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Science Content Knowledge: A Component of Teacher Effectiveness in a Primary School in Jamaica

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Abstract

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M. Ed. University of the West Indies, 2011

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Doctoral Study Submitted in Partial Fulfillment

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Abstract

Empirical evidence from the National Education Inspectorate suggested that teachers at the primary school in this study in an island country in the Caribbean have inadequate science content knowledge. Students' average performance on the science Grade Six Achievement Test (GSAT) has been below 40% for the last 5 years. The purpose of this bounded case study, guided by Shulman's conceptual framework, was to understand teachers' science subject matter knowledge (SMK). The guiding questions focused on teachers' abilities to demonstrate components of Shulman's SMK during science teaching and lesson planning and to gather their views on their abilities to meet the SMK components in grades 4–6. The 9 participants were primary-trained and each had taught science at grades 4–6 for a minimum of 2 years. Data collection consisted of interviews, lesson observations, and lesson plan reviews. Data were analyzed using open coding, axial coding, and themes from Shulman's SMK domains. The participants believed that they lacked proficiency in teaching science at the assigned grade level. They held misconceptions about the topics taught at the Grade 4-6 level and their lesson plans and observation data demonstrated lack of key components of SMK. Findings from this study were used to develop a science professional development project to empower teachers and, in turn, students in science content and processes. It is expected that implementation of the program could improve the science content knowledge of teachers at the primary school in this study. Positive social change might occur as improvement in teachers' science content knowledge might serve to improve students' learning outcomes in science at this and other settings in the island country.

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Dedication

This project study is dedicated to my mother Ms. Elsada King and my daughter Tiana Robinson. Elsada's love, commitment, dedication and devotion to her family, friends and community is immeasurable. I strive daily to acquire and emulate her strength of character. Tiana Robinson has been patient with me throughout the process. I am grateful for the sacrifices she made in order for me to complete this journey.

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I am indebted to a host of friends who reached out to support me in those times when I was on my face and without whose help I would never have made it to the end. Mr. Davion Leslie, who provided the additional technical support that I needed to complete this project study. Mrs. Kerrina Leslie for reviewing and editing this project study. Mr. and Mrs. Cowan, Mrs. Althea Ashley Burke and Miss Tanesha Smith for accommodating me in their homes with all my baggage when I needed a safe and sterile heaven which was sometimes missing from my home. I am thankful to my colleagues at my regional branch of the Ministry of Education for believing in me from the inception of the journey to the last step. Thank you.

My family members have been supportive financially, emotionally and psychologically. I am grateful and I promise to make you proud as I continue to serve humanity with high integrity, loyalty, passion and honesty.

I must express heartfelt gratitude to these participants who worked with me throughout the data collection and analysis portion of the research project. I am thankful

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Table of Contents

List of Tables

List of Figures

Section 1: The Problem

Introduction

The science content knowledge of primary school teachers has been an issue of great concern for educators and the science education community since the 1950s (Anderson & Clark, 2012; Cofré et al., 2015; Harrell & Subramaniam, 2015; McConnell, Parker & Eberhardt, 2013; Nowicki, Watts, Shim, Young & Pockalny, 2013; Oh & Kim, 2013). According to the science education literature, there is a deficit in many primary school teachers' science content knowledge that can inhibit effective science teaching (Crippen, 2012; Greene, Lubin, Slater & Walden, 2013; McConnell et al., 2013; Nowicki et al., 2013; Oh & Kim, 2013). This deficit has led to science teaching that is predominantly teacher-centered with little room to facilitate students' creativity and curiosity (Cofré et al., 2015; Nilsson & Loughran, 2012). Inadequate science content knowledge can lead to ineffective science teaching and ultimately students' underperformance in science (Alshehry, 2014; Cofré et al., 2015; Cone, 2012; Fitzgerald, Dawson & Hackling, 2013; Hodges, Tippins & Oliver, 2013; McConnell et al., 2013; Nowicki et al., 2013).

Effective science teaching is characterized by teachers' ability to create learning environments that challenge learners to develop a deep understanding of science concepts (Alshehry, 2014; Cone, 2012; Harrell, & Subramaniam, 2015; Oh & Kim, 2013). Science teaching that requires students to investigate, construct, and test explanations about the natural world is considered to be effective teaching (Alshehry, 2014; Johnson, Zhang & Kahle, 2012; Nowicki et al., 2013). Effective science teaching requires that science lessons be contextualized to appeal to students' interests and prior experience (Fitzgerald et al., 2013; Fuentes, Blooms & Peace, 2014). Hodges et al. (2013) stated that effective science instruction ultimately results in satisfactory students' performance in science.

Teachers must possess some key elements in order to be effective in teaching science at the primary level. Science teachers should have a thorough understanding of how students learn (Anderson & Clark, 2012; Cone, 2012; Fitzgerald et al., 2013; Haney & Beltyukova, 2012). Science teachers should have pedagogical knowledge of the subject and have comprehensive knowledge of the subject content. They should exude self-confidence in the teaching and learning environment (Anderson & Clark, 2012; Cone, 2012; Fitzgerald et al., 2013; Lumpe, Czerniak, Haney & Beltyukova, 2012). For teachers to be able to communicate adequate understanding of scientific knowledge, they need to conceptualize the content knowledge from multiple perspectives and at levels deeper than what needs to be presented to students (Ghazi, Shahzada, Shah & Shauib, 2013; Johnson et al., 2012). When teachers lack this depth, they might fail to challenge students' understanding or misunderstanding of science content, which could result in superficial learning (Alshehry, 2014; Anderson & Clark, 2012; Cone, 2012).

Lack of science content knowledge often limits teachers' ability to plan effectively and deliver meaningful science lessons (Nowicki et al., 2013; Oh & Kim, 2013). When science teachers possess superficial content knowledge, they may deliver erroneous content, which can lead to some students developing misconceptions (Ghazi et al., 2013). This qualitative project study focused on teachers' science content knowledge as a critical component of teacher effectiveness at a primary school in Jamaica. In this section, the problem is defined and a rationale—evidence of the problem both locally and in the reviewed literature—is provided. Additionally, the guiding questions are listed.

Definition of the Problem

Clarke Primary School (pseudonym) is a large school situated in West Central St. Catherine, Jamaica. This school has a population of 1,290 students and is managed by a staff complement of 40 teachers, inclusive of one principal and other administrative staff. Teachers at Clarke Primary School complained that they have difficulty teaching science in Grades 4–6 because they are not familiar with the content in these upper primary grades. They said they have difficulty, for example, teaching aspects of matter, density, plant nutrition, and the functions of different organs (S. Ranger, personal communication, June 7, 2015).

The principal of Clarke Primary School stated that teachers display reluctance to teach classes in the upper primary grades, which suggested that they were afraid to teach science (S. Ranger, personal communication, June 7, 2015). Similarly, Oh and Kim (2013) reported that in a national survey conducted in the United States, a high percentage of teachers felt themselves unprepared to teach some topics taught at the primary level. The submission records of science lesson plans at Clarke Primary indicated that, of the 630 lesson plans that should have been submitted for the Grade 4 - 6 level from September to March, 2015, only 240 (38%) were submitted (S. Ranger, personal communication, June 7, 2015). The principal added that these submission data is also indicated the low number of science lessons taught over the period at the Grade 4 – 6 levels (S. Ranger, personal communication, June 7, 2015). This situation caused the principal to write to individual teachers about the low submission rate and the infrequency of science teaching in Grades 4 – 6. According to Oh and Kim (2013), primary teachers with limited content knowledge sought to mask this limitation, and used various strategies, such as simply not teaching science, infrequent submission of science lesson plans, teaching only the concepts they are familiar with, creating learning environments that are not interactive, and relying heavily on textbooks. Flow: Transition sentence needed to show the relationship between this and the previous sentence.

The GSAT is a content-based national examination that is used to determine students' placement in secondary school (Ministry of Education, 2015). The school's GSAT average over the last 5 years has remained below 40%. This number is very low when compared with the school's average in Mathematics and Language Arts over the same period: both above 65%. Clarke Primary science average in the GSAT continues to fall below the national average, which has remained above 62% over the last 5 years. The school's low performance in science, as demonstrated in the (GSAT), led me to have discussions with the administrators and teachers at the school.

Inadequate science content knowledge that detracts from effective science teaching can contribute to students' underperformance in the subject (Hodges et al., 2013; Johnson et al., 2012; Lumpe et al., 2012; Ogunkola, 2013; Skourdoumbis & Gale, 2013). Based on discussions with teachers and administrators at the Clarke Primary School, it was determined that teachers have concerns about their knowledge of science content as well as their ability to deliver science instruction effectively in Grades 4 – 6. Gaps in science teachers' content knowledge might lead to students' continued underperformance in science (Nilsson & Loughran, 2012). Students taught by teachers with limited science content knowledge may not be fully prepared to advance in science-based courses (Ghazi et al., 2013).

In the 2004 report of the National Task Force on Educational Reform, one of the recommendations was that a National Quality Assurance Authority (NQAA) be established to address the issues of performance and accountability in the educational system in Jamaica (The Task Force on Educational Reform in Jamaica, 2004). The National Education Inspectorate (NEI) came out of this recommendation. It was established with a mandate to assess the standards attained by primary and secondary schools in Jamaica with special focus on leadership and the quality of teaching (Ministry of Education, 2015). The anecdotal evidence gleaned from the NEI report on lesson plan records and science lesson delivery, along with concerns raised by administrators and teachers at the Clarke Primary school, prompted my interest in this school and in the specific area of science content knowledge. The purpose of this project study at Clarke Primary School was to better understand teachers' science content knowledge as a component of their effectiveness as science teachers.

