participants’ views on the nature of scientific observation and inferences were *Transitional* (Figure 4.2).
Qualitative views collected by the VNOS-270B survey, free response on the SUSSI survey and interviews complemented and triangulated these findings. These views were labeled ‘Always same observation but sometimes different interpretations’. This is because the participants’ responses reflect that they correctly perceive that different conclusions and interpretations can be made of the same observations but the observations by the scientists must always be the same. For example, an excerpt from participant KYU – 016 interview transcripts states that “The observations are always the same but the interpretations will depend on the level of expertise and the assumptions under consideration.”

The study deduced that these 37 participants are most likely to have contributed responses on this SUSSI scale that spread over the full spectrum of the SUSSI Likert scale. Their responses expressed agreement both in the affirmative and in the negative on this scale. Based on the data as exemplified by the excerpt above, the study recognizes that these participants’ understanding of scientific observations fails to envision the influence of prior knowledge on what is observed. This influence is what scholars of NOS refer to as theory laden observations and inferences which contrast the objectivist thinking that perceives observations as being independent of the observer and therefore pure representation of the behavior of nature as recorded by the observers’ sense organ (Abd-El-Khalick, 2005; Chalmers, 1999a). In reality, these participants do not fully understand the possibility of a single or multiple observers of the same natural phenomenon seeing or registering different realities from the same observed phenomenon. In other words, they do not conceive scientific observations as being theory
laden or influenced by past experiences. However, their understanding of scientific
inferences is in agreement with the consensus view of teachable NOS (Lederman et al.,
2002). That is, they conceive that scientific inferences/interpretations of any observation
registered by the sense organs are influenced by prior knowledge and experiences of the
scientist and the theory guiding the particular study in which the observations occur.

These Transitional views on OBSINF do not fully conform to the consensus view
of teachable NOS. They reveal that the majority participants do not properly conceive the
subjectivity of scientific observations although they do for scientific inferences. Meaning
that, they do not recognize the possibility of theory laden observations, a possibility held
by the consensus view of teachable nature of science (Lederman et al., 2002).

Only 19 (30%) participants’ views qualified as Informed or consistent with the
consensus model of this aspect (Figure 8). These views were labeled ‘Prior knowledge
and skills color observations and their interpretations’ because they acknowledge the
role of prior experiences in what scientists observe and the interpretations they make. The
following excerpt exemplifies their views:

Scientists’ observations and interpretations may be different because of subjectivity brought about
by one’s prior experience. People observe/interpret objects through their lens of prior knowledge
on the often, hard scientists observation and interpretation may be the same because they follow
standard methods and procedures. (KYU – 022 interview transcript)

The study argues that these participants’ responses must have contributed to only
the majority 149 (59%) upper scale score, (goal responses) of the 252 responses on the
SUSSI survey (Figure 7). These responses were profiled as *Informed* or tutored conception of scientific observations and inferences because they were in agreement with those of the ‘consensus’ view of teachable NOS (Lederman et al., 2002). The views of these participants reveal an understanding that scientists approach study observations with prior knowledge or experiences and that these experiences influence or color what the scientists observe, its interpretation and the inferences reached, based on these interpretations (Chalmers, 1999a). In other words, these views support the theory laden view of scientific observations and inferences.

The consensus view of teachable NOS considers scientific observation and inference to be different by nature and to be subjective due to theory ladenness. It rejects the Absolutist/Objectivist or Radical empiricist view that, ‘the observation is independent of the observer and embraces the constructivists or Post positivist views that observations are not independent of the observer and the experiences they hold. It holds the view that observations and inferences are prone to subjective biases from the individual scientists. Epistemologically therefore, like all other forms of knowledge, observational knowledge shares the human attribute of subjectivity and fallibility (Lederman et al., 2002). The participants whose views were profiled as *Informed* are in agreement with the science education community, accepting that scientific observations and inferences are rather subjective and not objective.

Lastly, the results also showed that seven (11%) participants’ views were profiled as *Naïve* ‘un-tutored’ or un-sophisticated (Figure 8). These were labeled ‘*same reality, same observation always*’ because they argue that scientists will always make the same
observation and the same meaning of a natural phenomenon. An exemplar of these views is the following excerpt from participant KYU – 045 interview script:

Scientists’ observations and interpretations are the same when, for example, the objective is the same and the procedure or process of arriving at or conducting the experiment is the same, with other variables, being constant other than the one being investigated. Physical observations do not differ for different objects hence facts about such observations remain the same. (KYU – 045 interview transcripts)

The study adduced that these participants must have contributed to only the unacceptable lower scale scores 103 (41%) responses on the SUSSI survey (Figure 7). These responses reveal that these participants do not conceive, in any ways, that scientists observing the same natural phenomenon can through their senses register different impressions of the natural phenomenon being studied, let alone have different interpretations of the same observed phenomenon. In other words, these participants hold the understanding that observing the same natural phenomenon leads to acquiring the same experience, which is interpreted similarly by all observers. This view of the nature of scientific observations and inferences is totally the opposite of the views of the consensus view of teachable NOS (Lederman et al., 2002).

Participants’ views on OBSINF profiled as Naïve reject the subjectivity of scientific observations and inferences because they refuse to recognize the theory laden nature of these scientific activities.
Overall, participants’ views on the nature of scientific observations and inferences were *transitional* in nature particularly because of a visible objectivist understanding about the nature of scientific knowledge that the majority manifested in their quantitative and qualitative responses.

**Participants’ views on NOSTH.**

The 63 participants’ views on the nature of scientific theories scored a mean of 3.7 on a five point SUSSI scale (Figure 15). Although this was very close to the 4.0 (Agree) scale level it was still categorized as *Transitional*. The study however notes that this score (3.7) was the highest compared to the mean scores on all the other aspects of NOS meaning that their perspective on this aspect may be closest to the consensus view of teachable NOS (Lederman et al., 2002).

Moreover, data transformation revealed that all 252 responses on this scale could only be categorized into two typologies: *Transitional* 51 (81%) and *Informed* 12 (19%) views (Figure 10). The absence of the *Naïve* typology indicates an acceptable perspectives of the nature of scientific theories. The study adduced that the Transitional views are the result of responses spread across the whole spectrum of the NOSTH Likert SUSSI scale.

When analyzed by level of service subgroups, the university subgroup had a mean score of 3.7 and NPTC subgroup had a mean score of 3.6 on the 5-point Likert scale. The study determined that this is not a statistically significant difference between the two subgroups on their understanding of NOSTH.
Qualitative NOSTH views of the participants were collected by the VNOS-270B survey, semi structured telephone interviews, and free responses on the SUSSI survey. These views were analyzed using the typologies generated during data transformation or qualitization of SUSSI responses. In the case of NOSTH, the profiled Transitional views included those views that were not Naïve but not fully conformed to the consensus view of NOSTH as a teachable NOS aspect (Lederman et al., 2002). These views embodied the idea that there are grounded and ungrounded theories in science. Views in this profile were labeled ‘Grounded theories never change’ because they represent a perspective that emphatically conceives scientific theories as either grounded and not tentative or un-grounded and tentative. Such views were exemplified by the following excerpt from participant KYU – 042 who shared with the study that, “grounded theories such as those of evolution and inheritance cannot change with time.” Other views with the same persuasion included this from participant KYU – 036:

scientific theories do not change over time if there is concrete experimental evidence to support them e.g. Huygens’s wave theory of light was proposed and confirmed after sometimes through experiments. Experiments also showed that Einstein’s theory was true and is still true. (KYU – 036 interview transcript)

It is evident that the understanding of nature of scientific theories expressed in views such as these is more absolutist or objectivist than post-positivist or constructivist. It is not a radical realist understanding of the nature of scientific theories (Chalmers, 1999b). Matthews (1994), expounds on this radical realist/constructivist understanding of
NOSTH by saying that “Constructivists emphasize that science is a creative human endeavor which is historically and culturally conditioned, and its knowledge is not absolute” (p. 139). So it is safe to conclude that much as these views show that these participants are aware that scientific knowledge such as theories are tentative, they are not sure or not ready to accept that even understandings held over the long-term in science are still tentative in nature; a notion typical to absolutism of scientific knowledge.

An elucidation on their perspective on the NOSTH was further revealed by knowledge of why theories change. Participants with Transitional views on NOSTH agree that scientific theories may change but they attributed the change to the need for theories to become scientific principles or laws. They hold the belief that theories, if at all they ever change, they do so to progressively becoming scientific laws or principles which cannot change. In this regard, participant KYU – 032 shared this with the study: “Theories change because they are not principles. E.g. The theory of geocentricism (the earth is at the center of the universe).” And another participant KYU – 059 shared this with the study: “Theories are not laws therefore they may be based on several assumptions and are subject to review.”

These quotes show that the views of these participants are clearly still evolving. They agree that there is a tentative nature of scientific knowledge such as theories, but they are not fully committed to the idea that all scientific knowledge (theories, principles, laws, etc.) is actually tentative. Participants whose views were profiled as Transitional have an understanding of NOSTH loaded with notions of absolutism; their views still
evolving towards the goal conception of the nature of scientific theories and laws as attested to by the consensus view of teachable NOS (Lederman et al., 2002).

The views on NOSTH profiled as Informed views were labeled as ‘Theories are products of human cognitive activity and may change’ this is because they presented a perspective on NOSTH that conceives scientific knowledge and theories as tentative and revisable. Views in this profile were shared by a minority 12 (19%) participants (Figure 10). The study adduced that these 12 participants contributed to only the sum of the acceptable 169 (62%) upper scale responses on the SUSSI survey (Figure 9).

Qualitative views in this Informed typology can be exemplified by the following excerpt from participant KYU – 047:

Science as a body of knowledge is dynamic and ever changing, being a human activity. Scientific theories change over time as a result of on-going experimentation hence they may be revised e.g., theories about the transmission of some diseases keep changing as more knowledge is gained through the scientific process. (KYU – 047 interview transcript)

The twelve participants who shared views similar to those in the excerpt above are in conformity with the consensus view of teachable NOS on NOSTH (Abd-El-Khalick, 2005; Lederman et al., 2002). These participants, convinced about the tentativeness of NOSTH, hold strong views on why new evidence and technology make scientific theories tentative. They argue that advancement in technology enables scientists to make better observations of nature. For example, this understanding is evident in this quote from participant KYU – 004: ‘Observations change with accuracy of instruments
used, hence also interpretations will change and therefore theories will be put to test.” Another participant KYU – 015 seconds this view as seen in this excerpt “depending on the tools used, modern tools may possibly reveal some information which was not easily observable. If this is the case then a theory may change.”

The study is convinced that these Informed views correctly portray a rounded understanding of scientific knowledge such as theories as artifacts of human cognitive activities and just like any knowledge; scientific knowledge also is tentative and can change (Chalmers, 1999a; Matthews, 1994). Thus they are in epistemological conformity with the consensus view of teachable nature of science.

**Participants’ views on SOSCUL.**

The 63 participants had a mean score of 3.0 (Figure 15) on this SUSSI scale based on a 5-point scale. University level participants had a mean score of 3.1, while their NPTC counterparts had a mean score of 2.8 (Figure 16). These quantitative data analysis results reveal that overall; the 63 participants’ views on the SOSCUL aspect of NOS are Transitional.

Data transformation applied on the 252 responses collected using the SOSCUL scale of SUSSI survey returned three typologies of the participants’ views: Informed, Transitional and Naïve (Figure 11).

Qualitative data from free responses on the SUSSI, the VNOS-270B and telephone interviews were analyzed using typologies generated through data transformation. In the profile Naïve, the study interpretively labeled the participants’
views on this aspect of NOS with the generally expressed thinking that ‘Matter has no culture and science is objective.’ This is because these views presented a perspective that since science deals with the understanding matter and matter has no culture then scientists who work objectively cannot be influenced by any socio-cultural norms. Included in this profile were views of 17 (27%) participants (Figure 12). The study adduces that these participants contributed responses only to the unacceptable lower score scale responses 140 (55%) (Figure 11). An example of such responses is the following excerpt from participant KYU – 006 interview transcripts: “…a molecule is a molecule and can be specifically tested for in the same ways whether in Uganda, UK or Canada.” This conception is also clearly reflected in participant KYU – 056’s views when this participant stated that, “research on light will give the same results, whatever society and culture carries it out.”

These views reflected a conception of NOS that confused ontology of nature and epistemology of science, thus, creating a misunderstanding of NOS, by these participants. Their views reflect the perception that because the natural world is made up of matter, and matter has no culture or social affiliations, scientific knowledge about matter has no cultural influences because it is just matter (atoms, molecules, etc.). This view of scientific knowledge is not acceptable since scientists (themselves a form of matter) as knowers of the natural world do have culture and belong to societies with histories of studying the physical world (Matthews, 1994). These views revealed a false understanding of nature of scientific knowledge that does not recognize that scientists themselves are communities with social and cultural values and norms that they observe.
Moreover, they do not practice their trades in a vacuum but within larger communities like, religion, political, ethnical that influence what they do and how they do it (Chalmers, 1999b; Latour, 1987; Feyerabend, 2010). These views contradict those presented by the consensus views of teachable NOS on SOSCUL (Lederman et al., 2002).

Other participants with naïve or un-tutored views on this aspect of NOS held the belief that scientists carry out their work objectively thus avoiding social and cultural influences on what they do. For example, participant KYU – 013 said that, “society and culture do not affect scientific research and scientific laws because the scientific research is conducted purely, objectively and unbiased.” This thinking is also reflected in this quote from participant KYU-046 in which this participant stated that, “scientific research or investigations is a kind of problem solving process. This problem solving process has definite steps. If these steps are followed, they should eliminate the biases and pre-conceived ideas inherent in cultural beliefs in any society.”

These results are good evidence that participants whose views on SOSCUL aspect of NOS were profiled as Naïve had no proper understanding of the constructivist epistemology of scientific knowledge and were strong objectivists in their thinking about NOS (Chalmers, 1999b; Latour, 1987; Matthews, 1994; Popper, 2002).