Rationale

Evidence of the Problem at the Local Level

The Task Force on Educational Reform in Jamaica (2004) reported that the education system is overwhelmed by students' continuous underperformance in core subject areas, including science. This is noted in the context where there is greater focus on literacy at the primary level as against that which is placed on science teaching

(Whiteley, 2015). This increased focus on literacy is in response to the Ministry of Education Competency-Based Transition Policy, which requires that students at the primary level be certified as literate in order to transition to the secondary level (Alternative Secondary Transitional Education Program, 2011). Additionally, the NEI ranks schools at the primary level as *good, satisfactory* or *unsatisfactory* according to their performance in mathematics and language arts and not in science (Smith, 2012). Hence, PD activities and resources are directed toward language arts and mathematics, to the detriment of science education.

The management, supervision, and execution of science education at Clarke Primary School is similar to the treatment of the subject from a national standpoint. As such, the science score average of the school in the GSAT from 2010 to 2015 is below 40%. A review of science lesson plans conducted at the school by the NEI team, revealed elements of erroneous content (Ministry of Education, 2015). For example, the content of the plans reviewed highlighted undigested and indigestible materials as examples of excretion. When the teachers were asked about metabolism and the association with excretion, they said that *metabolism* was an unfamiliar term (Ministry of Education, 2015). Records at the school show that teachers are reluctant to write lesson plans. This action resulted in the omission of some concepts in the science syllabus at the Grade 4 – 6 levels. When asked to justify the lack of writing lesson plans and the deliberate omission of some concepts, teachers claimed that they had doubts about their ability to effectively teach these concepts due to their lack of knowledge of the content.

After conducting a study on Jamaican students' performance in biology, Bramwell-Lalor and Rainford (2014) outlined the fact that teacher effectiveness significantly influences students' underperformance in science. This claim is supported by the reports of the NEI (Ministry of Education, 2015), which stated that teaching and learning in science is deemed unsatisfactory at Clarke Primary School and the source is teachers' poor display of content knowledge. For example, chief inspector of the NEI, M. Dwyer, wrote that students are told that plants obtain food from the soil (M. Dwyer, personal communication, June 7, 2015). This misconception was also reported by Sodervik, Mikkila--Erdmann and Vilppu (2014) after conducting a study in Finland to determine elementary school teachers' concept of photosynthesis.

Similarly, the principal of Clarke Primary, S. Ranger (pseudonym), wrote that in a lesson observation at the Grade 6 level, the teacher had difficulty explaining concepts such as short-sightedness (myopia) and far-sightedness (hyperopia) and lacked the capacity to explain the functions of convex and concave lenses in correcting these eye conditions. In analyzing a similar situation, Oh and Kim (2013) stated that teachers should possess solid content knowledge to be able to stimulate students' understanding by exposing them to representations such as examples, analogies, pictorial and physical models.

Nowicki et al. (2013) asserted that while primary school teachers are trained as generalists, they are expected to deliver in-depth instruction on discipline-specific concepts such as earth, physical and life sciences in order to help students construct their own understanding of natural phenomena. M. Rose, a senior lecturer at a teacher training institution in Jamaica, suggested that, since teachers at the primary level are trained as generalists, they would benefit from being enrolled in more science content courses to be fully equipped to teach the content in the upper primary grades (M. Rose, personal communication, July 10, 2015). Furthermore, the preparation of science teachers by teacher training institutions usually focus on the pedagogical aspect of the content as opposed to science knowledge content (M. Rose, personal communication, July 10, 2015). Given this anecdotal evidence on the inadequacy of the science content knowledge of teachers at the Clarke Primary School, a research study is warranted to better understand teachers' science content knowledge as a component of their effectiveness.

Evidence of the Problem from the Professional Literature

Nowicki et al. (2013) and Sodervik et al. (2014) stated that expectations for primary school teachers have been incredibly high: they are responsible for teaching a wide array of subjects and doing it well. Studies have shown that primary school teachers have demonstrated ineffectiveness in the teaching of science (Diamond, Maerten-Rivera, Rohrer & Lee, 2013; Ogunkola, 2013). Gaps in teachers' science content knowledge have contributed to teachers' ineffectiveness in delivery of the science curriculum at the primary level (Alshehry, 2014; Andersson, & Gullberg, 2014). McConnell et al. (2013) reported that a significant number of studies have been conducted, which provide evidence to suggest that primary school teachers lack science content knowledge.

Kinghorn (2013) conducted a qualitative case study in the school districts of three states: Alabama, Iowa, and Kentucky. The aim was twofold: to identify gaps in science content knowledge that primary and middle school science teachers encountered during their teaching practice and to determine the point at which these gaps are recognised by the teachers. Interviews and lesson observations revealed that 75% of the events observed indicated gaps in teachers' knowledge of specific concepts. Also, Nowicki et al. (2013) conducted a mixed-method research study that examined the factors that influence the accuracy of science content in elementary science lessons. Findings from the study revealed that 11 participants, inclusive of pre-service and in-service teachers, presented lessons with less than 70% accuracy in the science content. During these lessons, teachers provided inaccurate explanations of the concepts they taught and struggled to correct students' misconceptions.

In a research study conducted in a large school district in the South-eastern United States, Diamond et al. (2013) tested elementary teachers' science content knowledge with an instrument designed for students at the fifth grade level. Items on the test instrument were developed by the National Assessment of Educational Programs (NAEP). Teachers' performance on this test yielded a mean of 30.81 out of 38 possible points, or 81.1% correct. Diamond et al. (2013) concluded that the score was unfavourable given that the instrument was designed for Grade 5 students. Diamond et al. recommended that teachers' depth of content knowledge in a subject area should exceed that which is required to be presented to students.

Sodervik et al. (2014) conducted a study in Finland with elementary teachers to determine how they would respond to open-ended questions about photosynthesis after it was taught to them systematically. Findings revealed that teachers were still unable to answer some questions correctly. Sodervik et al. concluded that teachers who have misconceptions about an important biological process such as photosynthesis may not be able to teach the topic to students with sufficient accuracy. According to Tretter, Brown, Bush, Saderholm, and Holmes (2013), an important aspect of science teaching is to recognize, acknowledge, and correct students' misconceptions.

Based on the personal communications with Dwyer and the findings from the studies of Bramwell-Lalor and Rainford (2014), Diamond et al. (2013) and Kinghorn (2013), it is reasonable to conclude that there might be gaps in content knowledge of teachers at the Clarke Primary School. Thus, it was important to conduct a project study with teachers at the school in order to better understand their science content knowledge.

Definitions

Special terms associated with this research study are defined in this section.

Primary Education: Curriculum designed to meet the learning needs of students prior to their transition into the secondary level of the education system (Sifuna, 2007). The basic goal of primary education is to allow for the development of literacy and numeracy skills as well as establishing foundations in science, mathematics and social studies. The term primary education is used interchangeably with elementary education (Sifuna, 2007).

Primary school teacher: An educator trained as a generalist to satisfy the curricular needs of students prior to advancing into the secondary system (Basu & Barton, 2010).

Science teaching: The deliberate efforts of teachers to support students to deeply understand science ideas, participate in the activities of the discipline, and solve authentic problems (Kind, 2009). Additionally, it is the set of instructions developed from a set curriculum that enable students to develop the skills, knowledge and attitudes necessary to gain proficiency in the subject area (Shulman, 1986). Planning, preparing and presenting lessons that cater to the needs of the whole ability range within a class to motivate pupils with enthusiastic, imaginative presentation to learn science (Kinghorn, 2013).

Content knowledge: The fundamental tenets of a subject and the organizing and defining principles that define that subject (Shulman, 1986).

Subject Matter Content*:* The units of facts or tenets of a particular subject which defines the subject and sets that subject aside from other subjects (Shulman, 1987). Shulman (1986) organized subject matter content into seven domains which included; the general subject matter, knowledge of the skills embedded in the subject, knowledge of education content of the subject, broad content knowledge relating to pedagogical aspects of the subject, curricular content of the subject and the history and philosophy of the subject (Ball et al., 2009; Kind, 1996; Shulman, 1987).

Teacher Effectiveness: Teachers' ability, skills, knowledge of pedagogy and knowledge of subject content that is used to bring about student learning (Alshehry, 2014; Cone, 2012)

Significance

This research study is significant because it strengthened the understanding in an area of science education that is under-researched in Jamaica. The findings from this study led to the identification of specific gaps in teacher's science content knowledge at

Clarke Primary and how these gaps influence the way science is taught. It is noted that gaps in teachers' science content knowledge can inhibit effective science teaching (Harrell, & Subramaniam, 2015; Hodges et al., 2013; Johnson et al., 2012; Lumpe et al., 2012; Ogunkola, 2013). This study provided a deeper understanding of Clarke Primary School teacher's science content knowledge and the implications for effective science teaching and learning.

Additionally, the information gathered in this research served as baseline data in informing a PDP designed to improve Clarke Primary School teachers' science content knowledge. Ultimately, this project study is expected to contribute to improved outcomes in instructional practices, science teaching, and science education at Clarke Primary School. Indeed, an improvement in science pedagogy for teachers is likely to result in improved teaching that will improve students' performance in science. Also, there may be an increase in the number of individuals entering careers such as medicine, science education, scientific research and technology for which science subjects are critical prerequisites.

Guiding Questions

An important requirement for teachers working at the primary level is a sound knowledge of the science content (Byers, Koba, Sherman, Scheppke, & Bolus, 2011; Harrell, & Subramaniam, 2015; Eberhard, 2013). But many primary school teachers do not have adequate knowledge of the science concepts they are required to teach (Tretter et al., 2013; Fuentes et al., 2014; McConnell et al., 2013). Given the findings of studies conducted outside of Jamaica and on the preliminary local data from informed educators regarding Clarke Primary School teachers' knowledge of science content, it was important to conduct a research study that yielded greater understanding of the issue of content knowledge for science. Shulman's (1987) concept of subject matter knowledge (SMK) provided a framework, which, in turn, helped develop the guiding questions. The guiding questions for this research study were as follows:

1. How do teachers at Clarke Primary School demonstrate SMK of science as outlined in Shulman's (1986) seven domains when teaching science at the Grade 4-6 level?
2. What aspects of SMK of science, as outlined in Shulman's (1986) seven domains are evident in the lesson plans written by teachers in Grade 4-6 at Clarke Primary School?
3. What are the views of the teachers at Clarke Primary School on their ability to teach the science content in Grade 4-6 at the primary level?

Literature Review

A review of literature is necessary in order to highlight studies which were done on the topic and to show gaps in the literature. To identify prospective, peer-reviewed articles and books, the following databases—EBSCOhost, Education Complete, ERIC, ProQuest, and Thoreau—were searched for the years 2011–2016 using the following keywords: *science teaching, Shulman's SMK, teachers' science content knowledge, gaps in science content, content knowledge, teachers' misconceptions, teacher effectiveness* and *teacher training* . I used the Boolean operators, AND and OR to optimize the results. Abstracts were used to judge an article's relevancy to the research questions.

In order to situate the local problem in the broader educational landscape, the following areas were identified and discussed in the literature review: the conceptual framework, historical background of teachers' science content knowledge, content knowledge as a component of teacher effectiveness, gaps in teachers' science content knowledge, sources of teachers' science content knowledge, and teachers' science content knowledge.

Conceptual Framework

A conceptual framework is an important component in a project study as it provides boundaries within which to situate the local problem under investigation (Anderson & Clark, 2012; Onwuegbuzie, Leech, & Collins, 2012; Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013; Wener & Woodgate, 2013). The conceptual framework which guided this study is Shulman's (1986) subject matter knowledge (SMK). This practice-based model is grounded in the work of Lee S. Shulman (Anderson & Clark, 2012; Sadler et al., 2013). Shulman (1986) classified SMK into seven domains of knowledge that underscore the different levels of interactions that account for the ways teachers think about and deliver the content of a subject.

As shown in the list below, these categories were intended to highlight the important role of content knowledge and to position content-based knowledge in the wider landscape of professional knowledge for teaching (Anderson & Clark, 2012; Sadler et al., 2013). Accordingly, this concept provoked broad interest with the indication that there is SMK that is unique to the PD of specific subjects (Shulman, 1986).

1. Knowledge of subject matter
2. Knowledge of the skills embedded in the subject
3. Knowledge of educational context, history and philosophy of the subject
4. Knowledge of education context of the subject
5. Knowledge of the content of the subject relating to pedagogical aspects of the subject
6. Knowledge of the learner
7. Knowledge of educational goals and purposes of the subject.

Based on Shulman's (1986) domains, the first domain, which is subject matter knowledge, refers to the units of facts and the organizing structure of a particular subject which defines the subject and set that subject aside from other subjects. The second domain, as proposed by Shulman (1986), addressed the knowledge of the various skills that are embedded in a particular subject. This refers to the skill-set that students must develop when exposed to a particular subject area. It is critical for teachers to develop these skills in order to be able to demonstrate them to their students (Anderson & Clark, 2012; Shulman, 1986). Furthermore, students should be able to demonstrate these skills when necessary so as to provide evidence that they have developed these skills after exposure to the subject matter (Shulman, 1986, 1987).

The third domain of Shulman's SMK is knowledge of the history and philosophy of the subject. The history and philosophy is in line with how the subject evolves over time in relation to new approaches regarding the subject (Shulman, 1986). This aspect also speaks to knowing and understanding the *why* and the *how* in the body of knowledge (Anderson & Clark, 2012; Kleickmann et al., 2013; Klu et al., 2014). Therefore, when teachers possess a sound philosophical understanding of a particular subject, they can explain why concepts in the subjects are connected and also state how they are connected in order to provide a holistic viewpoint for students (Shulman, 1986). In this research study, the subject matter that was examined is science at the primary level.

The fourth domain of Shulman's (1986) SMK is knowledge of education context of the subject. Thus, issues such as the contribution that this subject area should make to the broad sphere of education and growth is aligned to this domain (Kleickmann et al., 2013; Shulman, 1986). The fifth domain of Shulman's (1986) SMK is knowledge regarding the broad content relating to the pedagogical aspect of the subject. This aspect is aligned to teachers' ability to sequence, arrange, organize and explain the subject matter to students in an effective and appropriate manner (Anderson & Clark, 2012; Kleickmann et al., 2013; Shulman, 1986). The sixth domain, as displayed in is knowledge of the learner. It is important for teachers to know and understand the diversity of students that they are teaching along with the different strategies to cater to students' learning styles (Sadler et al., 2013). Additionally, teachers should know how to sequence the body of knowledge in the subject area based on appropriateness for the group of students (Kleickmann et al., 2013; Sadler et al., 2013; Shulman, 1986).

The seventh domain of Shulman's SMK, as, is knowledge of the goals and purposes of the subject. This body of knowledge is important as it influences the teachers' ability to transmit these purposes and aims to the learners (Anderson & Clark, 2012; Sadler et al., 2013). This aspect regarding exposing students to the aims and purposes of learning the subject is usually beneficial to both teacher and learner (Shulman, 1986). This comprehensive concept on SMK, as put forward by Shulman, encompasses all aspects of a subject in any discipline and contributes significantly to teachers' effectiveness (Harrell, & Subramaniam, 2015; Oh & Kim, 2013; Shulman, 1986). Consequent to the comprehensive nature of the Shulman's SMK concept, it was deemed quite suitable in providing the framework within which to investigate the science SMK of the teachers at Clarke Primary School in order to strengthen one's understanding of this phenomenon. Therefore, the purpose of this project study was to provide an understanding of the teachers' science SMK as a component of teacher effectiveness at Clarke Primary School.

According to this concept, teachers construct knowledge that is relevant to a subject when they have a chance to engage in discussions and develop strategies to display this knowledge (Tretter et al., 2013). Thus, this conceptual framework is widely used to guide teacher education in a wide array of subjects inclusive of science (Anderson & Clark, 2012; Kleickmann et al., 2013). Furthermore, it forms the framework for PDPs which address areas of content matter relevance, structure and development in science (Anderson & Clark, 2012; Klu et al 2014). Shulman's SMK concept was also employed as the framework that guided the case study research conducted by Tretter et al. (2013) which explored the reliability and validity of assessment instruments which measured teachers' SMK. Likewise, Oh and Kim (2013) used Shulman's SMK concept as the framework, which guided their case study research of Korean teachers' ability to transform science content knowledge into engaging classroom experience.

Shulman's SMK concept was used in guiding this research study in answering the guiding questions, through its application in data gathering, data analysis and interpretation of the findings. Each research question is directly aligned with Shulman's SMK model. The first research question is directly aligned to Shulman's (1986) SMK of science with specific reference to teachers' ability to demonstrate their knowledge of science content based on their delivery of science instruction. This encompasses the full range of Shulman's (1986) content knowledge as. Therefore, teachers' ability to demonstrate their understanding and use of science content during science instruction was interpreted against Shulman's description of the domains and the organizing structure of the subject in addition to its philosophical underpinnings. These include the *how* and the *why* of the concepts that characterize the subject.

The second research question allowed for the investigation of elements of Shulman's (1986) domains of SMK as was evident in the science content embedded in lessons plans written by teachers for science teaching in Grades 4–6. Additionally, the final research question allowed for the exploration of teachers' views of the SMK requirements for teaching science in Grades 4–6 and also their views of their ability to effectively deliver science content knowledge based on the philosophical and contextual requirements of the subject in Grades 4–6. The conceptual framework was employed in the collection and analysis of data in addressing these questions. Shulman outlined the education context of the subject and the relation and interplay of concepts within the subject along with purposes and aims of teaching the subject as critical aspects of SMK. These elements of SMK as outlined guided the interpretation of the findings coming from the data in answering the guiding questions.

This conceptual framework addresses content knowledge in the broadest sense at all levels of every educational system from infancy to the highest level. However, in this research study the focus was on science teaching at the primary level of the education system. Consequent to the extensive usage of Shulman's SMK concept in the assessment and development of content knowledge (Lekhu, 2013; Oh & Kim, 2013; Tretter et al., 2013), it was deemed a suitable framework to support a case study aimed at providing a deeper understanding of the content knowledge of teachers at Clarke Primary School.

It was important to examine the historical development of teachers' content knowledge, content knowledge as a component of teacher effectiveness and the sources of teachers' science content knowledge. This organization was necessary as it provided a background for the proceeding aspects of the literature review. Furthermore, the historical development also provided the connection between the conceptual framework and the literature that surrounds this research area.

Historical Development of Content Knowledge

Since the 1950s, there have been great concerns regarding the depth of science content knowledge of primary school teachers (Burnett, 1964; Hashweh, 1987; Heller, Daehler, Wong, Shinohara, & Miratrix, 2012; Howes, 2002; Risk, 1983; Shulman 1986). However, while there was this concern regarding the depth of science content knowledge, very few research studies focused on this area (Hashweh, 1987; McConnell et al., 2013).

As shown in the list, Shulman (1986) defined subject matter knowledge in a very broad way. In a similar manner Grossman and Richert (1988) defined subject matter knowledge to include professional knowledge, knowledge of pedagogical principles, skills and content of a subject to be taught. Leinhardt and a team conducted a study in which subject matter of teachers was discussed and described (Leinhardt, 1983; Leinhardt & Smith, 1985). Furthermore, Anderson and Smith (1984) conducted a study in which they explored the effects of subject matter knowledge on teachers' performance. Conversely, Shulman, Sykes & Phillips (1983) conducted a study which focused on the expansion of science content knowledge of teachers. These studies all concluded that the content knowledge of a particular discipline is necessary for teachers to teach the subject in an effective manner.