On the other hand majority 34 (54%) of the participants’ views (Figure 12) were categorized as Transitional in nature. The study argues that these 34 participants contributed responses to both the acceptable upper score scale 112 (45%) responses and the unacceptable lower score scale 140 (55%) responses on the SUSSI survey. These
responses were a mixture of both un-tutored and tutored conception of this NOS aspect. Such views were labeled as **Society and Culture affect “Taught science” not “Discover” efforts.** This is because they held the notion that culture and social norms can affect the school science syllabus but not the discovery efforts of scientific knowledge seeking. For example, participant KYU – 018 shared with the study that, “*society plays an important role on how and what science is taught at school because they are involved in aims and objectives for reading and learning science. Man power requirements ……so cultural beliefs may influence what science is taught but not how it is developed.*”

The study asserts that this view on the SOSCUL aspect of NOS is inconsistent with the consensus model of teachable NOS (Lederman et al., 2002) but it is one that is evolving in that direction. This is because, as already discussed, the scientific community has its own social cultural values and norms that affect scientific knowledge creation, just as the social-cultural values of the larger (national, regional, religious) community do to science and its products. This effect is not limited to school curriculum science but extends to all scientific experiences (Chalmers, 1999a; Matthews, 1994).

Another label given to some **Transitional** views was **Society and Culture affect the “Advancement” of science but not the “Process”.** Views that presented this understanding of the SOSCUL aspect of NOS correctly perceive that society and cultural values may affect the advancement or progressive efforts of scientific endeavors. However, these views disagree with the fact that the very process of creating scientific knowledge or the process of scientific investigation is also affected by society and cultural values. For example, participant KYU – 003 shared with the study during...
interviews that “culture may influence scientific development but not process of research.” To this, participant KYU – 020 added by saying “it’s just a matter of ethics, I doubt society and culture can affect scientific research if the ethical issues are all observed during the research process. Besides, if it is entirely lab work controlled and developed using objectivity…..”

This study again argues that the perception of objective pursuit of knowledge and the failure to conceive the scientific community as having its own culture is seen as having influences on these views. Participants who possess these views do not understand the fact that the community of scientists has its own set of values and norms (ethics of practice) far and above those of the society they live in that affects what they do. It was amazing that, for example, participant KYU – 020 was talking about ethics in science but was not acknowledging that these scientific ethics actually are values created and acceptable to the practitioners of the scientific community (Chalmers, 1999a; Latour, 1987).

Lastly, were views profiled as Informed. These came from 12 (19%) participants (Figure. 4.6) and were consistent with the consensus model of teachable NOS (Lederman et al., 2002). These views were labeled as ‘Society and science are inseparable’. The study argues that these 12 participants contributed responses only to the acceptable upper score scale 112 (45%) responses on the SUSSI survey. They correctly perceived that societies and communities including the scientists have embraced cultures and values that determine and create the scientific problems to be pursued. For example, in the following excerpt, participant KYU - 029 expressed this understanding:
Scientific research, society and culture are inseparable. The needs of the society will always influence what scientific research is pursued. For example, in famine stricken countries, scientists focus on how to improve food production, not nuclear bomb production. Likewise scientific research also relies on culture. (KYU – 029 interview transcript)

Furthermore, they understand that social – cultural values determine what questions to investigate and how to investigate them. For example, participant KYU – 027 shared with the study during interviews that: “Society and culture do affect scientific research particularly in the biological sciences. For example, research on producing test tube babies may be unacceptable in a developing economy or in a deeply catholic religious society.” In addition, participant KYU – 022 said “many research agendas in science are influenced by human activities. For example, environmental science is focused on pollution and environmental degradation which are partly caused by societies and their cultural values.” Furthermore, in this profile were views that societies and their cultural values guide future expectations in science knowledge creation as shared by participant KYU – 028. That:

The culture norm and expectation will guide what the future expectation is to be in scientific research and will help achieve it. This is true of production science from traditional approaches to through industrial revolution to internet connectivity where information and advance technology is used for faster results. (KYU – 028 Interview transcript)
Lastly, in this profile were views that demonstrate the understanding (in reference to the Human Subjects Institutional Review Board [HSIRB]), that society and cultural values determine the participants in scientific studies and what can be studied. This was evident in the following excerpt from the interview with participant KYU – 031: “You cannot carry out research using human beings as guinea pigs without their consent. You cannot excavate Mary the Mother of Jesus bones to establish their age, DNA, the Roman Catholics will not allow such.”

These findings led the study to adduce that participants with views profiled as **Informed** share the same conception of the SOSCUL aspect of NOS with the consensus view of teachable NOS (Lederman et al., 2002). Their views show that they agree with Latour (1987) and what he called “working with non-interference with psychological moods and finances of the department, walking the tight rope of big grants applied for and at the same time balancing involvement in national scientific projects by the scientist.” All departments in the above quote agreed to possessing cultural values that the scientists have to pay attention to for their scientific work to receive the most needed funding and to continue being part of the core programs of the university departments.

In general, the main lines of discussion of the participants’ views on this aspect of NOS were whether the participants understood that although science deals with understanding matter, its composition, organization and behavior and that matter by itself has no cultural values, those who study it do. First, scientists belong to some form of society or nation that has values. Second, they belong to scientific professional groups (societies) of sorts that have laid out values (ethics); values such as honesty, parsimony,
open-ness, favor of works that are replicable among others. Third, science being a human enterprise is funded by humans and their organizations which have espoused values meaning that scientific knowledge is created through pathways aligned to socio-cultural values making its products acceptable to the human beings. This way, science endeavors to work within acceptable human norms (Feyerabend, 1998, 2010; Matthews, 1994). Latour (1987) called this choosing to work with culturally compatible products of science. Those participants who in their views fail to focus on the scientist and the scientific process as the source of SOSCUL NOS and instead focus on what is being studied (object of knowledge) fail to understand and appreciate this aspect of NOS.

Participants’ views on CREIMA.

Overall, the 63 participants scored an average of 3.5 on the 5-point SUSSI scale (Figure 15). The university level participants scored a mean of 3.7 and the NPTC level participants scored a mean of 3.3 (Figure 16). When data transformation was applied to the 252 responses collected on this scale, three categories of views were revealed: Informed, 45%, Transitional, 33%, and Naïve, 22% (Figure 14). This study observes that it is only on this aspect of NOS that the highest percentages of participants’ views are Informed views (45%) although still not the majority. The perceptions on the CREIMA aspect of NOS were conclusively Transitional by nature.

Qualitative data from free responses on the SUSSI survey, the VNOS-270B and telephone interview were interpretively analyzed using the three typologies generated by data transformation. In the descriptive profile Informed, were all participants’ views that
were labeled ‘creative \textit{ity} and imagination are the heart and soul of science’ This is because their views presented a perspective that scientists always use creativity and imagination ubiquitously during the process of knowledge creation. The study argues that the 28 (45\%) participants whose views fall in this profile contributed only to the acceptable upper scale 162 (64\%) responses on the SUSSI survey. An example of such a response is the following excerpt from participant KYU-046 interview transcript: “Science is a human activity; therefore use of imagination and creativity is of paramount importance for the success of the scientific method.” Another participant KYU-042 defended this expressed perspective of CREIMA by saying “Scientists have to design scientific research tools, collect data, choose the best method to present data (ie percentages, graphs, charts etc) to enable them analyze and interpret the information. To do all these, they employ creativity and imagination.” Meanwhile, participant KYU-047 implored the study to consider that, “a scientist must be imaginative and creative in order to advance the frontier of science....”

Views in this profile demonstrate an understanding of creativity and imagination as vital aspects of scientists’ cognitive attributes and therefore very much part of whatever scientists do in their professional careers. Such views share in the affirmative with the consensus view of teachable NOS (Lederman et al., 2002).

The study suggests that this understanding of CREIMA should be the target conception for all participants and it should be promoted and propagated in classroom science learning. Creativity and imagination are the most used human attributes in science so much that they are heavily targeted by science reform curricula. Such curricula
target development and nurturing of critical and creative thinking patterns (AAAS, 1990; Matthews, 1994).

In the *Transitional* profile of CREIMA were views that were labeled as ‘Selective use of either creativity or imagination but never both.’ These views presented a perspective that scientific knowledge is a product of either imagination or creativity but not both. Based on Figure 14, such views came from 21 (33%) participants. The study argues that these participants contributed responses to both un-acceptable (36%) lower score SUSSI scale and acceptable (64%) upper score SUSSI scale responses. Thus their views were categorized as *Transitional.* Meaning that, their CREIMA views on NOS are still evolving towards the goal conception of this aspect of NOS. Following is an excerpt from participant KYU - 029 during interviews that portrays this understanding of CREIMA NOS: “Imagination and creativity in scientific investigation can produce fuzziness in data interpretation and collection. Empirical scientific inventions should not be imagined, whereas creativity such as improvisation is crucial in many scientific process skills.” Another participant KYU - 020 supporting the use of creativity but not imagination in creating scientific knowledge shared that, “creativity is very important in logical reasoning, I think. So long as they are not supposed to use imagination during data collection; they should embrace creativity during the data analysis.”

These excerpts are examples of views of many participants who in their understanding of NOS consider it acceptable and necessary to use creativity in science but they are not open to the use of human imagination. They consider human imagination a source of subjectivity (buzz) in the data. The study adduced that an Objectivist
conception of science was hindering these participants from understanding the very inter-twinned relationship between human creativity and imagination (Boujaoude, 1996; Matthews, 1994). The study established that the views of these participants may have been different if these participants had a post positivist / constructivist / radical realist epistemology of scientific knowledge (Chalmers, 1999b). This is because these perspectives consider knowledge including scientific knowledge to be artifacts of a creative and imaginative process by the knower.

Other views expressed within this Transitional profile of views agree that both creativity and imagination are applied but only at selected stages of the creative process and not to the entire process. An example of this view is portrayed in this excerpt from participant KYU – 034 free response on the SUSSI. This participant said that:

In designing instruments for data collection, theories, imagination and creativity are utilized by scientists. And also in data analysis for them to identify analogues etc. but they need to be objective enough in reporting and sample selection to avoid bias so they do not use it here. (KYU – 034 SUSSI free response)

This excerpt reveals the understanding that creativity and imagination are not needed when reporting scientific findings. For example, they are not needed when choosing between the use of line graphs and tables or bar graphs and pie-charts. And another participant KYU – 022 added to this and said
Scientists use their imagination and creativity when they observe phenomenon which has never been observed before. This helps scientists to make meaning of the observed phenomenon. They do not use imagination and creativity if what they are dealing with has been observed and has been reported in literature. (KYU – 022 interview transcript)

This participants’ view excludes the use of creativity and imagination during what Kuhn called normal science (Kuhn, 1996).

Yet other participants perceive that human creativity and imagination attributes are used in the process of creating scientific knowledge only in certain rare and difficult circumstances. Such views are evident in this excerpt from the free response writing of participant KYU – 035. That. “scientists use imagination where the instruments for data collection or the situation being investigated grossly deviates from the reality which calls for creativity of the scientists to arrive at a conclusion.” Another participant KYU - 015 in the same vein shared that “experimental investigation may require some form of creativity especially where appropriate tools are not available”. These participants hold views that express the vital use of creativity and imagination in science. However they also express a limited use of these two human cognitive attributes central to science and its advancement. The study reasons that such views of CREIMA NOS do not fully conform to the consensus view of teachable NOS. Scientist have demonstrated that use of creativity and immagination is ubiquitous in their work. They are not limited to any single stage or stages but are used at all stages most of the time (Latour, 1987; Latour & Woolgar, 1986; Matthews, 1994).
Lastly, on this aspect of NOS as shown in Figure.14, were 14 (22%) participants with Naïve views on this aspect of NOS. The study suggests that these participants contributed only to the 90 (36%) un-acceptable lower score SUSSI survey responses. Responses profiled as Naïve were labeled as ‘Creativity and imagination interfere with reality’ These qualitatively present a perspective that portrays CREIMA NOS as an interference to objectivity. For example, participant KYU - 058 in the free SUSSI responses asserted that “….scientists do not use imagination and creativity simply because these may never give you the exact truth about a phenomena”. Another participant KYU – 019’s free responses suggested that, “imagination and creativity are very likely to influence conclusions made after observation of facts and events. It is best if the scientists stands aside and looks at the situation independently in order to allow him/her to conclude objectively.” Likewise, participant KYU – 051 during interviews also added to this conviction by saying: “I think they do not use creativity because it may contradict the logical reasoning. Imagination may interfere with the observation and therefore the objectivity of the findings.”

Examining these responses, the study adduced that these participants’ views on CREIMA are contrary to the consensus view of teachable NOS (Lederman et al., 2002). It was evident that the participants hold a strong objectivist or Purist conception of the epistemology of science. Their conception conceives the scientist as an objective data collection instrument who is detached from the processes of knowledge creation such as, making sense of the data and choosing what constitutes data. These 14 participants’ Objectivist view of NOS blocked them from perceiving that human creativity and
imagination are the central ‘vehicles’ for knowledge creation in science (Boujaoude, 1996; Chalmers, 1999b). As such, it is obvious, based on their views on CREIMA aspect of NOS that they are simply unaware of theory ladeness in scientific observations and how creativity and imaginations play a central role in subjectivity of scientific knowledge (Matthews, 1994).

**Associations between participants’ views on aspects of NOS.**

A Pearson’s (r) correlation coefficient test was applied between the mean scores of each participant on each aspect of NOS investigated. The test revealed that there was a statistically strong association between participants’ views on SOSCUL aspect of NOS and CREIMA** (r = 0.326, p = 0.009), SOSCUL and OBSINF** (r = 0.505, p = 0.009). The test also reported a statistically significant correlation between participants’ views on OBSINF and NOSTH* (r = 0.309, p = 0.014).

The study argues that this existence of few statistically significant correlations between the four aspects investigated is an indicator of a compartmentalized conception of the aspects of NOS suggestive of a non-coherent, non-mature view of nature of science as a whole by the majority of the participants. Overall, this means that there is no observable cross-fertilization of conception of the different aspects of science. The study suggests that this is a contributor to their *Transitional* conception of NOS. For example, it may contribute to some participants having views that agree with the tentativeness of scientific theories but not of scientific laws, or having goal conception on the CREIMA
but a contrary conception on the theory ladenness of scientific observations and inferences.

The study asserts that the strong association between the SOSCUL and CREIMA, and OBSINF views of the participants are due to their global objectivist view or conception of science and its practices. Majority of these participants conceive a global practice of science which is based on objective observations and inferences, and not affected by society and cultural values of the practitioners. Implying an “Amoral” view of scientific practice associated with “Objective” epistemology of science.