Grossman and Richert (1988), in a case study conducted among a group of six teachers at Standard University, identified the characteristics of the content knowledge needed for teachers to effectively teach a subject. Findings from this study revealed that teachers do benefit from content courses during teacher preparation, however, more knowledge is gained while teaching and interacting with learners than is acquired during teacher training. After reviewing the studies conducted on teachers' subject matter knowledge, McConnell et al. (2013) indicated that there is a need for studies to be conducted on teachers' understanding of subject matter to be followed by further research studies on the effects of this understanding on the teaching process and teachers' effectiveness.

Content Knowledge: A Component of Teacher Effectiveness

Teacher content knowledge is a fundamental component of teacher effectiveness (Diamond et al., 2013; Garrett & Steinberg, 2014; Johnson et al., 2012; Nowicki et al., 2013). A significant number of studies suggest that there is a direct correlation between teachers' science content knowledge and teachers' effectiveness in delivering science instruction (Alshehry, 2014; Fitzgerald et al., 2013; Santau, Maerten-Rivera, Bovis & Orend, 2014). However, Oh and Kim (2013) suggested that while teachers' content knowledge is a necessary element of teacher effectiveness it is not sufficient, as there are other qualities that determine teacher effectiveness. Diamond et al. (2013) asserted that science teachers must have the ability to package science content knowledge into forms that students can understand. On the other hand, Nowicki et al. (2013) posited that teachers cannot explain to students what they do not know, thus, rendering content knowledge a critical component of science teacher effectiveness.

Darling-Hammond, Newton and Wei (2013) conducted a study in which the Performance Assessment for California Teachers (PACT) was used to measure the effectiveness of 1,870 teachers. Findings indicated that teachers' knowledge of content was a significant determinant of teacher effectiveness. Similarly, Fitzgerald et al. (2014), conducted a case study among four primary school teachers who were identified as effective science teachers in Western Australia. In this study teacher effectiveness was determined by knowledge of science content, pedagogical practices and students' achievement. While Fitzgerald et al. concluded that teacher effectiveness is a complex phenomenon, findings from the study revealed that adequate knowledge of science content contributed significantly to teacher effectiveness and by extension student achievement.

Students' achievement is used as an indicator of teacher effectiveness in a number of studies (Alshehry et al., 2014; Darling-Hammond, Newton & Wei, 2013; Fitzgerald et al., 2014; Garrett & Steinberg, 2014; Skourdoumbis & Gale, 2013). However, Garrett and Steinberg (2014) and Skourdoumbis and Gale (2013) made the point that students' achievement is an unreliable variable that is used in determining teacher effectiveness. Many variables are at work in a classroom setting which influence students' performance and by extension teacher effectiveness (Garrett & Steinberg, 2014; Skourdoumbis & Gale, 2013). Based on the foregoing issue regarding teacher effectiveness, there is an agreed position among researchers: science teacher content knowledge is a critical component of teacher effectiveness (Garrett & Steinberg, 2014; Johnson et al., 2012; Nowicki et al., 2013; Oh & Kim, 2013).

Sources of Teachers' Science Content Knowledge

Many research studies that examined teachers' science content knowledge reported that primary school teachers lack adequate understanding of science content (Gunning & Mensah, 2011; Nowicki et al., 2013; Oh & Kim, 2013; Sodervik et al., 2014). Furthermore, it was reported that this inadequacy affects the quality of these teachers' ability to delivery science instruction (Oh & Kim, 2013; Usak, Ozden & Eilks, 2011). This is because teachers cannot teach what they do not know (Nowicki et al., 2013). It is accepted that excellent science instruction is cultured from a broad and deep understanding of science content knowledge (Heller et al., 2012; Tretter et al., 2013). It, therefore, becomes necessary to examine the sources of teachers' science content knowledge.

Previous Learning Environments

Learning is dependent on what students already know (Usak et al., 2011). This is not different for the pre-service teachers, who come to the teaching context with their own previous knowledge (Sodervik et al., 2014). Therefore, Usak et al. (2011) concluded that one source of teachers' science content knowledge is the previous knowledge that the teachers take to teacher training. This knowledge would have been gathered over time as a result of interacting with science instructions delivered by teachers who would have taught these teachers when they were students at the different levels of the education system (Heller et al., 2012).

Teachers teach in accordance with their understanding of a concept – whether conceptually sound or not – and students' conceptions mirror this understanding (Ahopello, Mikkila- Erdmann, Anto, & Penttinen, 2011; Sodervik et al., 2014). Gunning and Mensah (2011) pointed out that the cycle of education, in which teachers teach students who then become teachers, is one agent responsible for perpetuating gaps and misconceptions in science content knowledge for teachers at the primary level. Also, Sodervik et al. (2014) asserted that teacher-student interactions of pre-service teachers with their own teachers at the training institutions are a significant source which can result in gaps in teachers' science content knowledge.

Teacher Training Programs

Primary teachers acquire formal training at teacher training facilities that are designed to prepare educators with the necessary pedagogical and content knowledge deemed critical for students at that level (Oh & Kim, 2013; Tretter et al., 2011; Usak et al., 2011). However, Nowicki et al. (2013) outlined that the duration of time for which pre-service teachers are enrolled in these teacher training institutions is inadequate and does not allow for teachers to be properly prepared for teaching science at the primary level. This can be viewed against the background that primary teachers are trained as generalists and are expected to develop the skills necessary to teach a wide array of subjects during the time they are enrolled in teacher training (Ahopello et al., 2011; Sodervik et al., 2014; Tretter et al., 2013). Additionally, the duration of time for which pre-trained teachers are enrolled in teacher training institutions also has financial implications (Usak et al., 2011). Thus, if the timeline for teachers to complete the process of certification is to be increased the cost for the certification will also be increased (Usak et al., 2011; Yoon, Joung, & Kim, 2012).

Nowicki et al. (2013) and Yoon et al. (2012) reported that the courses students are offered at the training institutions usually provide little opportunity for experimenting and 'hands-on' learning that would help students develop conceptual understanding. In addition, numerous studies have reported findings that indicate that pre-service teachers are entering teacher training institutions without the necessary background knowledge in science (Oh & Kim, 2013; Park, Jang, Chen & Jung, 2011; Usak et al., 2011).This is evident in a study conducted by Usak et al. (2011) in which 30 beginning science teachers were tested to determine the science knowledge base with which they entered teacher training. Findings from the study revealed that these teachers did not demonstrate appropriate levels of conceptual understanding of the basic topics on which they were tested, which included basic geology, physical phenomenon and motions of matter. This lack of conceptual understanding was evident in that teachers were not able to provide correct answers to the questions on the test nor were they able to supply scientifically-accurate explanations for the answers that they gave. Further review of the literature revealed that this problem is linked to teacher training and teacher preparation.

Since the 1980s in the United States, teacher educators have frequently faced criticism from politicians, education critics, and policy makers concerned with the quality of teachers (Park et al., 2011; Risk, 1983; Sodervik et al., 2014). For example, Risk (1983) pointed out that teacher preparation programs needed substantial improvement. It further stated that the teacher preparation curriculum is weighted heavily with courses in "educational methods" at the expense of courses in subjects matter knowledge. In Jamaica, 30 credit hours are allotted for educational method courses while nine credit hours are allotted to science for teacher training at the primary level (Joint Board of Teacher Education [JBTE], 2014).

In the United States, classroom science education has undergone radical changes in recent times; these changes include revision of curriculum and the development and establishment of new standards (American Association for the Advancement of Science 1989, 1993; National Research Council, 2011). However, teacher training institutions with the responsibility to train science teachers for the primary level have not made the required changes to the science programs that are being offered (Nowicki et al., 2013;

Usak et al., 2011). This level of dissonance does create a problem for novice science teachers as they emerge from these training institutions to embark on this new career path (Usak et al., 2011).

Teacher-training institutions should have been a reliable source in providing newly-trained teachers with the subject matter knowledge that is deemed critical to be able to function effectively in the science classroom (Kleickmann et al., 2013). However, this is difficult to attain as the duration of time spent in these teacher-training instructions is not sufficient to satisfy these conditions (Nowicki et al., 2013). Also, an increase in the duration of time pre-trained teachers are enrolled in these institutions would require more money in order to complete the training and certification (Sodervik et al., 2014; Usak et al., 2011; Yoon et al., 2012). Furthermore, greater portions of the time at these training institutions are spent on developing the *how* of teaching and not the *what* to teach (Diamond et al., 2013). This situation in the teacher training facilities necessitates a reasonable balance so that teachers emerge with the requisite skills and competencies.

Teachers' Interactions with the Physical–Biological Environment

One important source of teacher's science content knowledge is their everyday interactions with the physical-biological environment that result in vicarious learning (Ahopello et al., 2011; Sodervik et al., 2014). Students who sometimes become teachers commonly develop inaccurate or incomplete ideas about scientific processes and phenomena before formal instruction (Ahopello et al., 2011; Burgeon et al., 2011). This source of teachers' science content knowledge is very influential in shaping and forming the background for science content knowledge in an informal way (Ahopello et al., 2011;

Sodervik et al., 2014). However, while this source of content knowledge is sometimes reliable, it can contribute to misconceptions in science content knowledge, especially as it relates to hypothetical concepts such as photosynthesis and heat transfer in solids (Burgoon et al., 2011; Sodervik et al., 2014). The findings of a study conducted by Sodervik et al. (2014) revealed that in-service teachers held the misconception that water is the food source that plants used. This misconception develops as a result of observing wilted plants reacting to water (Sodervik et al., 2014). The process involved in plant nutrition is difficult for teachers to understand by simply observing wilting plants respond to water (Sodervik et al., 2014). It is the responsibility of science teachers to first identify these misconceptions at the primary level and design strategies to guide students in the construction of the correct concept (Sodervik et al., 2014). Unfortunately, pre-trained teachers become teachers without the necessary conceptual change which may very well be passed on in the cycle of education.