Considering that majority participants have *Transitional* perspectives on NOSTH (81%) and OBSINF (59%), the study argues that these majorities, in both cases, hold an erroneous objectivist conception of scientific practices and knowledge. They erroneously conceive observations as being immutable facts. This view accorded scientific theories a wrong ontology of being pre-existing in nature while in reality they are built from observations by the scientists using prior knowledge, imagination and creativity (Chalmers 1996a; Matthews 1994).

**Comparison of University and NPTC participants’ views on NOS.**

This study used a paired sample t-test to compare University and NPTC science teacher educators’ views on NOS by comparing the two sets of mean scores on the SUSSI for the participants. The test returned results that showed that there was no statistically significant difference in their overall average scores.
The study speculated that since the NPTC science teacher educators are actually products of their university counterparts, these results clearly represent the epistemological relationship that exist between them.

However, when comparison was switched to individual SUSSI scales, the study established that there was a significant difference between their views on nature of scientific observations and inferences (OBSINF) \((p = 0.003)\) at alpha level \((0.05)\). This difference implies that this observed difference in the university and NPTC mean scores on the (OBSINF) scale is not due to chance. The study reasons that the difference can be attributed to professional maturity of the university science teacher educators’ OBSINF views owing to rich career experiences that have greater opportunities for research and scientific experimental investigations compared to their NPTC counterparts. NPTC job descriptions do not expect these science teacher educators to be involved in meaningful scientific research.

**Uganda Science Teacher Educators’ Perspectives on PSP**

Question two of the study was, “What are the preferred pedagogical approaches to science teaching among Uganda science teacher educators?” Participants’ views on their preferred science pedagogy were obtained from their responses to the POSTT-II survey instrument (Cobern et al., 2012), semi-structure telephone interviews, and by a content analysis of their science teaching methods syllabi. A total of 1008 responses from the 63 participants were collected and analyzed for frequencies of expressed preferences of the different choices of teaching orientations on the survey. The preference choices the
POSTT-II provided were Didactic Direct (DD), Active Direct (AD), Guided Inquiry (GI), and Open Inquiry (OI).

This study observes that although all four teaching orientations views were preferred by the participants for different teaching scenarios, a majority gravitated towards GI (59%) and OI (24%) teaching orientations (Figure 18). The study notes that these participants preferred science teaching orientations that portray science in the classroom as ‘science in the making’ over those that present it as ‘already-made science’ (Latour 1986). This study highlights a readiness among its participants for child centered pedagogies (CCP), and hopes that science education reformers and organizations that offer professional development to science teacher educators can capitalize on this.

The observation above however, is contrary to what has been previously reported by studies on CCP involving classroom science teachers. Classroom teachers have been reported as lacking adequate understanding and competencies for CCP approaches. But the teachers have also registered complaints claiming that even the facilitators of their mandatory CCP professional development experiences (science teacher educators) lack adequate CCP knowledge (Altinyelken, 2010a, 2010b). The situation was so worrying that Altinyelken (2010b) wondered if there was any sense in pushing for pedagogical changes in the Sub Saharan Africa. She suggested the need to rethink if CCP is even suitable and attainable in developing economies especially those of sub Saharan Africa. The results of this study may alleviate these fears and contribute a firm, positive and confident view of Uganda science teacher educators.
Next the study discusses the views of the Uganda science teacher educators on each of the science pedagogies

**Participants’ views on Guided Inquiry as a PSP.**

During Guided Inquiry (*GI*) Students explore actively phenomenon or ideas with the teacher’s guidance towards desired science content understanding (Cobern et al., 2012). The study established that a majority 37 (59%) participants indicated that their most preferred pedagogical orientation was GI (Figure 18). Interview data was typologically analyzed using the four typologies of: *DD, AD, GI, OI*.

Interview data codes interpretively described and profiled as GI included only those views from participants who chose guided inquiry as their preferred science pedagogy. Their views were loaded with the notion that *GI* was “*Pedagogy*” as opposed to other orientations to science teaching. When asked to explain what they viewed as their most preferred science pedagogy during interviews, these participants kept referring to a “new” approach to teaching called “pedagogy”. They would then expound on GI (guided inquiry), insisting that it is different from all others. An example is this excerpt from Participant KYU – 013 interview transcripts:

> Pedagogy teaching is where the learner is involved all the time. It is the learner who handles most of the learning process……..in pedagogy the students are encouraged to look for explanations themselves ..... I put the students into groups and they discuss that information then I ask them questions to answer using that information. I may not give all the detailed information which is required, so they will also have to look for more information by getting it from friends……..my
questions will guide them to achieve a certain objective which I want...... then the different
groups present. Now during the presentations the students add whatever information they think the
others have that they do not have. That is how I move with my teaching. (KYU – 013,
Interview transcript)

The study adduces that these participants view their preferred science pedagogy
as one in which the students are fully actively involved and their (participants) role as
that of a ‘More Knowledgeable Other’ who facilitates the process of socially constructing
knowledge (Novak, 2005). In this excerpt also, the study recognizes that participants who
selected GI as their PSP understood how to use questions to guide knowledge
construction, something pertinent to GI orientation to teaching (Ciardiello, 1998; Vogler,
2005, 2008). Moreover, the excerpt indicates that such participants hold the view that GI
encourages learners to take charge of their own learning process meaning that it is student
centered or learning centered (Bain, 2004). Furthermore, these participants also
understand that it is important for the instructor to unravel students’ prior conceptions for
their facilitation to result in meaningful learning. This was captured in the following
excerpt from participant KYU – 022 during interview:

For me, I believe in mainly knowing what the learners know about what I am going to teach and
that forms the basis for what I present. That means it is always a two way dialogue, where I ask
them questions, present issues ask what I present what does it mean to them. I make it free for
them to say what they believe in and that way I feel comfortable when we interact. I teach old
people and I believe they know a lot, so I think it is important to share experience, my experience
with them and theirs with me. I do not believe the entire force of what I teach depends on me, so
my learners come with knowledge and what is important to help them put this knowledge into context. (KYU – 022, Interview transcript)

Lastly, these participants also view hands on activities as vital portions of their PSP as seen in the following excerpt from participant KYU – 057 who shared that:

.....I use the hands on methodology ...... also I teach skills of how to add and adapt information from other areas. Like if you are bringing materials in class, you can add more by teaching them how it is made, say a skeleton, you can get local materials to make it so you do it as the students are looking, like a demonstration, after demonstrating, you can group them , after grouping them you ask them to do what they can, then they display, after displaying you do a gallery walk, you appreciate their work and they ... audibly, let them correct their work, and where they did not get it, that is when you come in as supervisor or moderator. (KYU – 057, interview transcript)

Based on these qualitative excerpts and quantitative data gathered by the SUSSI survey, the study realized that qualitative data complemented the quantitative data on participants’ views on GI as their PSP. There was also good triangulation of quantitative data in that the majority views expressed in the interviews reflected the majority view in the statistical data (John Creswell & Plano-Clark, 2007). These excerpts relayed salient features of participants’ views on GI as their PSP. Brooks and Brooks (1993) pointed out that classroom experiences like the use of different cognitive level questions, students sharing freely with their peers or with the teachers, using hands on minds on activities, allowing for argumentations, are salient aspects of GI learning environments (Brooks & Brooks, 1993a). The study speculates that the participants that chose GI as a modal PSP
might be some of those that have benefitted from the recent surge in professional
development activities targeting science teacher educators by organizations like Teacher
education across Sub-Saharan Africa (TESSA) and the Uganda National Association of
the Sciences (UNAS) (Ssebuyira, 2010, Stutchbury, 2011).

**Participants’ views on Didactic Direct as a PSP.**

When using the Didactic Direct (DD) teaching orientation, the instructor presents and
explains science content directly and may illustrate with examples or demonstrations
(Cobern et al., 2012). There is no active participation by the learners just as it is in a
normal lecture where the instructor does an exposition of the material and the learners
quietly listen and take notes. Only one science teacher educator and specifically from the
NPTC level indicated that DD was the PSP. Unfortunately, qualitative data to supplement
the quantitative data on this PSP choice were not captured by interviews. The study
surmised that this choice by that lone participant was an outlier in this sample with
responses that were not thought through. The study suspects that this participant
thoughtlessly filled the POSTT-II survey and that this data is meaningless.

**Participants’ views on Active Direct as a PSP.**

When using the Active Direct (AD) science teaching orientation, the teacher presents and
explains science content directly, and students participate in verification /confirmation
activities (Cobern et al., 2012). From Figure 18, ten (16%) participants indicated that AD
was their most preferred science teaching orientation. Interview qualitative data interpretively profiled under the $AD$ typology expressed an understanding of the DA orientation that carried the notion that ‘it is not hammering points’. These participants basically said that one need not stand in front of the class and preach at students but should allow them to participate, in some way. Participants who chose AD as their PSP have difficulty understanding the difference between “pedagogy” ($GI$) and their $AD$.

The study postulates that these participants are the ones that are just dropping their traditional lecture method and adopting the AD mode as they progress on their pedagogical reform journey. They refer to the low level student participation in AD mode as constituting a similarity with GI and making both the same and different from DD or the traditional lecture method. Their views are best illustrated by this excerpt from participant KYU – 005’s interview transcript:

In the traditional way, for example you teach, you ask questions, you demonstrate you do that as a way to involve the learners….. You do not only listen but you make the learners all of them participate also. It is not direct teaching like say hammering the points but you accept all answers from all the learners as they contribute and you bring all those points together other than you coming and saying you must do that and that and that. (KYU – 005, Interview transcript)

Evidently, participants with an AD view on PSP perceive that pedagogy should allow for only limited or low level student participation. Even what would have been a whole class hands on activity is better if presented as a demonstration by the instructor. Participants whose views on PSP were described by this profile consider themselves as
using improved traditional teacher-centered methods. By allowing for the low level student participation, instead of them “hammering points” they consider their pedagogical views improved.

The study argues that by large participants with AD as their PSP have views that prefer teacher-centered or subject centered pedagogical practice. Learners in such learning environments are not actively engaged in the learning process, the questions asked by the instructor are rhetorical in nature, and the learners wait for evaluative feedback from the instructor without making much effort to be actively engaged in knowledge construction (Brooks & Brooks, 1993).

The study also observes that most of these AD profiled views were from university level participants who are not mandated by their syllabi to teach using particular orientations. The study speculates that these faculty still holding onto the old traditional ways of teaching, have not yet had chance to benefit from science pedagogy reform efforts by organizations like Teacher Education across Sub-Saharan Africa (TESSA) and Uganda National Association for the Sciences UNAS (Ssebuyira, 2010, Stutchbury, 2011).

**Participants’ views on Open Inquiry as a PSP.**

When an instructor employs the Open Inquiry (OI) teaching orientation, students actively explore phenomenon or idea as they choose. The teacher guides but does not prescribe the pathway to learning or what has to be learned (Cobern et al., 2012). In this study 15 (24%) participants (Figure.18) indicated OI as their most preferred science
pedagogical orientation. These participants were especially from the vocational sciences departments of Sports science, Agriculture, Home economics and human nutrition. Their views as profiled under the typology OI carried the notion that they prefer research based instructional approaches. The excerpt below from participant KYU – 014 interview transcripts was a typical response when participants with a preference for OI were asked to explain what they understood about or perceived as their PSP:

Yes it is research based. You will find that most of it is very practical and we want the students to discover on their own some of the challenges that surround them in the environment and how great they can improve the environment……. We want it to be more of research so that the students are able to discover a number of things and a number of challenges and how they can overcome those challenges to make the environment a much better place to live in. (KYU – 014, Interview transcript)

The study notes that their views on preferred science pedagogy encompass a targeting for competences in research and problem solving through immersed experiences. These qualities may be the reason why these participants are attracted to OI; the extreme form of inquiry teaching that involves very minimal instructor guidance, if at all any. These participants argue that when their students learn practically, they are empowered to understand and handle the challenges in their future careers.

However, the study found their pedagogical preference intriguing since their syllabi showed that these instructors had time constraints. The study wonders how they might complete the given programs of study if they use a time consuming, non-structured
pedagogical approach like OI. These dilemmas, although pertinent to this study, cannot be fully answered by this study since this would require classroom observations which the study did not do.

The study is inclined to speculate that these participants were expressing their desires/preferences had they been in an ideal situation but were not reporting their perceptions in their current settings. Nevertheless, their views are relevant to science education reformers since they show that these participants are desirous of a pedagogy which portrays classroom science as ‘science in the making’ rather than ‘already-made science’. Such pedagogies allow learners to actively, socially and meaningfully construct their own knowledge on the natural phenomenon they are interacting with (Latour 1987; Latour & Woolgar, 1986; Novak, 2005)

**Comparison of University and NPTC participants’ views on PSP.**

Table 7 shows that the majority university 28 (80%) and NPTC 23 (82%) participants prefer orientations that present classroom science as ‘science in the making’ (Latour, 1986). However, 20 (71%) of NPTC science teacher educators prefer GI, the more executable and reform recommended pedagogical orientation (Tukacungurwa et al., 2012) compared to only 16 (46%) of their university counterparts. On the other hand, more university science teacher educators 7 (20%) indicated a preference for the AD compared to only 4 (14%) of their NPTC counterparts.

These results imply that the trend in pedagogical reforms may be faster among NPTC instructors. Generally, the NPTC instructors seem to be gravitating and
consolidating their science pedagogical views to align them with reform based views. Meanwhile, university participants seem to be either still at the initial stages or midway in their exodus from teacher centered to reform based child centered pedagogies.

Content analysis of the university syllabi by the study backed these findings. Pedagogical practices such as lectures and classroom discussions were mentioned as the recommended teaching practices. Actually 7 (20%) university participants manifested AD related views. According to Kember (1997), there exists a transition content pedagogical value orientation that lies between the teacher/subject and the student/learning poles. He called it the student-teacher interaction orientation. Kember suggests that instructors with this orientation believe in interactive teaching, which allows students to participate in the process of knowledge construction but with the instructor taking the lead. With this value orientation, the metaphors for the instructor are presenter and tutor.