Science Resource Materials

Nowicki et al. (2013) put forward the view that it is likely that science teachers may operate optimally if provided with appropriate curriculum material. Curriculum materials in science can include textbooks, software, science kits, scholarly journals and other educational publications, community resources from places such as museums, environmental entities, government agencies and science resource websites (Nowicki et al., 2013). These curriculum materials are additional sources that can inform teachers' science content knowledge (Nowicki et al., 2013). In a study conducted by Nowicki et al. (2013) it was noted that teachers who used science kits were able to provide students with science experiences that offered sound science concepts. It was also highlighted that teachers who did not use science kits were more likely to communicate misconceptions and inaccuracies to their students (Nowicki et al., 2013). Science kits are mainly used at the primary level to enrich science lesson delivery and conceptual understanding. However, some poorly financed schools may not be able to provide teachers with this tool to enhance the teaching of science.

Textbooks are more widely used than the other forms of curriculum materials to enhance teachers' understanding of science concepts and also in the preparation of instructional material and activities for students (Cone, 2012; Usak et al., 2011; Yoon et al., 2012). Oh and Kim (2013) stated that a sound knowledge base is critical for science teachers so as to prevent total reliance on textbooks. Oh and Kim (2013) further stated that even if textbooks and other curricular materials are well-developed teachers are required to make sound judgement in selecting, reorganizing and modifying these so they can be comprehensible for the learner. Based on the forgoing it is important for teachers to acquire conceptually sound science knowledge in order to make accurate decisions regarding suitable content when using curriculum resource materials.

Gaps in Teachers' Science Content Knowledge

A deep understanding of science content knowledge is important in order to teach the subject at the varying levels of the education system (McConnell et al., 2013; Oh & Kim, 2013; Yoon et al., 2012). This wide content knowledge is essential, as science teachers are expected to engage students in authentic science experiences and discourses while simultaneously exposing them to the content knowledge, concepts and vocabulary that is relevant to the subject area in accordance with students' developmental stage (Gunning & Mensah, 2011; McConnell et al., 2013). As early as the 1950s, there have been concerns regarding the science content knowledge of primary school teachers. (Heller et al., 2012; Howes, 2002; Shulman 1986). It is observed that teachers' content knowledge in some concepts taught at the primary level is very limited. These topics include basic astronomy, density, weather and climate, plant nutrition, and properties of matter (Gunning & Mensah, 2011; McConnell et al., 2013; Oh & Kim, 2013; Yoon et al., 2012). According to McConnell et al. (2013), these topics are taught at the primary level so that new knowledge can be built on them at higher levels of the education system.

Conversely, Nowicki et al. (2013) suggested that the expectations for primary school teachers have been unreasonably high. This point was made against the background that primary teachers are trained as generalists and are expected to teach multiple subjects to a diverse range of learners. However, the findings from various studies conducted to measure primary teachers' depth and breadth of science content knowledge revealed that teachers lack critical science content knowledge (Byers et al., 2011; Eberhard, 2013; Krajcik, & Sutherland, 2010). This deficit at the primary level has ramifications for science education at every level and ultimately science related professions (Tretter et al., 2013).

Teacher Training in Jamaica

The JBTE is the body with responsibility for teacher training in Jamaica (JBTE, 2014). Pre-trained teachers who are enrolled in primary education program are required to complete three courses that cover science content and skills. These are Science for

Primary Teacher I, Science for Primary Teacher II and Science for Primary Teacher III (JBTE, 2014). In addition, these pre-trained teachers also complete two courses – Science Methodology for Primary Teachers I and II. The general objectives that guide the teaching of science in the teacher training institutions for primary education as outlined in the JBTE (2014) are as follows:

- For teachers to develop positive attitude and skills in science
- For teachers to become motivated to be life-long learners of science accepting and sharing responsibility for their own learning
- For teachers to gain knowledge of science content, selected for its applicability to primary education
- For teachers to gain some understanding of the interconnections among science discipline, as well as among science and other subject areas
- For teachers to develop and use materials and equipment in active, hands-on learning effectively. (p. 5)

These general objectives are further broken down into three broad content-based themes which are taught in five courses during the 3 years of enrolment. These are 'Living Things' which is biology-based and is covered in the course Science for Primary Teachers I, States of Matter which is chemistry-based and is covered in the course Science for Primary Teachers II, 'Forces and Energy' which is physics-based and is covered in the course Science for Primary Teachers III and Science Methodology which is completed in the course titled Science Methodology for Primary Teachers (JBTE, 2014). Based on studies reviewed, these content areas outlined by JBTE are areas in which teachers have traditionally demonstrated gaps in science content knowledge (Gunning & Mensah, 2011; McConnell et al., 2013; Oh & Kim, 2013; Usak et al., 2011; Yoon et al., 2012).

Assessing Gaps in Teachers' Content

The assessment of teachers' science content knowledge is considered very important as it provides teacher educators, researchers in education, PD consultants and policy makers with information that can be used to make informed decisions (McConnell et al., 2013; Nowicki et al., 2013; Tretter et al., 2013). These decisions include:

- Designing PDPs for teachers
- Determining the impact of workshops and courses
- Revising programs at teacher training institutions
- Providing information regarding gaps in pre-trained teacher programs
- Informing contents for new curricula (McConnell et al., 2013).

However, the assessment of teachers' science content knowledge can be a time consuming activity (Heller et al., 2012; Tretter et al., 2013). Nowicki et al. (2013) stated that research studies which involved the assessment of teachers' science content knowledge usually include simple science content tests, teachers self-reports, grades obtained in science courses while training and teacher-developed lesson plans. Nowicki et al. further indicated that these measures do not truly measure the depth and breadth of teachers' science content knowledge nor do the results indicate that students' learning needs are not adequately addressed.

McConnell et al. (2013) stated that, while there are difficulties in measuring teachers' content knowledge, there are measures that can be used in providing reliable results regarding the state of teachers' science content knowledge. Diamond et al. (2013) concurred and suggested that teachers' content knowledge in science is usually measured with a combination of a number of instruments each of which has strengths and limitations. For example, Traianou (2006) employed a combination of interviews, classroom observations and teachers' writings in measuring the depth of primary school teachers' science content knowledge. While concluding that the process is reliable, McConnell et al. (2013) suggested that it is quite time consuming and would pose some amount of difficulty if used when assessing the science content knowledge of large groups of teachers.

McConnell et al. (2013) designed an open-response assessment tool, which assessed the depth and breadth of primary school teachers' science content knowledge. McConnell et al. outlined that the items on the instrument were authentic tasks which could highlight teachers' strength in a particular concept. Furthermore, McConnell et al. offered that the written responses teachers would need to generate during the assessment are the same information teachers would be required to provide in a typical classroom situation. Content validity of the instrument was taken care of by having three content specialists from the areas of chemistry, physics and biology review the instrument. In order to increase the reliability of the scores obtained the instruments were first transcribed and de-identified by teams of three specialists who are experts at the local university.

This assessment is effective in measuring teachers' depth and breadth of science knowledge. It is time consuming as individual items on the instrument have to be analyzed. Thus, McConnell et al. (2013) concluded that the instrument would not be recommended to measure teachers' depth of knowledge across a large number of concepts. Based on the literature, it is important to note that the choice and design of instruments to be used in the assessment of teachers' science content knowledge should be chosen based on the number of teachers to be assessed and the number and depth of concepts to be measured (Nowicki et al., 2013;Tretter et al., 2013). Additionally, consideration should be given to the validity of the instruments and the reliability of the findings from the assessment.

Teachers' Gaps and Student Achievement

The National Commission on Teaching and American's Future (1996) offered that teachers' knowledge and skills are the most influential factors in students' learning. It is noted that numerous research studies have been conducted to determine the depth, breadth and possible gaps in teachers' science content knowledge (Byers et al., 2011; McConnell et al., 2013). However, Diamond et al. (2014) indicated that, while many research studies focused on identifying gaps in primary teachers' science content knowledge, very few investigations were done to determine the effects of identified gaps on students' performance in science. Nowicki et al. (2013) posited that there is a correlation between students' achievement and teacher depth of knowledge of the subject. Thus, Nowicki et al. outlined that teachers who know more invariably teach better and students who are taught better usually perform better in the subject. Nowicki et al.

outlined that the reverse is also true, where it is noted that when teachers are lacking in knowledge of science content, students' performance is usually lower.

Similarly, in a study conducted by Diamond et al. (2014), teachers' performance was matched against that of their students. Findings from the study revealed that students' performance mirrored their teachers. In support of these findings, Burgoon et al. (2011) and Nowicki et al. (2013) stated that teachers with sound science content knowledge usually engage students in enriching class discourses. These included posing questions which required higher-order thinking skills and allowing students more time during instruction to speak. Conversely, Burgoon et al. observed that teachers with limited science content knowledge resorted to lecturing, avoided class discussions, were intolerant of students' spontaneous questions and, as such, failed to facilitate the development of important science concepts during science instruction. Furthermore, these teachers were unable to identify misconceptions held by students and accordingly were not able to engage students in the process of conceptual change (Burgoon et al., 2011). Misconceptions invariably influence students' performance in a negative way and can indirectly affect students' ability to access science content at higher levels.

Correcting Gaps in Primary Teachers' Science Content Knowledge

Diamond et al. (2013) and Heller et al. (2012) indicated that it is very surprising that many studies have been conducted to determine the state of teachers' science content knowledge but very little research is conducted on how to address and improve teachers' knowledge in science content. Gaps in teachers' science content knowledge are well documented (Byers et al., 2011; McConnell et al., 2013; Usak et al., 2011). Based on this finding there is a need for a strategic approach in correcting this problem that has far reaching implications for the future of science (Gunning & Mensah, 2011; Usak et al., 2011).