Conversely, the majority 20 (71%) NPTC participants’ views aligned well with the pedagogical expectations of their syllabus. Their syllabus pointed out clearly that the preferred teaching orientation was GI. The syllabus did not mention or encourage any teacher-centered pedagogies like lectures or large classroom discussions (AD) nor the use of open inquiry orientations like OI.

The study also noted from participants’ bio-data that more NPTC participants had participated in reform pedagogy related professional development activities compared to their universities counterparts. The study suggests that these experiences and exposures to
reform mandated ways of teaching may have contributed to the difference in views reported by the two subgroups of participants.

**Uganda Science Teacher Educators’ Perspectives on CLE**

Question three of the study was, ‘What are Uganda science teacher educators’ perceptions of their classroom learning environment?’ Participants’ views were collected using the CLES-II (20) survey (Johnson & McClure, 2000), content analysis of their science teaching method syllabus and through semi structured telephone interviews. A total of 252 responses were collected on each of the five aspects or scales of the survey: Personal relevance (P-relev), Uncertainty (Uncert), Critical voice (C-voice), Shared control (S-cont), and Student negotiation (S-nego).

The study established that participating science teacher educators’ views on all aspects of CLE are *Transitional*. Their views on Personal relevance, Shared control and Student negotiation (group means of 4.1, 4.2 and 3.7 respectively on the survey scale) represent a perspective of CLE more consistent with the constructivist learning environment (CoLE) than their views on Critical voice (group mean of 3.1) and uncertainty (group mean of 2.5), see Figure 30. Although impressive, the study notes that these results are what participants themselves report (based on their perceptions) about what happens in their classrooms. Therefore, these results cannot be used to deduce what actually happens in the classrooms as that would only be possible if this study had observed participants’ teaching sessions.
Overall, participants’ responses represented the required understanding for the CoLE. Majority of the participants have a working understanding of the need to use student lived experiences when presenting science learning experiences so as to enhance a deeper understanding of the science content and a transfer of the scientific knowledge acquired to future life experiences. They have good knowledge on the need for allowing shared control of the learning process to facilitate construction of peer vetted knowledge and to create a community of learners. These participants also understand fairly that students are able to contribute to the content and manner in which it (content) is delivered in the classroom.

However, they have poor views on how to present science in the classroom so that learners appreciate and are comfortable that science is not a panacea for human problems. In the same vein, they do not understand how and why it is necessary to give students’ academic freedom to criticize both how they are taught and what they learn.

Following is the discussion on participants’ perceptions on each aspect of CLE:

**Participants’ views on Personal relevance.**

Personal relevance views are indicators of how participants make classroom science relevant to the students’ daily lives outside the school (Johnson & McClure, 2000). The 63 participants had a group mean of 4.1 on this aspect or scale. Of the 252 responses on this scale, most 196 (78%) responses were at the “often” (4) or “almost always” (5) occurrence level and only 52 (21%) were at the “sometimes” (3) occurrence level. Only 4 (1%) of responses were the unacceptable “seldom” (2) or “almost never” (1) occurrence
level (Figure 20). The study was able to make limited meaningful interpretations on the
nature of the views expressed by these responses. The only meaningful observation on
the data at this stage was ascertaining majority and minority responses.

Thus the study transformed the above quantitative data (qualitizing) into
categorical data giving rise to the following: Transitional 38 (60%), Performers 25
(40%) see Figure 21.

Data transformation was useful in that it added another layer of meaning from the
data. However, to make even better meaning of the categories of views of understanding
the Personal relevance aspect of a CoLE, the study needed qualitative exemplars for each
category of views. So the study used the generated categories as typologies to analyze,
interpret and profile the qualitative interview data.

Twenty five (40%) participants’ views reflected the Performer level
understanding and observing of the P-relev aspect of the constructivist learning
environment (CoLE). An exemplar of this understanding is represented in this excerpt:

... Class science will still need to be triangulated into life. Science should not remain in class
because it will not be useful the ideas in class must be translated into real life. like when they do
field excursions when they go out and explore...... the tendencies is for the teachers to teach soil
erosion, theoretically, they say they do not have time to take the students where the soil erosion
occurs eg in the gardens, or the sides of the roads, for example these murrram roads to see and that
it .you know many students drop out and they should be able to use what we teach them to either
solve their day to day problems or earn a living. (KYU – 046 Interview script)
As noticed in this excerpt, Uganda science teacher educators’ responses profiled as *Performer* expressed a good perspective of the aspect of personal relevance of the CLE. In this case they emphasized *the need to vocationalize classroom learning experience*. Essentially, this means making classroom science learning experiences relevant to learners’ experiences outside the classroom; an act that may help them to transfer the classroom scientific reasoning and understanding to their out of school life experiences. Their views were candid and aligned to reformed science teaching practices as stipulated by learning environment scholars (Bain, 2004; Fraser, 2007). These scholars promote making learning experiences and the CLE relevant to the lives of the students outside of the classroom. The study believes that these participants with *Performer* perspectives contributed responses only to the 77.6% upper scale scores in Figure 20.

During the time of the study, the president of Uganda was promoting the policy of ‘vocationalization’ of school learning experiences. The study adduced that the presidential push for vocationalization of classroom experiences contributed to the strong and elaborate participants’ positive views on this aspect.

There were 38 (60%) responses categorized as *Transitional*. The study adduced that the 38 participants with Transitional views contributed responses to all scale scores of the survey in Figure 20. Views such as the one shared in this excerpt from participant KYU -048 interview transcripts, “…*when you teach you get time to tell the students the implication and the life skills they get outside class and how they can integrate the concept that I have taught in their day to day living.*” These views were profiled as *Transitional* because although they carry the notion of personal relevance in the learning
environment, they were not expressive of active experiences by the learners. It was mere mention of a life skill to be learned without actively relating the experience to real life experiences outside the classroom. In other words, the relevance in such cases would only be heard as mentioned but not a lived experience (Brooks & Brooks, 1993b).

Another reason behind observed *Transitional* views on P-relev was incapacitation because of the education received. This was evidenced in this excerpt from participant KYU – 062 interview scripts, a participant who shared their views on this aspect of personal relevance of the classroom learning environment.

That one is a challenge…., because like we say the curriculum must serve the society as society serves it. Integrating student experiences with curriculum content needs an extra mile. Like since many of us were not taught that way, we try to break away from that way, otherwise basically it is just teacher, chalk and talk. Now the attitude of these students towards the subjects and towards the tutor will really depend on how you integrate what is in the curriculum and what is familiar to them. Interpreting this curriculum into applications and daily activities will be the order of the day. (KYU – 062 Interview transcript)

In this excerpt this participant expressed courage and effort when trying to integrate learners’ life experiences in the CLE. Yet the participant overtly accepts that it is a challenge and this is so partly because that is not the way this participant was taught. This participant knew that the curriculum had to serve the society yet he expresses the struggle of not having the required competences to interpret the curriculum in such a way that he can incorporate the learners’ out of the classroom life experiences in the CLE.
In conclusion, although overall the 63 study participants had a mean score of 4.1 points on this scale of the CLES-II (20) most of their views were Transitional in nature. Meaning that the majority of these participants understand the aspect just enough to make a more than ‘sometimes’ experience or manifestation of the aspect in the CLE.

**Participants’ views on Uncertainty.**

The Uncertainty views of participants reflect their knowledge of presenting science correctly so that it is portrayed as an evolving process; not having all answers to all problems, and culturally and socially determined (Johnson & McClure, 2000).

Quantitative data comprised of 252 responses on the CLES-II (20) from the participants. These responses consisted of 83 (33%) on the sometimes (scale score 3.0) reflecting a fair conception of the aspect by participants. The groups’ mean on the scale was 2.5 on a 5-point survey scale. Only 89 (35%) of the views reported were classified as “often” and “almost always” and 80 (32%) were classified as “seldom” and “almost never” by occurrence level (Figure 22).

Data transformation revealed that of the 252 responses collected 4 (6%) were categorized as *Performer*, 1 (2%) *Struggler* and 58 (92%) as *Transitional*, see Figure 23. Thus, the *Transitional* category was the majority category of participants’ perspectives on this aspect. The study deduced that majority participants’ responses on the four statements in this scale were spread across the Likert scale of the survey.

The majority 58 (92%) *Transitional* views on the uncertainty aspect of the CLE expressed can be exemplified by this excerpt:
Yes, we do that is why we have the induction training we take them to those areas where our services are wanted and when they reach there they register what challenges they meet and they try to use scientific approaches towards solving those challenges. In case they get stuck they consult with us and we help them to sort out the challenges. (Participant KYU – 014 Interview transcript)

This excerpt illustrates that the instructor lacked the confidence to allow for uncertainty in a science learning environment. Even though the uncertainty experience was there in the class it was not a planned outcome. In other words, experiencing uncertainty in science in these cases depends on the individual learners even though the science teacher educator is expected to understand this aspect well and to plan the CLE so that every learner experiences this aspect of uncertainty in science (Bain, 2004)

On the other hand, the Performer profile included responses from only four (6%) participants. The study adduced that these four participants only contributed to the 89 (35%) upper scale scores on the survey (Figure 22) and had an understanding that resonates with the requirements of this aspect of Uncertainty in a CLE. An exemplar of this understanding is this excerpt.

It can happen several times when something comes up may be somebody has read further and a student asks a question and nobody knows the answer. Normally what I do is refer everybody to find out about that information. Then the following time it is what is used to introduce the new lesson, with that discussion of what have you found out sometimes you may fix them to deal with unknowns answers in science. (KYU – 013 Interview transcript)
There is expressed knowledge of the uncertainty aspect in the above view. This knowledge is used to plan and allow the whole class to experience the aspect of uncertainty in science. In this excerpt, the participant displayed a greater understanding of the aspect making it easier for them to deploy this knowledge, thus allowing the students to experience the fact that science is done by people and may not bear immediate solutions.

Lastly, views on the uncertainty scale profiled as *Struggler* were expressed by one (2%) participants. The study adduced that these participants contributed responses only to the lower scale scores in Figure 22. Their understanding of the aspect of uncertainty was exemplified by this quote from participant KYU 051 that, “no at least I have not got that experience before of something that I cannot scientifically address as far as nutrition is concerned. I have not”

In the above quote, the participant expresses the dilemma science teacher educators have in understanding uncertainty in science and how to allow its amplification and visibility during science teaching. The *Struggler* views on the uncertainty aspect of the CLE suggest that these participants have a limited understanding of the aspect. Therefore, they are not ready or do not take time to explain to teacher candidates that science does not answer all questions, it is a social product, and it is largely a product of scientists’ creativity and imagination (Abd El Khalick, 1995; Chalmers, 1999a).

In summary, results on the understanding and practice of this aspect of the CLE indicate that only four (6.3%) participants have full operational knowledge of the aspect;
operating at the level of ‘often’ and ‘almost always’. Majority 58 (92%) participants have an understanding of the uncertainty aspect of the CLE that allows them to operate mostly at the ‘sometimes’ level.

**Participants’ views Critical voice.**

The Critical voice views portray the participants’ readiness to allow students to feel free and empowered to question their pedagogical plans and methods (Johnson & McClure, 2000). Participants’ views on this scale scored a group mean of 3.1 on a 5-point scale (see Figure 30). Data transformation of the quantitative data revealed that the 252 responses could be grouped into **Struggler** 2 (3%), ** Transitional** 56 (89%) and **Performer** 5 (8%), see Figure 27. Implying that majority of the responses represented **Transitional** perspectives or views on the aspect of CLE.

Typological analysis of interview data returned responses that fitted the three profiles of **Struggler** Transitional and Performer. The **Struggler** profile contained responses that reflected views with poor understanding and execution of this aspect of CLE. Participants with such views must have contributed to only lower score scale responses in Figure 26. Views expressed in the following exchange between the study and participant KYU – 048 are good exemplars of perspectives profiled as **Struggler**.

**Interviewer:** so would you say you are the type that readily welcomes being criticized by your students?
KYU – 048: no uuuuuh yeah but it has to be a positive criticism in a way that is geared towards the students learning.

In this interview exchange the participant evidently shows a struggling posture on the idea of Critical voice in the CLE. This participant first says no to criticism and then with a sigh of doubt expresses an agreement to criticism but with a caveat of “it has to be constructive”. This exchange and others of the same kind enabled the study to establish that participants with these kinds of views on the Critical voice aspect of the CLE are not open to criticism of their pedagogical practices. Meaning that students rarely get the opportunity to participate or contribute to their learning experiences (Bain, 2004)

_Transitional_ views encompassed responses that represented views on the Critical voice aspect which were between _Struggler_ profiled views and _Performer_ views. The following excerpt is an exchange between the study and participant KYU – 051 who expressed views that fit the _Transitional_ profile.

**Interviewer:** Do you allow them to question how or what they are learning?

KYU 051: They do not question how but what they are learning. How is this going to help us? How does it improve our teaching?

**Interviewer:** But you do not allow them to question how you are teaching

KYU 051: Not that I do not allow them to, but they rarely question how I teach

**Interviewer:** Would you want them to ask you how you are teaching?
KYU 051: I would not mind for example: Madam why are you teaching us this way? Why are you telling to do research?

Interviewer: So do you encourage them to ask you why you do the things you do

KYU 051: Yes actually we encourage them to ask us and also encourage them to state whether they are comfortable with those methods or not. That is especially for the diploma level.

In this exchange the responses represent a two-fold understanding of the aspect of Critical voice in a CLE. First is the notion that it is alright for the learners to question what they are learning but not how they are learning it. This understanding does not allow for learners to contribute to how the CLE is managed or how the learning experiences are presented.

The second notion presented in this exchange is the implied fact that it depends on students and not the instructor for the aspect of Critical voice to manifest in the CLE. The study established that this notion highlights a deliberate effort of the science teacher educators not to plan nor allow for the manifestation of the aspect. This could be due to the lack of adequate knowledge on what to do to allow for Critical voice or the importance of this aspect to the learners. So to avoid being blamed, science teacher educators pass on their responsibility of nurturing and manifestation of the aspect during teaching to their students (Brooks & Brooks, 1993)

Those responses from participants that understand well the Critical voice aspect were categorized and profiled as Performer views. Participants with such views most
likely contributed responses only to the upper score scale 116 (46%) in Figure 26. Qualitative data also had views deemed fitting the *Performer* profile. Exemplars of these views are presented in the Critical voice views represented in this exchange between the study and participants’ KYU – 014:

**KYU - 014:** *That is ok. It is healthy for them to critic my teaching and may be bring out ways in which they would go about the same content and that is ok*

**Interviewer:** So in your learning environment they are free to critically speak about what is going on

**KYU - 014:** *Exactly, they are and that is what we love. it is very healthy for them to comment on how you are teaching, the method you are teaching with, the content you are teaching how you have handled a content whether it is from complex to easy or easy to complex that is very healthy…*

Views similar to those expressed in this exchange belong to science teacher educators who are well positioned to allow all forms of criticism from their learners on what they do and how they do it as long as it benefits the learners. Such science teacher educators have a good understanding of the Critical voice aspect of the CLE, plan and nurture its manifestation in the CLE. Brooks and Brooks (1993) deemed such instructor efforts useful in addressing learners’ suppositions so that they know what to bring, what to expect in the learning environment and their role in the whole knowledge construction task.
Participants’ views on Shared control.

The Shared control views reflect participants’ knowledge of how to make sure students have opportunities to explain and justify their ideas, and to test the viability of their own and other students’ ideas during their teaching (Johnson & McClure, 2000). The 63 Participants’ responses on this aspect scored a mean score of 4.2 on the 5-point Likert scale representing a good understanding of this aspect by the participants. Their mean score on this aspect was the highest on the CLES II (20) survey (Figure 30).

There were 252 responses on this aspect from all the participants. Of these 193 (77%) scored as “often” and “almost always”, 44 (18%) as “sometimes” and 15 (6%) scored as “seldom” and “almost never” (Figure 24). This analysis revealed that the upper score scales had a majority 193 (77%) occurrence levels, thus the study established that participants’ views on this aspect of the CoLE were beyond average.

To make better meaning of the quantitative data, the study subjected them to a transformation (qualitizing) to categorical data of Struggler, Transitional and Performer (Figure 25). This yielded zero Strugglers, 41 (65%) Transitional and 22 (35%) Performer views.

Participants’ Performer views were exemplified by the following excerpt:

You may use some questions, you do not directly give them the answer but you ask questions around it to try to make them understand where the problem is so that you get more people joining the argument I mean more people agreeing on the right answer. So my work is to ask questions such that I seek improvement in their understanding of the content presented by the problem so
that from there they can now deduce the answer and agree and accept that that is the right answer.

(KYU – 013, Interview transcript)

This excerpt exemplifies the efforts of a ‘More Knowledgeable Other’ (MKO) as suggested by Vygotsky (Novak, 2005) deploying their understanding of a CLE. Science teacher educators with a good understanding of the CLE are competent to promote this aspect of Shared-control by allowing for argumentation. This then allows students to examine their own thinking against that of their peers and that of the instructor. It promotes ownership of knowledge created and construction of valid defenses or validations of this knowledge. This is an aspect of what Bain (2004) called a “natural and critical learning environment. The study labeled the views expressed in this excerpt and the participants who hold such views argumentation promoters.

For the perspectives profiled as Transitional, the study chose the views expressed in this exchange between the study and participant KYU – 057 to exemplify them:

**Interviewer:** Ok imagine that in that kind of environment you end up having a student or a group of students or two students disputing or disagreeing over something e.g. the material you are teaching or it could be the way you are teaching the material, and they go into an argument about it and you are in the class how would you handle such a situation?

**KYU - 057:** “If it is a group of course I have to call for their attention, then I ask them what the matter is then I come in to correct them and show them the right way to go”

**Interviewer:** What else do you think you can do to address the situation?
KYU - 057: Yes alternatively I can get another group which is not arguing and it has done the work as I wanted, to work together with the other one (arguing group) so that they do child to child or teacher to teacher .....I think it can work best, whichever so that the other group cannot remain in darkness.”

The S-cont views expressed in this exchange show that this science teacher educator (like all participating science teacher educators with transitional views on this aspect) has fair knowledge of the aspect. They show efforts to allow for S-cont as an alternative when the opportunity arises during classroom exchanges. In the exchange the participant manifests as the principal authority on knowledge validation instead of being the intentional default through allowing for intentional student vetting of knowledge during its construction. Science teacher educators with fully blossomed S-cont views would otherwise set knowledge validation to student –student position and allow themselves to be the default position.

Qualitative results therefore established that participants actually wanted their students to get involved in the class arguments and to acquire socially constructed knowledge vetted by their peers. Qualitative data also triangulated quantitative data by showing that none of the participants had a Struggler (absolute survey lower scale score) understanding of the aspect of Shared-control in a constructivist learning environment.
Participants’ views on Student negotiation.

The Student negotiation scale views reflect participants’ enforcement of student opportunities to contribute to the design and management of learning activities, criteria of assessment, and social norms of the classroom (Johnson & McClure, 2000). The 63 participants’ responses secured a mean of 3.7 on a 5-point Likert survey scale (Figure 30). Thus their knowledge of the aspect was judged as fair. This was their third highest score on the whole survey.

There were 252 responses from all the participants on this scale. Majority 140 (55%) of these views were scored as “often” and “almost always”, 91 (36%) as “sometimes” and 21 (9%) as “seldom” and “almost never” (Figure 28). Thus the only quality of the responses that the study could establish from these data was that majority 140 (55%) were on the upper score scales and only nine percent were on the lower score scale.

To make better meaning out of these quantitative data, mixed method data transformation was performed on the 252 responses. This systematic process yielded two categories of perspectives inherent in these responses as follows: Transitional category 42 (67%), and Performer category 21 (33%), see Figure 29.

However, data transformation provided the study only with numbers of participants with their categorized views or understanding of the aspect of S-nego. The study needed exemplars. So qualitative data from interviews was typologically analyzed and interpreted using these two categories as profiles.
As for the *Transitional* profile, the study forwards this exchange with participant KYU – 057 as an adequate exemplar.

**Interviewer:** Do you ever ask your students to help you plan the content?

**KYU - 057:** yes, yes yes I use them

**Interviewer:** How do you do that?

**KYU - 057:** “Especially when I have a lot of work, I pick a certain group of students then I give them to research it in their groups, they bring what I had asked them to do then I use it for teaching”

**Interviewer:** In that way they get involved in planning the experiences you will be using?

**KYU - 057:** “Yes and I think they enjoy it because by the time I stand confidently teaching them, I know I will have some participation among the learners”

Evident in the above exchange is the overt acknowledgement that it is not uncommon for participants such as KYU – 057 to admit that they allow their students opportunities to contribute to preparation of learning experiences and creation of the learning activities. This active participation culture in planning learning experience contributes to the realization of S-nego. However, the study in this exchange adduced that those participants whose views on S-nego were profiled as *Transitional* have limited working knowledge of the aspect. This was demonstrated by the caveat given or the conditions that led to S-nego manifestation- “Especially when I have a lot of work...”

Implied in this statement is that if the instructor was not having a lot of work, then S-
nego. was not to be manifested in the CLE. This is an indicator that their perspectives on this aspect of Student negotiation are still evolving towards the required standards.

Lastly, on this aspect of the CLE is an exemplar for those views profiled as Performer. The following interview exchange with participant KYU – 061 is a good exemplar.

**Interviewer:** Do you allow your students to get involved in deciding which activities you should work best with?

**KYU - 061:** Yeah there is a situation where you can ask them to decide what work is best to use and they come up with their ideas.

**Interviewer:** but most cases?

**KYU - 061:** In most cases we are the ones who decide for them the activities but once in a while you may leave them the liberty to select their own way of study.

In this exchange it was evident that the participant is knowledgeable on the aspect and he rightly has command on what and when to allow for Student-negotiation to manifest in the CLE. In this exemplar the frequency of manifestation of S-nego was a function of the deliberate knowledge driven decisions of the participant, a strong indicator of good command of understanding of the aspect. This participant did not fret at the idea of working with learners on what they deemed as the best learning experiences. In doing so, the participant displayed respect for the students and passed onto them the
responsibility for their own learning and building their metacognition muscles for better monitoring of their own learning (Bain, 2004; NRC, 2000).

**Comparison of university and NPTC participants’ views on CLE.**

When institutional level scores were compared using calculated scales mean scores for each group in a student’s two sample t-test, there was a statistically significant difference between the university and NPTC scores on the aspects of Uncertainty ($p = 0.18$) and Shared control ($p = 0.17$).

The study argues that the revealed difference on the Uncertainty scale can be explained by the differences in their formal education. The university subgroup was made up of holders of masters and doctorates while the NPTC subgroup did not feature any PhDs and also had fewer Master’s Degree holders. A better understanding of the aspect of Uncertainty in science is associated with one’s understanding of NOS. Learning history and philosophy of science (HPS) is a common curriculum practices at graduate school; an experience that most NPTC participants had not yet attained.

On the other hand, the difference in scores on the Shared control scale can be explained by the difference in the curriculum the two different subgroups teach. The NPTC science and science education syllabi are produced by the National Curriculum Development Center (NCDC). The NPTC tutors and lecturers are mandated to teach and cover it in stipulated time limits to match the national school calendar since the NPTC students do national examinations. The study argues that this puts a constraint on the NPTC level instructors hence limiting their willingness to allow for S-cont or just not to
bother about it. The opposite is true for the University instructors. They do not have a
mandated curriculum to teach, they do have the luxury of self-pacing and they set their
own examinations hence the freedom to allow for S-cont in their CLE.

**Correlations of participants’ views on aspects of CLE.**

Participants’ views on classroom learning environment (CLE) as measured by the CLES-
II (20) returned the following scores: (4.1) on Personal relevance scale, Uncertainty (2.5),
Critical voice (3.7), Shared control (4.2), and Student negotiations (3.1), See Figure 30.
ANOVA test with post-Hoc Tukey’s HSD test was applied to these means to establish if
there were significant differences between them. The results showed that there was a
statistically significant difference between all the scale mean scores except those of
Personal relevance (4.1) and Shared control (4.2) scale views (Table 10).

This closeness between these two scales (P-relev and S-cont) can be explained by
the similarity of the classroom practices that allow these two aspects of the CLE to
manifest. Instructors allow Personal relevance to manifest during the learning
experiences when they allow learners to identify and relate their lived experiences to the
expected life skills in the curriculum and the scientific concepts they are learning. As
students indulge in these moments, they apparently have opportunities to explain and
justify their ideas, and to test the viability of their own and other students’ ideas; a factor
in shared control (Johnson & McClure, 2000).

Internally, reported views on some scale scores were found to be correlated.
Views on the scale of Personal relevance were found to have a strong statistically
significant correlation with those on Shared control (p = 0.008) and Student negotiation (p = 0.01), these had just a significant correlation with views on Critical voice (p = 0.02) aspect.

It was also established that views on Critical voice scale had a strong significant correlation with those on Student negotiation (p = 0.002) and just a statistically significant correlation with views on shared control (p = 0.05). Uncertainty scale had a statistically significant correlation only with Critical voice (p = 0.04).

The observed significant associations between participants’ views on the different aspects of the CLE indicate that, to a fair extent, their views on CLE are internally coherent with possibilities of perspectives on one aspect informing the perspective on others. However, the study suggests that it would have been better if there was even greater diversity and consistence in statistically significant correlations between the views on the scale. This would suggest intense and diverse interconnections among the conceptions of the aspects that compose the mega concept CLE.

**Correlation between Views on NOS, PSP and CLE**

Question four of the study was, ‘How are Uganda science teacher educators’ views on nature of science, preferred science pedagogy and classroom learning environment correlated in any ways’? This question was answered by first computing the average scores on all the three surveys: SUSSI, POSTT-II, and CLES II-(20) for each participant. Then a Pearson (r) correlation analysis involving the set of three average scores was run.
It revealed that there was no statistically significant correlation whatsoever between the views of the participants on any of the three areas.

The study argues that the lack of any statistically significant correlation among the views of the participants on the three areas indicates that most participants do not have a cohesive, robust philosophy encompassing their views on all the three areas investigated. In other words, most (but not all) of these participants are appealing to a different epistemology for their views on anyone of the three areas investigated. In addition, their epistemologies for the three areas foundational to science education reform are not greatly interconnected. For example, their understanding of NOS, say the human being as a data collection apparatus, may not inform their need to employ the most relevant science pedagogical orientations (Human constructivist orientations) and the need to create learning environments in which learners employ some of the mental and social practices scientist employ during knowledge creation (argumentation, justification of evidence and sharing of ideas) (Brooks & Brooks, 1993; Chalmers, 1996; Matthews 1994).

The above scenario is seen in the participants’ pedagogical preferences versus their reluctance to allow for fuller manifestation of uncertainty and critical voice in the classroom learning environment. These participants were clearly indicating that they were preferred teaching science as “Science in the Making” yet they were showing reluctance to allow for a fuller manifestation of those ingredients or aspects of the learning environment that would make this very possible and real. This was a clear indicator that their perspectives on pedagogy in science and a constructivist learning
environment are not sharing same the same conceptual ecology. If so there are no conceptual connections between these two aspects of science teaching and learning.

Views on NOS, PSP and CLES Reflected in Science Methods Syllabi

Question number five of the study was, ‘How are views of Uganda science teacher educators’ on nature of science, preferred science pedagogy and classroom learning environment evident in their science methods course syllabuses’? The study sought to answer this question by carrying out a content analysis of the science teaching methods syllabi used by the study participants. The results were a mixture of sorts. Ten syllabi from both the University level (eight) and the NPTC (two) level were analyzed.

University Syllabi

The eight University syllabi did not have any recognizable evidence for the views espoused by the participants on matter concerning NOS and CLE. However the syllabi overtly pointed out that they should use lectures, class discussions, and projects as the preferred pedagogies. These pedagogies resonate with all PSP choices the University level participants report except Guided Inquiry (GI) which was reported as the favorite by 46% of the university participants. In fact, the study established that majority (80%) university science teacher educators reported a combined preference for the GI and OI pedagogical orientations and only 20% reported DA as a preferred science pedagogy. These preferences however, cannot fully be verified against the pedagogical views documented in their science teaching methods syllabi. The best the study could do was to speculate that may be their AD views are reflective of some active lecturing method in
The study argues that the university syllabi are either very old or were not assembled by their current users. Alternatively, it could be that it is not mandatory to include details but only the broad topics of what is to be covered in the university syllabi.