While there may not be an answer or a single strategy or approach to solve this problem (Kleickmann et al., 2013), there are strategies that can provide some remediation to the situation. Usak et al. (2011) recommended that an assessment of teachers' content knowledge be conducted at the point where students enter teacher training. Following this assessment, an evaluation of the gaps should be conducted and respective courses should be developed to cater to these gaps. On the contrary, Nowicki et al. (2013) pointed out that the training program for primary teachers is very compact with a variety of courses that must be covered over a very short period. In Jamaica, pre-trained teachers enrolled in the primary education program are required to complete three science content-based courses over the period of three years (JBTE, 2014). These are Living Things which is biology-based, States of Matter which is chemistry-based and Forces and Energy which is physics-based.

Therefore, Nowicki et al. (2013) put forward the recommendation that in-house mentoring, PD and cultural exchange programs within the profession can help to improve teachers' science content knowledge in addition to academic preparation. Also, Ferreira (2015) made the point that although teachers acquire some skills during their certification program, PD plays an important role in a teacher's future growth. These opportunities include enhancing their knowledge and skills, sustaining their motivation and widening their collaborations with others in the profession (Ferreira, 2015; Nowicki et al., 2013).

Burgoon et al. (2011) suggested that PDPs should be flexible and adaptable to different contexts and the diversity of needs that are identified in teachers.

In line with the recommendation made by Nowicki et al. (2013) and Burgoon et al. (2011), the National Science Teachers Association (NSTA) developed a comprehensive online program for science teachers called the NSTA Learning Centre (Byers, 2011). This program provides science teachers the opportunity to assess themselves, identify the gaps they may have based on the results of the assessment and make use of PD resources in order to address the gaps identified. Another benefit of this PDP is the opportunity provided to teachers to plan, track and document their growth over time (Byers, 2011). The impact of this PD opportunity can be very great due to the fact that the program is free and online. Furthermore, it is offered on an international scale. Therefore, well-designed and implemented PD activities have the potential to increase teachers' science content knowledge, beliefs about teaching science and ultimately student's performance.

PD and Science Teachers' Content Knowledge

Effective PD is a calculated comprehensive sustainable mechanism; designed to enhance educators' ability to create the environment needed to increase students' achievement (Patton, Parker & Tannehill, 2015; Sun, Penuel, Frank, Gallagher & Youngs, 2013; Van Driel, Meirink, Van Veen & Zwart, 2012). Consequent to the current state of teachers' science content knowledge, coupled with the research findings on the efficacy of PD it is viewed that effective PD can play a significant role in remediating the situation (Nowicki et al, 2013; Roehrig, Dubosarsky, Mason, Carlson & Murphy, 2011).

Roehrig et al. (2011) used a mixed methods approach to conduct a long-term study to determine the impact of PD on teachers' science content knowledge. The quantitative aspects of the research were designed to provide a measure of the improvement of the participants. The qualitative element of the study consisted of interviews, surveys, and observations of PD sessions and teaching, in order to develop a deeper understanding of the teachers' experiences teaching science. Findings from the research indicated an improvement in teachers' content knowledge which contributed to improvement in science teaching.

Penuel, Harris and DeBarger (2015) conducted a study in which science teachers from numerous school districts were exposed to PD sessions which focused on core science content, analysis of their practice and the use of high instructional materials. Data collection methods included teachers' instructional logs, teachers' lessons plans, video recordings of teachers' and interviews with teachers' coaches. Teachers overall performance in science teaching improved. Additionally, there was also marked increase in students' performance. Similar findings were reported by Taylor et al. (2015) from a study conducted in 18 schools in Washington. Based on the findings from studies conducted, PD can be implemented as one strategy that can be used to improve science teachers' content knowledge.

Summary of the Literature Review

The goal of this review of literature was to highlight studies which were done on the topic and to show gaps in the literature. Shulman's (1987) conceptual framework on subject matter knowledge provided an overarching context which guided the themes around which the review was structured. There are numerous sources which inform teachers' science content knowledge inclusive of teacher training institutions. As a result of the duration of time pre-service teachers are enrolled and the number of courses offered at these institutions, it is difficult to satisfy the content knowledge required to ensure competence of teachers. Continuous PD sessions for in-service teachers can be a reliable solution in catering to the gaps in science content knowledge as highlighted in the research studies. Teachers' confidence in their ability to deliver sound science content knowledge can be improved if teachers are exposed to continuous PD.

Having reviewed the literature it was deduced that there are gaps in the literature regarding science teachers' content knowledge at the primary level. Science content knowledge of teachers in Jamaican primary schools was one area that was not covered in the literature. It was important that a research study be conducted in this area which provided a sound understanding of this situation in the Jamaican context. Therefore, this study explored Jamaican primary school teachers' science content knowledge.

Implications

Having a solid knowledge base in science content should be a requirement for teachers teaching science at any level. The responsibility is placed on teachers at the primary level to stimulate learners by engaging them in authentic science processes and arguments while preparing them with knowledge of science fact, vocabulary and concepts. Based on the literature reviewed it is noted that there are gaps in primary teachers' science content knowledge in areas such as basic astronomy, density, weather and climate, plant nutrition, and properties of matter (Gunning & Mensah, 2011;

McConnell et al., 2013; Oh & Kim, 2013; Yoon et al., 2012). This finding has far reaching implications for science instruction at that level and the future of science in general (Petrilli & Scull, 2011).

Teachers who have limited science content knowledge will have difficulty engaging students in instructional activities that will initiate early scientific literacy and provide an inclination toward the subject. This could result in a reduction in the number of students enrolled in science courses at higher levels of the education system and science- related professions. The shortage of science majors can contribute to a loss not only of economic competitiveness, but also of fields in science and technology (Maltese & Tai, 2011; Petrilli & Scull, 2011). A study which explored the state of content knowledge of Jamaica primary teachers was necessary in order to understand this situation locally.

In this research study I employed the use of a qualitative research design in order to provide a deep understanding of science teachers' content knowledge at the primary level in Jamaica. A case study design, centered on a search for meaning and understanding (Bogdan & Biklen, 2007; Lodico, Spaulding & Voegtle, 2010) was employed in gathering the data. A combination of a number of data gathering sources is most reliable in assessing the depth and breadth of science teachers' content knowledge (McConnell et al., 2013). McConnell et al. (2013) used a combination of interviews and open-response questions in the assessment of teachers' science content knowledge. Based on the recommendation of McConnell et al. (2013) lesson observations, lesson plan analysis and interviews were used in the data collection process in this study.

The findings from this study might be used by educators locally to inform decisions regarding primary school science teacher education programs. In addition, findings from this research study might provide baseline data that can inform the design of a PDP for teachers at the primary level who display deficiency in science content knowledge. Nowicki et al. (2013) recommended that PD for teachers should be developed according to the specific needs that are displayed by teachers. Guided by the recommendations of Nowicki et al., a PDP might be developed based on gaps identified from the data. It is hoped that with the development and implementation of a PDP, any identified gaps in science content knowledge of teachers at Clarke Primary School might be abridged.

Summary

In this section, the problem of primary teachers' science content knowledge was introduced and defined. A rationale was provided with evidence of the problem discussed both locally and globally. Special terms associated with the problem were defined and the significance of the problem outlined. The guiding questions that guided the data collection process in the research were outlined. A comprehensive examination of the literature from a wide variety of sources was presented and, based on the major themes discussed in the literature review; a number of conclusions were drawn.

Findings from research studies indicated that, in general, teachers at the primary level have gaps in science content knowledge. These gaps are the result of a number of factors which include teachers' interaction with their environment, misconceptions and inaccurate concepts passed on by previous teachers and limited time interacting with the subject at the teacher training institutions. Based on the literature reviewed, there appears to be a relationship between teacher science content knowledge and students' performance. In cases where teachers display adequate science content knowledge, the instructional activities that students are engaged in are informative, enriching and usually impact positively on students' performance. Teachers' self-confidence is also influenced by their depth of science content knowledge. In cases where teachers have limited science content knowledge, the level of confidence to engage students in authentic classroom science activities is usually much diminished.

The methodology is outlined in the following section. This is inclusive of the research design and approach, participants, access to participants and the research site, data collection, data management, data analysis and the validity and the trustworthiness of the findings; and limitations of this study are described. Additionally, the research strategies, reliability and validity measures, data presentation, ethical considerations, and protection of participants' rights are discussed.

Section 2: The Methodology

Introduction

A review of the literature indicated that there are gaps in some primary school teachers' science content knowledge (Burgoon, Heddle & Duran, 2011; Byers et al., 2011; McConnell et al., 2013; Oh & Kim, 2013; Seung, Park, & Narayan, 2011). Therefore, the purpose of this study was to better understand the science content knowledge of teachers teaching at the Grade 4–6 level at Clarke Primary School. A qualitative case study design was used.

Rationale for a Qualitative Study

A qualitative approach was deemed most suitable for conducting this project study due to the fact that qualitative research design is applicable when there is a need to gain insight into a problem. Avraamidou (2013) asserted that the value of a qualitative research design is in providing deep understanding of a phenomenon in comparison to a quantitative research design which provides numeric data in order to measure differences, make predictions and test hypotheses. Also, quantitative research design is most suitable when there is a desire to make generalizations from a sample of a population (Bahari, 2012; Lodico et al., 2010; Merriam, 2009; Vaismoradi, Jones, Turunen & Snelgrove, 2016; Yilmaz, 2013). On the other hand, qualitative research design is most suitable when there is a need to develop a deep understanding of a problem in order to explain it (Bahari, 2012; Merriam, 2009; Seung et al., 2011). A deep understanding is usually achieved through the collection of intensive narrative data (Bahari, 2012; Lodico et al., 2010; Merriam, 2009). As the researcher in this study, I was not concerned with measuring differences, making predictions, testing hypotheses, or generalization of the findings outside of the local setting but rather to develop a deep understanding of Clarke Primary School teachers' science content knowledge. As such, data collection included science lesson observations, lesson plan analysis and interviews. These multiple sources were used to generate rich, thick data that facilitated an understanding of the problem.