**NPTC Syllabi**

The two NPTC syllabi analyzed, on the other hand, had enough evidence that reflected the views on PSP and CLE (but not NOS) espoused by the NPTC instructors. The syllabi, although not specific on outlines or specific teachable aspects of NOS, was ubiquitous with espoused knowledge, skills and attitudes on Nature of Scientific Inquiry (NOSI) which was not covered by this study.

As for preferred science pedagogy, the syllabi categorically stated that Guided Inquiry (GI) was the preferred orientation. The syllabi used phrases like: Students brain storm and discuss, tutor guides students in groups or as individually, in group discussion, through library and internet search students will find out, in groups students display, in groups students prepare and demonstrate, as a project students carry out; to describe and articulate the pedagogical orientation to be followed. The syllabi encouraged the students to actively get involved in the learning, guided by the science teacher educators (tutors).

Correspondingly, the majority (71%) of NPTC participants suitably reported views preferring Guided Inquiry (GI) as their science pedagogy and 11% chose Open Inquiry (OI). The study argues that on matters dealing with PSP, the NPTC syllabi reflects the espoused and preferred pedagogical practices of the participants from that
level since the descriptions and prescriptions of pedagogical approaches suggested by the syllabi match the PSP choices made by the participants.

Furthermore, the syllabi promote a constructivist learning environment CoLE. The syllabi overtly exalt the users to promote the following values in the learning environments they create: Care, togetherness, concern for others, cooperation, patience, sharing, and appreciation as desirous for the teacher candidates to develop. The study notes that these qualities were reportedly developed by the students in the Crawford (2000) study. They facilitate creation of classroom learning environments that can allow for: Discussion, free interaction in groups or individually, allowance to research materials, argumentations and presenting before the class; activities overtly suggested in the NPTC syllabi (Bain, 2004; Brooks & Brooks, 1993a). Interestingly, NPTC participants reported an acceptable, Transitional-(sometimes) understanding or views on CLE.
CHAPTER VI

CONCLUSION AND IMPLICATIONS OF THE STUDY

This concurrent mixed method research study grounded in a human constructivist framework and a pragmatic paradigm investigated the perspectives of Uganda science teacher educators on the Nature of Science (NOS), Preferred Science Pedagogy (PSP), and Classroom Learning Environment (CLE); three areas foundational to science education reform and its globalization.

The study sought to understand the perspectives of 63 science teacher educators from four universities and five National/Primary teacher colleges (NPTC) in Uganda using four surveys, semi-structured telephone interviews, and content analysis of the science methods syllabi used by these instructors. Resultant views were profiled as documented in this report.

This study did not observe classroom science teaching but based its findings on self-reported perspectives by its participants. Therefore, its findings cannot be directly interpreted as the teaching practices of these participants. Instead the results of this study can be used to understand the epistemological commitments and assumptions that influence the participants’ teaching practices, and how and why they plan and execute their science teaching. The findings of this study will be useful in understanding Uganda science teacher educators’ views in these areas.

First, this study sought to determine what Uganda science teacher educators understand regarding nature of science. The participants’ perspectives on four aspects
of NOS (Nature of scientific observations and inferences, nature of scientific theories, the role of social and cultural values in science and the role of creativity and imagination in science) was investigated. This study established that a majority (95%) of participating Uganda science teacher educators possess an overall *Transitional* conception of NOS. Their conceptions of NOS do not fully reflect the salient features of the consensus view of teachable NOS (Lederman et al., 2002). They reflect an epistemological embrace of empiricism infused with bits of radical realism philosophy. These instructors do not fully understand that the human being (scientist) doubling as a knowledge seeker being a data collection instrument (tool) is the main source of subjectivity in science. As such their views on NOS assert that:

- All scientists observing the same natural phenomenon always make similar observations about the phenomenon. They may, however, make differing interpretations of these observations depending on their unique subjective qualities.
- All laws, theories and principles of science are unchangeable. Although theories may be revisable, they are revised into laws.
- Science is Amoral since matter has no culture and scientists work objectively.
- There is a limited role of creativity but not imagination in the construction of scientific knowledge, since imagination is loaded with human subjectivity.

Specifically, their understanding of the nature of scientific theories and the role of creativity and imagination in the creation of scientific knowledge exceed their conception
of the nature of scientific observations and inferences and the role of social and cultural
values in the construction of scientific knowledge. Table 4.4 illustrates these differences.

The study attributed the reported conception of NOS to the participants’ limited
knowledge of history and philosophy of science. Only 11% of the participants had been
formally exposed to both fields of study. Differences in the levels of formal education
and work place experiences also seem to contribute to the observed statistically
significant difference in the conception of the nature of scientific observations and
inferences by NPTC and University science teacher educators. Most university
participants had undertaken graduate studies and participated in various scientific
research activities unlike their counterparts who had mostly not attended graduate school
and are not professionally required to engage in research.

Lastly, this study revealed that there is poor and inconsistent associations among
participants’ views on all four aspects of nature of science investigated. The study argued
that the observed incoherence indicates possible compartmentalized understanding of
these aspects of NOS with possibly very poor or no transfer of understanding or
knowledge of one aspect to another. This is disadvantageous since it creates
disconnections in the NOS conceptual ecology of the participants, thus encumbering their
transfer of knowledge and a possible distortion of their understanding of NOS ([NRC],
2000; Abd-El-Khalick, 2005)

The participating Uganda science teacher educators’ views of NOS have several
implications for science education in Uganda:
Science Literacy Development:

Their objectivist/purist view of science dismisses the effects of personal qualities of the human being (investigator) on the nature of the products of the investigations. That is, their views minimize the effects of personal meaning making by the human beings in their quest for knowledge (Novak, 2005). This knowledge stance makes science and its investigations authoritative, dogmatic and tyrannical (Feyerabend, 1998, 2010). There is also a danger of portraying science as boring, mechanical and only suited for a few gifted individuals. The objectivist perspective of science also restrict an individual’s creativity and imagination, two human qualities that play central roles in the development and learning of critical thinking (Brooks & Brooks, 1993b). The objectivist view of nature of science, therefore, could be detrimental to the development of a culture of science that expands scientific literacy to achieve ‘Science for all’ (SFA), an aspect of Uganda’s millennium development goals (MDG) for education.

Therefore, there is a noble cause for science educators in Uganda to address this encumbering perspective so as to realize the National goal of SFA and its social, political and economic benefits.

Science Teacher Educator Professional Development:

Most of the participating Uganda science teacher educators expressed transitional views on NOS. There is need for efforts to assist them in filling the gaps that exist in their understanding of NOS and to help them develop competencies for teaching NOS and assessing student NOS knowledge. There is an urgent need to ameliorate their robust objectivist view of science.
Uganda Science Teacher Education Curriculum:

The findings also expose the absence of NOS as an education outcome in the science education syllabi and curriculum especially during teacher education. There is need to mandate the teaching of appropriate aspects of NOS at all levels of science teacher education. There should not be just a single exposure to formal NOS education but multiple exposures since knowledge of NOS is a moving target just as science is (Lederman et al., 2002) and multiple exposures cater for addressing increased sophistication of NOS.

Science Education Research in Uganda:

Science education research has concentrated on understanding the classroom discourse and equipping of the science laboratory. This study did not find any other empirical studies (on Uganda) on science teacher educators’ understanding of NOS or NOS related issues such as Social Scientific Issues (SSI), Science, Technology and Society (STS) nor investigations of NOS representation in the science text books used in Uganda. This study (and its findings) possesses scholarly strength as a current empirical study on areas foundational to globalization of science education. Uganda science education researchers should be able to use the findings of this study to extend NOS research in Uganda.

The second task of this study was to determine what *Uganda science teacher educators prefer as science pedagogical approaches*. Their preferred pedagogical choices from four standard orientations for teaching science (Didactic Direct, Active Direct, Guided Inquiry and Open Inquiry) were investigated for 16 different science teaching scenarios. The results revealed that a majority (59%) of the science teacher
educators clearly prefer Guided Inquiry science pedagogy. It is important to note that these preferences are not necessarily their current classroom practices; they are only expressed views, by the participants, on what they prefer. The study adduced that the Uganda government policy and on-going campaigns to ‘vocationalize’ classroom science experiences, a recent overhaul of the NPTC syllabi by the national curriculum development center (NCDC), and the surge of reform based pedagogical professional development activities, may be major influences behind this observation. This study also noted with interest that its participants preferred the two pedagogies (Guided Inquiry and Open Inquiry) that portray learning of science as ‘science in the making’ over Didactic Direct and Active Direct that present science as ‘already-made’.

Participants (59%) who are prefer Guided Inquiry erroneously called their science pedagogy choice, ‘pedagogy,’ implying that Guided Inquiry because they refused to acknowledge that other science teaching orientations were also pedagogies. This study chose to name them the “Pedagogists.” These Pedagogists have been exposed to Guided Inquiry professional development and mentorship. They have a strong understanding of the use of active learning, group work and the use of students’ prior knowledge to inform instruction (Brooks & Brooks, 1993b; Novak, 2005).

On the other hand, participants preferring Open Inquiry (24%) were named “Vocationalists”. They are mostly vocational science teacher educators who hold the opinion that it is only by Open Inquiry that their students learning experiences are most relevant to their professional practices.
This study agrees with the Vocationalists that Open Inquiry equips teacher-candidates with skills to cope and or overcome career challenges. Under ideal situations, the Open Inquiry orientation suits vocational science education. However, in light of the constraints of limited time for instruction and other logistical elements, this study wonders if these participants’ preference for an almost apprentice kind of instruction (over the more structured Guided Inquiry) means that they are unaware of the implications of their choices. This pedagogical preference raises the question: Do vocational science teacher educators in Uganda fully understand what is required to implement Open Inquiry in a structured curriculum? This question will need further investigation.

Additionally, 17% of the participants prefer the traditional pedagogical practice of Active Direct that portrays classroom science as already-made science (they were referred to as “traditionalists”). They view this choice as an improved and modern pedagogy by using terms like question and answer method and discussion method to describe it. These participants basically embrace the traditional lecture (Chalk and Talk) methods but allow low levels of student participation. The study postulates that they are on a slow exodus away from their traditional practice.

This study also noted that although most instructors at both levels of university and NTPC possess PSP views that present classroom science as science in the making, more (71%) NPTC tutors have pedagogical views (GI) compatible with current science education reforms compared to their University (46%) counter parts. This study argued that that the mandatory change of the NPTC syllabi instructional philosophy to GI is enabling the development of needed pedagogical reform views by the science teacher
educators on that level. In addition, the organization, TESSA (Teacher Education in Sub Saharan African) has heavily invested in pedagogical transformations of science teacher educators with NPTC instructors as a priority (Altinyelken, 2010b; O’Sullivan, 2010).

These views on preferred science pedagogy espoused by the Uganda science teacher educators have implications on the following aspects of science education:

University Science Teacher Education Curriculum

This study determined that University instructors lean exclusively more to the AD orientation of teaching. This means that their teacher candidates have less or no opportunities to experience reform preferred pedagogies as modeled by instructors. There is an on-going revamping of the instructional method mandates in the NPTC syllabi to reflect targeted Child Centered Pedagogy (CCP) to meet Uganda’s millennium development goals for education. However this has not been applied to the universities. The results of this study reveal the urgent need for universities to ramp up their ‘catch up game’ with the NPTC whose government mandated syllabus overtly mandates them to use reform preferred pedagogies.

College Level Science Teaching Research:

The findings of this study warrant further investigations to understand Uganda college level science teaching (especially science teacher preparation) and its contribution to the national and international goal of science pedagogical reform.

Pedagogical Professional Development for Science Teacher Educators

The results of this study indicated that pedagogical practitioners referred to in this study as pedagogists, vocationalists and traditionalists co-exist at the colleges and universities
in Uganda. Since the views on preferred science pedagogy of the latter two 
\textit{(vocationalists} and \textit{traditionalists}) differ from the goal GI, they need professional interventions to address their instructional philosophy. This study specifically recommends introducing them to self-study (Action research), an approved tool for monitoring and improving one’s pedagogical practices (Berry, 2009). This action may also encourage them to develop into a better community of practice.

Lastly, this study was mandated to establish \textit{according to Uganda science teacher educators, what the classroom learning environment looks like when preferred science teaching is taking place}. The participants’ views on classroom learning environment (CLE) were collected using the CLES-II (20) survey, content analysis of their science teaching method syllabus and through semi structured telephone interviews. Five aspects of CLE were measured including Personal relevance, Uncertainty, Critical voice, Shared control, and Student negotiation.

The study results showed that all 63 Uganda science teacher educators possess transitional views on CLE. They obtained a mean score of 3.5 on the CLES-II (20) 5-point scale revealing that a majority of them:

- Have good views representing a working knowledge of relating student lived experiences and classroom science learning experiences in the teaching-learning discourse.

- Have good perspectives indicative of knowledge that it is beneficial (for a deeper learning of science) to allow shared control of the learning process since it
facilitates peer-vetted construction of knowledge in vibrant democratic communities of learners.

- Possess fair perspective on students benefit if they are involved in creating the CLE by contributing to the nature of content to be learned and the pedagogical manner in which it (content) is delivered in the classroom.

- Have poorly workable views on how to present classroom science in manners useful for their students to realize and be comfortable that science is not a panacea for all human problems.

- Have moderately workable perspective on how to allow their students to use their academic freedom to criticize both curriculum content and its delivery to benefit the science learning process.

These findings bear implications on curriculum development, professional development, and science education research in Uganda.

Professional Development (PD):

In addition to the matters of PD that have already been discussed, there is need to add a component of CLE targeted PD for these participants and indeed for Uganda science teacher educators. The PD should target improving the views and practices of the participants to beyond Transitional especially targeting the two areas in which they possess inadequate views (Uncertainty and Critical voice)

Curriculum Development:

The findings of this study again showed that the university curriculum lacked guidance on this area just as it did on PSP. Studies leading to adequate ways to develop and deploy
progressive science teacher education and science education syllabi at the university levels should be initiated.

Science education research

The previous discussions pointed to the need to enhance science education research in the NOS and PSP areas. This is also true for CLE. Studies on how to enact a productive constructivist learning environment in the Uganda context as a form of pedagogical content knowledge (PCK) for inquiry teaching are definitely needed. So the study recommends that research efforts seek to understand this particular PCK for the Uganda context and the most appropriate ways to help science teacher educators attain it.

Strength of this Study and Reflections on Future Research

This study may be among the first (if not the first) to investigate NOS, PSP and CLE perceptions by science teacher educators in an empirical way, applying both quantitative and qualitative methods. The findings of this study therefore are useful to inform both policy and practice.

In prospection, the findings of this study demand that further studies are done since the science education community now has known Uganda science teacher educators perspective sin these there foundational areas to science education reform. There is need to investigate:

1.) What their general pedagogical practices look like.

2.) How they teach and assess knowledge of aspects of NOS if at all they teach it.

3.) How their students perceive the classroom environments they create for them.
5.) The alignment between the National science education policies, curriculum experiences in science education, and assessment of these experiences.
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Appendix A

Survey Instruments
You have had years of experiences with science, in the classroom and in real life. This survey asks you to think about science and describe your ideas. **There is no right or wrong answer**, as these are simply your ideas at this time. Please respond as completely as you can. You can use as much space as you need.

Some questions have more than one part. Please make sure you write your answers to each part.

1. What, in your view, is science? How can you determine when something is science (such as biology or physics) and when something is not science (such as religion or philosophy)?

2. How are science and art similar? How are they different?
3. (a) What is a scientific experiment? Give an example.

(b) Does the development of scientific knowledge require experiments?

If yes, explain why. Give an example to defend your position.

If no, explain why. Give an example to defend your position.

4. Scientists agree that about 65 millions of years ago the dinosaurs became extinct. However, scientists still disagree about what caused this extinction.

(a) Why do you think they disagree even though they all have the same information?

(b) Do you think this controversy could be resolved? If so, how? If not, why not?
(c) How do you think scientists know how dinosaurs looked and moved?

5. There are many types of phenomena (past, present, and future) that scientists study, but cannot see. For example, scientists have never seen “dark matter”, the center of the earth, or into the nucleus of an atom. Yet many scientists use their understanding of these phenomena to do research.

(a) If they have never seen these things, what kind of information do scientists use to figure out these things exist or what they look like?

(b) Should we, as a public, accept scientists’ explanations or descriptions of things they have not seen? Why or why not?

6. Scientists try to find answers to their questions by doing investigations. Do you think that scientists use their imagination & creativity in their investigations?
(a) If you think “YES”, explain why and in what part of their investigations (planning, analysis of data, interpretation, etc.) you think they use their imagination & creativity

(b) If you think “NO”, explain why imagination & creativity are not part of science.

7. (a) What do you think is the difference between a scientific theory and a scientific law?

A scientific theory is….

A scientific law is….

(b) Give an example of a scientific theory and an example of a scientific law.
Example of a Scientific Theory:

This is a theory because….

Example of a Scientific Law:

This is a law because…..

(c) Do you think scientific theories we have today will change in the future? Why or why not?

(d) Do you think scientific laws we have today will change in the future? Why or why not?

8. Some people claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social,
political, and philosophical values, and intellectual norms of the culture in which it is practiced.

(a) Circle what you believe?

I believe that science reflects social and cultural values.

I believe that science is universal.

(b) Explain your choice and defend your answer with examples.
Thinking about Science Teaching

Dear respondent

This assessment is composed of classroom science teaching vignettes similar to teaching practices one can find in any classroom today. Practicing teachers contributed ideas for many of the vignettes; others are based on teacher observations, or on science curriculum standards.

As you read each vignette, think about how you might teach science in a similar situation. Respond accordingly.
Scenario. 1 - Frog dissection

Mr. Kayima is doing a frog dissection with his S. 6 students as a way to help teach them about anatomy.

Thinking about how you would teach the same lesson, of the following, which is most similar to what you believe is the best way to incorporate a dissection into a lesson?

A. It should be used as a stand-alone activity for students to explore and discuss on their own.

B. It should be used as a follow-up student activity after Mr. Kayima explains what students need to know.

C. Students should do the dissection first, followed by teacher-led discussion.

D. It should be used as a demonstration with Mr. Kayima explicitly pointing out what students need to know.
Scenario. 2 - Lesson on force and motion

Ms. Nakuya is preparing a lesson to introduce her S.2 students to the relationship between force and motion, namely that a net force will cause an object to speed up or slow down (Newton’s 2nd Law). The classroom has available a loaded wagon to which a pulling force can be applied. Ms. Nakuya is considering four different approaches to the lesson.

Thinking about how you would want to teach this lesson, of the following, which one is most similar to what you would do?

A. Raise the question of what kind of motion results from a constant force. I would then guide my students to explore the question themselves by pulling on a loaded wagon and observing what happens. From the evidence they would then propose a possible law.

B. Write a clear statement of Newton’s 2nd Law on the board and explain it carefully for my students. I would then have the students verify the law by pulling on a loaded wagon themselves and confirming what type of motion results.

C. Raise the question of whether there is any relationship between force and motion. My students would then be free to explore this safely in the lab. Afterward we would have a class discussion of their findings.

D. Write a clear statement of Newton’s 2nd Law on the board and explain it carefully for my students. Then I would demonstrate the law by pulling on a loaded wagon with a constant force in front of the class as they observe the motion.
**Scenario. 3 - Bar charts**

Ms. Balikoowa is teaching her P.4 class how to make a simple bar chart. She begins by handing out an example of a bar chart she already made comparing the numbers of red and blue blocks in a box.

Thinking about how you would teach the same lesson, of the following, which is most similar to what you would do next?

A. Count the red and blue blocks aloud for the students and show them how the bar chart represents the count for red blocks and the blue blocks. I would also plan to have some green and yellow blocks that the students could work with. I would have the students count the green and yellow blocks and then make their own chart following the example of the chart for the red and blue blocks.

B. Rather than handing out the bar chart example, I would hand out sets of blocks and ask the students to draw pictures that showed how many blocks of each color there were. After discussing their pictures, I would pass out “my drawing” (the example bar chart), and I would have the students discuss how this picture might also represent how many blocks of each color there were.

C. Count the red and blue blocks aloud for the students and show them how the bar chart represents the count for the red blocks and the blue blocks. I would also plan to have some green and yellow blocks. As we counted out the green and yellow blocks, I would show the students how to make a chart for the green and yellow blocks.

D. Give the students sets of the red and blue blocks and ask them if they can figure out what the bar charts tells us about the blocks. After discussing their ideas, I would have them demonstrate their understanding by having them make their own charts using another set of green and yellow blocks that I would have ready to pass out.
Scenario. 4 - Earth materials

Mr. Sanyu wants his P.4 students to be able to recognize and describe different types of earth materials, namely rock, mineral, clay, gravel, sand, and soil samples, which he has available for use in the lesson. Mr. Sanyu is considering four different approaches to the lesson.

Thinking about how you would teach the same lesson, of the following, which one is most similar to what you would do?

A. I would write the different types of earth materials on the board and define them for my students. Then I would individually describe the unique characteristics of each type of material to the students, and pass the samples around.

B. I would have the students sort and describe the various earth materials displayed on their tables, according to their unique characteristics. I would then guide a class discussion about these different types of earth materials.

C. I would write the different types of earth materials on the board and define them for my students. Based on the descriptions on the board, I would then ask the students to sort the earth materials, and describe why they sorted the materials the way they did.

D. I would ask the students to think about what types of materials the earth is made up of. The students would be free to explore this question with different earth materials in the classroom, and then report back on their conclusions.
Scenario. 5 - Thermometers and how they work

Mr. Dombo is developing a science lesson for his P.6 grade students, in which he would like them to acquire an understanding of thermometers and how they work. He has real thermometers available. He also has materials that students could use to assemble their own basic thermometers (small bottle as bulb, cork with hole, straws and colored water). Mr. Dombo considers four different ideas about how to structure and teach the lesson.

Thinking about how you would teach this lesson, which one of the following is most similar to the approach you would take?

A. Start by telling the class that today they will discover something for themselves. Each group will have a bottle, cork, straw and colored water, plus containers of hot and cold water. Show them how to assemble the materials but give no further guidance. They can explore as they wish and come up with ideas, which they can then report to the class.

B. Start by telling students that today they will make a mystery device, see how it behaves and then try to conclude what it might be used for. Then show the students how to put their materials together, and have them explore what happens to the water column in the straw when they put the bulb in cold and hot water. Ask them to suggest what they have ‘invented’ and what it can be used for. Finally wrap up with a discussion of thermometers and how they work.

C. Ask the class what they know about thermometers. List student responses on the board, and then working from some of their ideas, draw a thermometer and explain how it works. Then have students use thermometers at their tables, measuring the temperatures of cold and hot water.

D. Write the lesson title ‘Thermometers’ on the board and draw a thermometer diagram. Then explain how a thermometer works and answer student questions. Conclude by placing a real thermometer in cold and hot water and showing students how the thermometer reading changes.
Scenario. 6 - Inheritance

Mr. Mobutu was teaching his S.4 students about inheritance. After introducing the topic and demonstrating how to use a Punnett square to determine genotypes and phenotypes of possible offspring, he asked students to solve a variety of application problems in small groups.

Thinking about how you would teach this lesson, how would you end this lesson?

A. Since students would have already discussed the problems in their small groups and developed their own understanding of the topic, I would end the lesson here.

B. I would give the students the right answers to the problems.

C. I would ask students to explain their answers to the class. Drawing on their explanations, I would guide them to the correct answers.

D. I would review the correct answers to the problems with the students as a class discussion.
Scenario. 7 - Sundial

Ms. Naava is planning a 7th grade lesson on the changing position of the sun in the sky during the day and how this is the basis of a simple ‘sundial’ to tell time of day. The basic sundial is a simply a vertical stick on a piece of board, and in sunlight the angle of the stick’s shadow can be marked on the board. Ms. Navetta also has a larger demonstration model with lines marked at various angles and labeled with hour of day.

Ms. Navaa considers various ways to conduct the lesson. Of those below, which is most similar to how you would teach?

A. Explain how a sundial works related to sun position in the sky. Have each group assemble a basic sundial, using a prepared handout sheet with lines and hour markings. Then take the students outside to try out their sundials and see that they indicate the correct time of day.

B. Do not explain sundials but take the students outside and have each group set up a stick and board. Ask them to brainstorm what this might be useful for, and to expand on their ideas. Have them come back every hour, anticipating that they will mark a series of shadow lines to make a sundial.

C. Explain how a sundial works, in relation to sun position in the sky. Then gather the class outside around the demonstration model, so they can see how the sundial indicates the correct time of day. Come back an hour later to see that the shadow has moved to the next marking.

D. Instead of explaining sundials take the students outside and note the location of the sun in the sky. Have each group set up a stick and board and mark the position of the shadow. Ask them to suggest how this might be used as a ‘shadow clock’ to tell time of day. Have them come back every hour and mark a new shadow angle, labeling it with the hour, to make a sundial.
Scenario. 8 - Magnetic attraction

Mr. Godi is beginning a unit on Magnetism with his P.3 students, and his objective is for them to learn about magnetic attraction. He gives each student group a bar magnet and a tray that contains a paper clip, a coin, an iron nail, school scissors, a pencil, some keys, a marble, a crayon, aluminum foil, some sand, and students can add a few objects of their own. Mr. Godi introduces the term "magnetic attraction," and demonstrates how to test a couple of objects with a magnet. Student groups are then asked to sort the objects in their trays according to whether they are attracted by the magnet or not.

Thinking about how you would teach the same lesson, of the following, how would you evaluate Mr. Godi lesson?

A. Instead of beginning with terminology, Mr. Godi should have had the students first test the various objects themselves and discuss their ideas about it. In wrapping up the session, Mr. Godi could introduce the term magnetic attraction, and how it applies to what they observed.

B. This is a good lesson because Mr. Godi introduces the important terminology right at the start. However, having demonstrated how to test an object using a magnet, he might as well have demonstrated what happens with all the objects, sorting as he goes.

C. Mr. Godi should have allowed the students to explore freely with magnet and objects, without bringing up terminology. He could then let them discuss any ideas they might have about it and share these with the class. The only contribution he needs to make is to present the term magnetic attraction at the end.

D. This is a good lesson because Mr. Godi introduces the important terminology right at the start, and follows up with the students doing a hands-on activity, testing and sorting the objects themselves.
**Scenario. 9 - Succession**

Ms. Tutu’s S 4 class has just finished an introductory lesson on plant succession. The students now understand that succession can be initiated either by the formation of a new, unoccupied habitat (*primary succession*) or by some form of disturbance of an existing community (*secondary succession*). She is now considering the use of a follow up activity at a green space near the school campus and has several options.

Thinking about how you would teach, of the following, which is most similar to what you would do?

A. Provide the students with a map of the green space demarcating succession. I would then walk the students through the succession areas pointing out the plant life specific to each area.

B. Provide the students with a map of the green space demarcating succession. The students’ task would be to identify the types of plant life in each succession area.

C. Ask the students if they thought they could identify succession and how they would do it. Then we would go to the green space, and the students’ task would be to map out succession at the green space, developing and documenting their own maps.

D. Take the students to the green space and ask them to observe as much as they could corresponding to our recent studies on succession. I would leave it to the students’ own imaginations on how best to use their observations of a real succession environment, and how to document those observations.
Scenario. 10 - Volume and displacement

Ms. Katinko is doing a lesson on volume in her S.1 classroom. Part of the lesson will involve using a graduated cylinder partially filled with water for determining the volume of small irregular objects.

Thinking about how you would teach this lesson, of the following choices, how would you advise Ms. Katinko to structure her lesson?

A. Ms. Katinko should open the lesson by clearly stating the learning objective: the use of displacement as a measure of volume. The teacher then asks the students what happens to the water level in the bathtub when they climb in. She tells them that this is an example of displacement and then assigns an activity using graduated cylinders where the students measure the displacement caused by various objects.

B. Ms. Katinko should open the lesson by asking the students what happens to the water level in the bathtub when they climb in. She uses their ideas to introduce an activity using graduated cylinders where the students measure the displacement caused by various objects. Following further discussion of their observations, the teacher clarifies that the students have been measuring volume.

C. Ms. Katinko should open the lesson by having the students freely explore what happens when various objects are placed in the graduated cylinder. The students should first record their observations and then discuss their findings amongst themselves and with the teacher.