Oh and Kim (2013) used a qualitative approach in their investigation of science content knowledge in Korean teachers teaching at the elementary level. Similarly, Usak et al. (2011) used a qualitative approach in their investigation of Turkish teachers' science content knowledge and its impact on their pedagogical content knowledge. The problems investigated in these studies are similar to the problem in this research study. As such, Shulman's SMK concept, the problem investigated, the research purpose, and the guiding questions are fundamental elements that were considered in determining the approach used in this study (Bahari, 2012; Elo et al., 2014; Merriam, 2009; Wahyuni, 2012).

Rationale for Case Study Design

In this study, a qualitative case study design— an in-depth description and analysis of a bounded system (Bogdan & Biklen, 2007; Creswell, 2012; Merriam, 2009)—was used because of its boundaries which were similar those of the case studies conducted by Hanuscin, Lee and Akerson (2011) and Park, Jang, Chen and Jung (2011) in which similar aspects of science education were explored. The boundaries of this case study were defined by the nine primary school teachers—a small participant pool that shares a common feature (Merriam, 2009; Petty, Thomson & Stew, 2012; Shaw, 2013)—

and the research site, Clarke Primary School. Qualitative case study has antecedents in anthropology, sociology and psychology; however, it was not until the 1980s that it came to prominence as a research methodology in education (Cetin, Dogan, & Kutluca, 2014; Hyett, Kenny & Virginia Dickson-Swift, 2014; Merriam, 2009; Shaw, 2013; Yin, 2008).

In the literature review, it was observed that case study design was used in numerous research studies which investigated science teaching and were grounded in the Subject Matter Knowledge (SMK) conceptual framework (Lekhu, 2013; Oh & Kim, 2013; Tretter et al., 2013). These studies provided evidence to support the use of the SMK conceptual framework in studies which employed the case study tradition. Thus, in light of the literature reviewed, the problem examined, the guiding questions posed and the conceptual framework that guided the interpretation of the data, case study design was justified.

Merriam (2009), Bahari (2012) and Wahyuni (2012) declared that the descriptive and heuristic nature of case study design accounts for the rich data which can serve to illuminate the reader's understanding of the phenomenon. Data were gathered with the use of lesson observations, lesson plan analysis and interviews. The data garnered in this case study led to an understanding of the depth and breadth of science content knowledge of the teachers in Grades 4–6 at the Clarke Primary School. The findings from this project study were used to inform the design and the development of a PDP to be undertaken. It is hoped that this project, if implemented, might address the content knowledge deficiencies that were identified through data collection and analysis processes that were employed in this study.

Summary of Other Research Designs

There are numerous research designs, such as case study, phenomenology, grounded theory, ethnography and auto-ethnography, which could be employed in qualitative research (Abrams, 2010; Hyett et al., 2014; Petty, Thomson & Stew, 2012). Case study research design is usually employed based on the problem that is identified as opposed to grounded theory in which the problem emerges during the research process (Petty et al., 2012). Phenomenology is most suitable when describing experiences as they are lived while ethnography is suitable when exploring and describing cultures and cultural characteristics (Merriam, 2009; Petty et al., 2012; Yin, 2008). Case study on the other hand, is suitable in research studies that investigate a case in order to provide in-depth data which can lead to greater understanding of that case (Bogdan & Biklen, 2007; Cetin et al., 2014; Creswell, 2012). The case that was investigated in this study is Clarke Primary School teachers' content knowledge. This project study was able to provide a deeper understanding of the science content knowledge of nine teachers at the Clarke Primary School.

Criteria for Selecting Participants

In selecting the participants for the study, a number of criteria were taken into consideration. These included the area of specialization in teaching, years of experience and current deployment (Bogdan & Biklen, 2007; Cetin et al., 2014; Creswell, 2012; Yin, 2008). A researcher should "create a list of the attributes essential to the study and then proceed to find or locate units to match the list" (Merriam, 2009, p. 77). The criteria for the participants in this research study were:

- Teaching at Clarke Primary School in Grades 4-6
- Have at least 2 years of experience at the grade 4-6 level
- Have training in primary education

These criteria were considered to be important in determining participants who could provide in-depth and reliable information for addressing the questions in this research study. The participants were teachers at the Clarke Primary School. The teachers who were targeted were those who had acquired at least a diploma in primary education. This was important as the project study was conducted at the primary level. Additionally, the participants taught science in Grades 4–6 for a period of at least two academic years. Two years teaching experience at the grade level was considered to be sufficient for the participants to develop self-confidence and, as such, were likely to accommodate me as I observe them teaching science lessons and would participate in interviews as part of the research process (Harrigan, 2014; Kinghorn, 2013). Additionally, this experience at the school and at the grade level allowed participants to acquire adequate information regarding the science curricular requirement for Grades4–6 which was useful in answering the guiding questions.

Sample Size

Elo et al. (2014) stated that "selection of the most appropriate sample size is important for ensuring the credibility of content" (p. 4) when conducting research studies. Hanuscin et al. (2011) conducted a research study which explored the impact of teachers' knowledge of the nature of science on instructional practice. This study, which had a sample size of seven participants, was grounded in SMK concept. Park, Jang, Chen and

Jung (2011) conducted a research study, which explored the depth of pedagogical knowledge necessary for efficiency in science teaching. This study, which was grounded in SMK concept, had a sample size of eight teachers. Similarly, Morgan (2012) conducted a study in which teachers' confidence and their ability to teach science was investigated. The study had a sample size of eight primary school teachers. The sample size used in these research studies provided rich data considered sufficient in providing a deeper understanding of the different science education issues that were explored (Hanuscin et al., 2011; Morgan, 2012; Park, Jang, Chen & Jung, 2011; Wahyuni, 2012). According to Elo et al. (2014) "there is no commonly accepted sample size for qualitative studies because the optimal sample depends on the purpose of the study, research questions and richness of the data" (p. 4). In light of the literature reviewed, the sample size in this qualitative case study was nine primary school teachers teaching science in grades 4 – 6 at the Clarke Primary School.

These nine participants created a boundary within which I operated in this case study. These participants were able to provide rich data until a point of redundancy or saturation was reached (Hanuscin et al., 2011; Merriam, 2009; Patton, 2015). Based on the findings from the studies reviewed, a sample size of seven or eight participants would have been practical and sufficient for reaching this point of saturation. However, as a cautionary measure nine teachers were targeted so that in the event one or two teachers had decided to discontinue in the research process the research would not have been compromised as a result of the number of participants.

Sampling Strategy

Sampling procedures are very important elements of the qualitative research process (Bogdan & Biklen, 2007; Elo et al., 2014; Hanuscin et al., 2011; Patton, 2015; Yin, 2008). Bogdan and Biklen (2007) stated that these elements are important as they are intricately tied to the credibility, dependability and transferability of the findings of the study. Elo et al. (2014) suggested that questions such as "What is the best sampling method for my study? Who are the best informants for my study and what criteria should I use for selecting the participants?" (p. 4), should be asked when deciding on the sampling strategy for a study. Nevertheless, in some cases, the sample and sampling procedure evolve as the study progresses such as in the case of grounded theory (Merriam, 2009; Wahyuni, 2012). However, when a case study approach is employed these elements are usually predetermined due to the fact that they are important in creating the boundaries for the case (Merriam, 2009; Yilmaz, 2013).

Purposeful sampling was employed in this qualitative research study (Abrams, 2010; Creswell, 2012; Merriam, 2009; Patton, 2015). This type of sampling involves both the participants and the research site (Patton, 2015). This is because the aim of the qualitative researcher is not to generalize the findings of the study but rather to gather comprehensive data in order to understand the group or situation under observation (Creswell, 2012; Merriam, 2009; Patton, 2015). Therefore, specific participants were chosen because they are involved in or they are affected by the phenomenon and can relate to it (Abrams, 2010; Patton, 2015; Yilmaz, 2013). These participants were able to contribute significantly in helping me to understand the phenomenon that was under investigation (Yin, 2008). Based on the foregoing argument, purposeful sampling was considered appropriate to be used in this research study.

Summary of Purposeful Sampling Strategies

There are various types of purposeful sampling strategies, including homogenous sampling, maximum variation sampling, typical case sampling, extreme case sampling and criterion sampling (Damianakis & Woodford, 2012; Elo et al., 2014; Patton, 2015). Maximum variation sampling, also called heterogeneous sampling, is used when the researcher requires variance in the sample in order to provide a deep understanding of a phenomenon (Damianakis & Woodford, 2012). Maximum variation sampling would not have been appropriate for this study as teachers from other schools would be needed to account for variation. This research study was interested in the teachers at Clarke Primary School. Teachers at Clarke Primary School were most suitable in providing reliable information that led to deep understanding of science content knowledge of the teachers at that school.

Typical case sampling is used when the researcher wants to highlight what is deemed to be normal or average in a situation (Abrams, 2010; Creswell, 2012; Patton, 2015; Polit & Beck, 2010). Extreme case sampling is used when there is a focus on cases that are unique or special (Palinkas et al., 2015). Typical case sampling and extreme case sampling were not suitable for this project study as I was not concerned with the average or typical case in the general population but rather with the Clarke Primary School teachers who fit certain identified criteria. Rather, criterion sampling technique was used in this research study. According to Patton (2015), “criterion sampling involves selecting cases that meet some predetermined criteria of importance" (p. 238). This sampling strategy is used when the researcher is interested in selecting individuals who share some established criteria (Creswell, 2012; Elo et al., 2014; Polit & Beck, 2010). Criterion sampling strategy, when used with the other case study techniques; was suitable in unearthing relevant, rich and in-depth information that was adequate and suitable in answering the guiding questions.