D. Ms. Katinka should assign an appropriate reading in a science textbook on volume and displacement. The students read in class, then the teacher shows the students how to determine the volume of an irregularly shaped object by water displacement in a graduated cylinder. The teacher then has the students find several objects around the room to test on their own using the displacement method.
Scenario. 11 - Rain and water flow

Ms. Wamala wants to start teaching her P.3 students about water movement and bodies of water on Earth, i.e., to understand that when rain falls on Earth the water flows downhill into bodies of water (streams, rivers, lakes, oceans), or into the ground.

Thinking of how you would design a lesson for your students, which of the following approaches would you suggest Ms. Wamala should take?

A. Have student groups shape soil into hills and valleys and sprinkle water onto it, but don’t tell them in advance what it is about or what to focus attention on. Have them report what they observe happens and suggest if this is similar to anything on Earth.

B. Project a diagram showing rain falling onto the earth, and water running downhill to form streams, rivers, lakes and oceans, with some going into the ground. Then go over each aspect carefully while pointing to it on the diagram, taking questions along the way.

C. Tell students that rain falling on the ground will flow downhill to form streams, rivers, lakes and oceans. Demonstrate this with a model: a large shallow box of soil, shaped into hills and valleys. Students watch as she sprinkles water from the spray nozzle of a watering can, and asks them to notice how it flows downhill to form streams and then ponds.

D. Provide a box of soil at each bench and have groups shape landscapes in it with hills and valleys. Have them suggest what might happen if they sprinkle water on it to represent rain. Then have them try it out, report their observations and relate that to what happens on Earth.
Scenario. 12 - Sediments and water

Ms. Doka would like her S.3 grade students to understand the erosive effect of water on various types of sediment, and that running water erodes some types of sediments more easily than others.

Thinking about how you would teach this lesson, of the following, which one is most similar to how you would teach the lesson?

A. I'd ask the students if they think water erodes some sediments more easily than others, and allow them to complete an activity using sand and silt to help them determine the potential for each to erode.

B. I'd explain that the more water a sediment can hold, the more erosion will occur, and use samples of sand and silt to demonstrate.

C. I'd explain that the more water a sediment can hold, the more erosion will occur, and have the students do an activity themselves to verify this.

D. I'd ask the students to explore the effect of water on various sediment samples and come to their conclusions on each sediment’s potential to erode.
Scenario. 13 - Light reflection

Ms. Bakele is teaching her S.3 students the law of reflection: when a ray of light strikes a mirrored surface, it leaves at the same angle as when it arrived. Ms. Baker has to decide how she will teach the lesson.

Thinking about your own teaching, of the following, which is most similar to how you would teach the lesson?

A. I would write the law of reflection on the board and illustrate with a diagram. Next I'd show them a real example, using a light ray source, mirror, and protractor. Then we would discuss any questions the students might have.

B. I would ask students to find out what they can about light behavior around mirrors by exploring on their own with an assortment of available items, including light ray sources, mirrors, and protractors. Then the students would report back on what they did and what they found out.

C. I would first pose a question about reflection for the students to explore. The students could investigate using light ray sources, mirrors, and protractors, and then discuss their findings. I would close the lesson by giving them a summary of the law of reflection.

D. I would write the law of reflection on the board and illustrate with a diagram. Then I'd have the students verify the law using light ray sources, mirrors, and protractors. We would then discuss their findings.
Scenario. 14 - Photosynthesis

Ms. Hamida has been teaching her S.3 students about photosynthesis, and in particular that chlorophyll production in plant leaves is light-induced. She sets up an example to illustrate this. She has placed fast-growing seedlings where they are exposed to different levels of light intensity. The students observe the growing plants over several days and estimate the amount of chlorophyll using a color chart to record leaf color. They record their data in their science notebooks and on a classroom data table. On the last day, Ms. Hamida reviews the role of light in chlorophyll production as illustrated by the activity.

Thinking about how you would teach this topic, of the following, which is the best evaluation of her lesson?

A. This is a good lesson design overall because Ms. Hamida begins with an explanation of the concepts she wants the students to learn followed by an activity for students to confirm that chlorophyll production is light-induced.

B. Ms. Hamida begins appropriately with an explanation of the concepts she wants the students to learn. This being so, it is not clear that the activity is needed, especially since it requires so much class time.

C. Ms. Hamida’s approach is too pre-organized and prescriptive. It would be better for students themselves to decide how to set up plants and lights, see what happens, and figure out a way to compare chlorophyll production in the leaves.

D. The instructional sequence would be better if the students do the plant observations first, showing that chlorophyll is light-induced, after which Ms. Hamid can explain the process more fully.
Scenario. 15 - Sink or float

Ms. Halonda has her P.2 students gather around a small pool of water. She has a set of objects of different sizes and different materials; some will sink and some will float. Ms. Halonda’s goal is for her students to first distinguish the objects by whether they sink or float, and then realize that this does not depend on the size of the object but on what it is made of (e.g., the stones will all sink no matter how big or small they are, and the wooden blocks will all float).

Thinking of how you would teach this lesson, of the following, what would you most likely do?

A. Have students come by one by one and drop an object into the water, with everyone calling out whether it sank or floated. Ask them to suggest what this depended on; when some suggest size and others what it is made of, have them test these ideas by dropping more objects. Then have them agree on a conclusion.

B. Have students come one by one and drop an object into the water, with everyone calling out whether it sank or floated. Point out that all the stones sank, no matter how big or small, and all the wooden blocks floated, etc. Conclude with the lesson objective, that it is not size that matters but the material the object is made of.

C. Drop objects one by one into the water, and have the children notice that some sink and some float. Point out that all the stones sank, no matter how big or small, and all the wooden blocks floated, etc. Conclude by stating the lesson objective, that it is not size that matters but the material the object is made of.

D. Have all the students drop various objects in the water and seeing what happens. Then have them talk among themselves about this and ask volunteers to give their ideas about it, with others saying if they agreed or not.
Scenario. 16 - Varieties of wheat

Ms. Koka will be teaching her P.4 students a unit on edible plants. Today’s topic is that wheat comes in many different varieties.

Thinking about how you would teach, of the following, which is most similar to how you would use a transparency such as the one shown in this diagram?

A. It is important to state the intended learning outcome at the start of the lesson, so I would use the transparency as I explain the concepts to be learned, and show them an example of a wheat stalk of each kind.

B. I would give my students many types of wheat to sort by appearance. Once the task was completed, I would show the transparency and ask the students how their sorting compared with the pictures on the transparency. I would then conclude the lesson by reviewing the intended learning outcome.

C. I would not use a transparency such as this, as it would make the lesson too teacher directed. I would give my students samples of wheat to sort by characteristics of their choosing and then record their results. The lesson would conclude with a discussion of their findings.

D. I would give my students samples of wheat to look at. As I explained the concepts to be learned, I would have them identify the wheat samples by referring to the transparency.
Constructivist Learning Environment Survey II (20)

Instruction for Completing Instrument:

Use the PENCIL PROVIDED to respond to each of the 20 statements by shading the letter that represents your CHOICE.

Response choices for all items are:

- Almost Always  A
- Often  B
- Sometimes  C
- Seldom  D
- Almost Never  E

Learning about the world (Personal Relevance)

In my class as I teach

1.) Students learn about the world in and outside of school.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

2.) New learning relates to experiences or questions about the world in and outside of school.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

3.) Students learn how science is a part of their in- and outside-of-school lives.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E
4.) Students learn interesting things about the world in and outside of school.
Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

**Learning about science (Uncertainty)**

**In my class as I teach**

5.) Students learn that science cannot always provide answers to problems.
Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

6.) Students learn that scientific explanations have changed over time.
Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

7.) Students learn that science is influenced by people's cultural values and opinions.
Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

8.) Students learn that science is a way to raise questions and seek answers.
Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

**Learning to speak out (Critical Voice)**

**In my class as I teach**

9.) Students feel safe questioning what or how they are being taught.
Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

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10.) I feel students learn better when they are allowed to question what or how they are being taught.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

11.) It is acceptable for students to ask for clarification about activities that are confusing.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

12.) It is acceptable for students to express concern about anything that gets in the way of my learning.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

Learning to learn (Shared Control)

In my class as I teach

13.) Students help me plan what they are going to learn.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

14.) Students help me to decide how well they are learning.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

15.) Students help me to decide which activities work best for them.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E
16.) Students let me know if they need more/less time to complete an activity.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

Learning to communicate (Student Negotiation)

17.) Students talk with other students about how to solve problems.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

18.) Students explain their ideas to other students.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

19.) Students ask other students to explain their ideas

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E

20.) Students are asked by others to explain their ideas.

Almost Always  A; Often  B; Sometimes  C; Seldom  D; Almost Never  E
Understanding of Science and Scientific Inquiry Questionnaire

Name: ____________________________  ID: ____________________________
Institution: ____________________________  Title: ____________________________

Part I: Please read EACH statement carefully, and then indicate the degree to which you agree or disagree with EACH statement by circling the appropriate letters (A or B or C or D or E)

SD= Strongly Disagree,  D= Disagree More Than Agree,  U= Uncertain or Not sure
A= Agree More Than Disagree,  SA= Strongly Agree

1. Observations and Inferences

A). Scientists’ observations of the same event may be different because the scientists’ prior knowledge may affect their observations.

(a): SD. (b): D (c): U (d): A (e): SA

B. Scientists’ observations of the same event will be the same because scientists are objective.

(a): SD. (b): D (c): U (d): A (e): SA

C. Scientists’ observations of the same event will be the same because observations are facts.

(a): SD. (b): D (c): U (d): A (e): SA

D. Scientists’ may make different interpretations based on the same observations.

(a): SD. (b): D (c): U (d): A (e): SA

With examples, explain why you think scientists’ observations and interpretations are the same OR different.

2. Nature of Scientific Theories

A. Scientific theories are subject to on-going testing and revision.
Scientific theories may be completely replaced by new theories in light of new evidence.

Scientific theories may be changed because scientists reinterpret existing observations.

Scientific theories based on accurate experimentation will not be changed.

With examples, explain why you think scientific theories change OR do not change over time.

3. Scientific Laws vs. Theories

Scientific theories exist in the natural world and are uncovered through scientific investigations.

Unlike theories, scientific laws are not subject to change.

Scientific laws are theories that have been proven.

Scientific theories explain scientific laws.

With examples, explain the difference between scientific theories and scientific laws.
4. Social and Cultural Influence on Science

A. Scientific research is not influenced by society and culture because scientists are trained to conduct “pure”, unbiased studies.

(a): SD. (b): D (c): U (d): A (e): SA

B. Cultural values and expectations determine what science is conducted and accepted.

(a): SD. (b): D (c): U (d): A (e): SA

C. Cultural values and expectations determine how science is conducted and accepted.

(a): SD. (b): D (c): U (d): A (e): SA

D. All cultures conduct scientific research the same way because science is universal independent of society and culture.

(a): SD. (b): D (c): U (d): A (e): SA

With examples, explain how society and culture affect OR do not affect scientific research.

5. Imagination and Creativity in Scientific Investigations

A. Scientists use their imagination and creativity when they collect data.

(a): SD. (b): D (c): U (d): A (e): SA

B. Scientists use their imagination and creativity when they analyze and interpret data.

(a): SD. (b): D (c): U (d): A (e): SA

C. Scientists do not use their imagination and creativity because these conflict with their logical reasoning.

(a): SD. (b): D (c): U (d): A (e): SA
D. Scientists do not use their imagination and creativity because these can interfere with objectivity.

(a): SD. (b): D (c): U (d): A (e): SA

With examples, explain why scientists use OR do not use imagination and creativity.

6. Scientific Investigation

A. Scientists use a variety of methods to produce fruitful results.

(a): SD. (b): D (c): U (d): A (e): SA

B. Scientists follow the same step by step scientific method.

(a): SD. (b): D (c): U (d): A (e): SA

C. When scientists use the scientific method correctly, their results are true and accurate.

(a): SD. (b): D (c): U (d): A (e): SA

D. Experiments are not the only means used in the development of scientific knowledge.

(a): SD. (b): D (c): U (d): A (e): SA

With examples, explain whether scientists follow a single, universal scientific method OR use different methods.

Thank you for your participation
Appendix B

Interview Protocol
Interview Scripts

ALL interviews will be semi structured and based on the instrument/questionnaire items. Several items of the questionnaires that need clarification and more information depending on the subjects’ responses to these items will guide the interview discourse.

The instruments are:

1. SUSSI for Nature of science

Examples of follow up questions

- Could you elaborate further on your conception of what is science?
- Could you give me an example of what to you is science and what is not?
- In your concept of science you say that scientist use creativity and imagination, can you elaborate on that further giving any examples?
- In your conception of nature of science do you think there is a clear demarcation between scientific theories and scientific laws?

2. VNOS 270-B for Nature of science

Follow up questions will be very similar to those of the SUSSI

3. POSTT-II: For preferred science pedagogy the interviews will be semi-structured based on responses on the survey.

Example of follow up questions

- Depending on the experience you have accumulated on this job by now, what is your science pedagogy of choice?
- Do you think your perspective of science pedagogy fosters the concept of critical thinking?
- Could you elaborate further using examples on your conception or perspective on your preferred science pedagogy?
• Could you give me an example of how you foster critical thinking outside the classroom during your teaching that illustrates your perspective or view of what it is

• In your answer you have mentioned processes such as analysis, synthesis, evaluation, and application. Can you with examples tell me how you have promoted any of these mind processes during your teaching?

4. CLES-II (20): For Classroom learning environments the questions will be semi-structured based on the responses on the CLES-II (20).

Example of follow up questions

• In your own words what would a good classroom environment look like when you are teaching science using your chosen or preferred pedagogy?

• In that environment what would you think should be the role of the students?

• In that environment what would you think should be the role of you the instructor?

• What do you think are the roles that you should share with the students to facilitate the existence of the environment you are talking about?
Appendix C

HSIRB Approval Letter
Date: September 27, 2012

To: Bill Cobern, Principal Investigator
    Robert Etisha Kagumba, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number 12-09-20

This letter will serve as confirmation that your research project titled “Ugandan Science Teacher Educators: A Concurrent Mixed Methods Investigation of Nature of Science, Pedagogy, and Classroom Environment Perspectives” has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may only be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., you must request a post approval change to enroll subjects beyond the number stated in your application under “Number of subjects you want to complete the study”). Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: September 27, 2013