Gaining Access

This project study was conducted at the Clarke Primary School in St. Catherine, Jamaica. I gained access to the research site by requesting permission in writing from the Regional Director with responsibility for all schools in the parish of St. Catherine. Additionally, permission to access the school was sought and gained from the principal of Clarke Primary via the use of a data collection coordination request.

The principal was informed of the nature of the study along with the rationale for conducting the study. After gaining approval from IRB (approval number 10-26-16-0417299) and permission from the Regional Director and principal, a visit was made to the school to meet with teachers who are assigned to classes in grades 4 – 6. A PowerPoint presentation (see Appendix B) which outlined the purpose, sample size, rationale, risks and benefits of the study was presented to these teachers (Aluwihare-Samaranayake, 2012; Damianakis & Woodford, 2012). The teachers also received a brochure which outlined my professional history in the field of education along with major aspects of the project study such as the background, purpose and methodology. The consent form was discussed with teachers. Following the discussion of the consent form, teachers were informed of a locked box that was placed in their staff room. Interested teachers deposited their signed consent forms in this locked box.

Establishing the Researcher-Participant Relationship

The relationship between a researcher and participants in a qualitative research study should be built on trust (Aluwihare-Samaranayake, 2012; Brewis, 2014; Petty et al., 2012). Trust is essential as the researcher is dependent on participants to guide them into unfamiliar territory (Abrams, 2010; Cresswell, 2012; Merriam, 2009). It is vital for researchers to initiate and maintain a relationship that is respectful, nonjudgmental and nonthreatening (Abrams, 2010; Bogdan & Biklen, 2007). These characteristics should inspire the participants' willingness to share openly during the research process (Bogdan & Biklen, 2007).

I had no supervisory relationship with the teachers at Clarke Primary School. Due to the fact that I did not know the participants and they did not know me, the initial meeting was also used to initiate a relationship with teachers in grades 4-6 at Clarke Primary School. As such, the PowerPoint presentation that was presented contained information such as my experience as a teacher and expertise as a science specialist. Information regarding my research journey, purpose, methodology and progress of the research was also communicated in the presentation.

Teachers were given the opportunity to ask questions and share professional information about themselves. Light refreshment was served during the session. This interaction and sharing initiated the researcher-participant relationship which increased as the research progressed. Throughout the research process, the interactions with the participants were transparent and respectful at all times. Furthermore, the relationship that was engendered along the research journey was built on trust; as a result, the participants shared in an unreserved manner.

Protection of Human Subjects

Damianakis and Woodford (2012) stated that "qualitative researchers have a dual mission: to generate knowledge through rigorous research and to uphold ethical standards and principles" (p. 708). The protection of human subjects in research studies is an ethical issue that must be given adequate attention before, during, and after a research study (Bogdan & Biklen, 2007; Creswell, 2012; Houghton, Casey, Shaw & Murphy, 2013; Merriam, 2009; Yin, 2008). Having pursued a course on protection of human subjects in research (see Appendix C), I achieved a certificate to indicate that I successfully completed the course and that I have demonstrated competence in the area and as such was qualified to work with human participants.

In this project study, ethical consideration was given sufficient attention. First, approval was obtained from the Walden University Institutional Review Board (approval number 10-26-16-0417299) before entering the research site. Obtaining informed consent is a critical element of protecting research participants from undue risks or harm (Czymoniewicz-Klippel, Brijnath & Crockett, 2010; Damianakis & Woodford, 2012; Hammersley, 2014; Houghton et al., 2013). Importantly, informed consent provided the participants with information reassuring them that they were contributing freely to the research process, as opposed to being coerced (Hammersley, 2014; Houghton et al., 2013). Also, the informed consent documents contained information regarding participants' unrestricted right to discontinue the research process if they felt the need to do so (Dongre & Sankaran, 2016; Taylor, 2014).

Second, the signed informed consent document was obtained from the participants before the data collecting process was initiated. It had a basic description of the project study inclusive of the purpose for conducting the research (Houghton et al., 2013). Third, the risks and benefits that were associated with this project study were outlined in the informed consent document and discussed during the initial meeting of the teachers. As the researcher, I was open, truthful and transparent throughout the research process.

The aim of qualitative research is to generate in-depth understanding of an issue (Anyan, 2013; Brewis, 2014). Interviews are considered to be suitable and reliable tools that are used in collecting data when conducting qualitative research (Nespor & Groenke, 2009; Tracy, 2010). Some risks that may be associated with interviews are anxiety and distress (Petty et al., 2012). These risks are generally dependent on the experience of the participants and sensitivity of the issue that is being studied (Wahyuni, 2012). These risks are also associated with observations when used in qualitative research (Petty et al., 2012; Phelan & Kinsella, 2013). All reasonable efforts were made to consider the potential risks and also communicate the nature and possibility of risk to the participants before seeking their consent and participation in the research process.

The matters of privacy and confidentiality are important ethical considerations that must be addressed in qualitative research (Dadzie, 2011). These must be addressed in order to prevent any harm such as stereotyping that may result from divulging the identity of participants and sharing sensitive information gathered during the research process (Dadzie, 2011; Petty et al., 2012). In addressing confidentiality in this research study each participant was assigned a pseudonym. Also, the name of the school to which the participants are employed was not mentioned in the research study. Additionally, along with the participants, I signed a confidentially agreement document as a commitment to secure the information gathered during the research process with the strictest of confidence. Importantly, the information gathered during the research process is stored in a filing cabinet in a secure office space at my home. No other person has access to this cabinet. This information will be stored for a period no longer than five years.

Misrepresentation and misinterpretation are issues that can increase risks in qualitative research studies (Walford, 2012). Researchers' preconceptions and research skills in addition to the interpretive nature of qualitative research can contribute to misrepresentation and misinterpretation of research findings (Ferguson, 2016; Walford, 2012). Member checking was employed throughout the interpretive phase of this research process. Creswell (2007) stated that member checking "involves taking data, analysis, interpretations, and conclusions back to the participants so that they can judge the accuracy and credibility of the account" (p. 208). This technique provided the participants an opportunity to review the information gathered and the interpretation of such information in order to prevent misrepresentation and misinterpretation of the data gathered (Creswell, 2012; Merriam, 2009). This research process was supervised by an assigned research committee consisting of three research practitioners inclusive of a designated chair who provided professional guidance throughout the research process (Lodico et al., 2010).

All participants were informed of the expected benefits and possible risks that they could experience as a result of participating in this study. Similarly, mitigating features were discussed with participants. Furthermore, precautionary measures regarding privacy and confidentiality were approved by Walden University Institutional Review Board (approval number 10-26-26-0417299) and discussed with all participants before initiating the data gathering process.

Instrumentation

It has long been accepted that science teachers' content knowledge is important for the delivery of the science curriculum. As early as 1987, for example, researchers found that teachers shifted from expository styles of teaching to a pedagogy that is more focused on the development of concepts (Anderson & Smith, 1987). Also, Smith and Neale's (1989) study showed that elementary teachers' ability to link a new curriculum to students' understanding was limited by their subject matter knowledge. While there have been mixed findings in more recent works – for example, in the research of Cetin, Dogan and Kutluca (2014), who found that content knowledge did not affect the quality of pre-service teachers' argumentation – there is general consensus on the central and key role played by content knowledge in determining the quality of science instruction (for example, see Krall, Lott, & Wymer, 2009). Concomitant with this acknowledgement are repeated attempts by researchers to measure teachers' science content knowledge (SCK).

Since Shulman (1986) first introduced the concept of pedagogical content knowledge (PCK), there has been consensus that researchers need strategies "for assessing teacher content knowledge that is efficient but authentic, offers some level of standardization, can be applied to multiple content areas, and provide insight into teachers' deep understandings of science concepts, even when applied to small sample groups" (McConnell et al., 2013, p. 718). A review of the extant literature showed that researchers, in measuring Shulman's SCK, have shown a preference for quantitative methods that make use of standardized tests administered to large groups of beginning or experienced teachers. The Diagnostic Teacher Assessments of Mathematics and Science (DTAMS) instrument, for example, has received significant support in the research literature with Tretter et al. (2012) showing that it is both a valid and reliable measure of SCK. In addition, test batteries and concept inventories such as the Forced Concept Inventory developed by Savinainen and Scott (2002) and the Conceptual Inventory of Natural Science first suggested by Anderson, Fisher and Norman (2002) are "reliable measures of knowledge, especially when sample size is large [and] are good at assessing a person's ability to recognize accurate descriptions or explanations, and allow comparison across groups" (McConnell et al., 2013, p. 720).

Given the convenience presented by using quantitative approaches, it is not surprising that a number of researchers such as Tanel (2013) and Santau, Maarten-Rivera, Bovis and Orend (2014), have employed this methodology in investigating SCK. Despite the advantages to be gained from using quantitative approaches to measure SCK, however, researchers have acknowledged that they are not without their challenges.

Concept inventories, while robust, do not assess teachers' ability to explain and apply concepts to new situations, both of which are critical skills for science teachers [and] seem to question teachers' professional qualifications, because they lack the aspect of valuing teachers' thinking associated with open-response items (McConnell et al., 2013, p. 720).

Also, as Nowicki et al. (2013) argued, there is usually a dissonance between teachers' SCK as demonstrated on static, contrived content tests and their content knowledge as manifested in authentic, dynamic classroom encounters with children. Against the background of these challenges, some researchers have tempered the synthetic environments created by content tests by combining both quantitative and qualitative approaches while others have used purely qualitative methodologies. Greene et al. (2013), for example, mapped changes in science teachers' content knowledge by using concept maps, which were scored for quantitative analysis, but which were also reviewed and analysed using qualitative approaches. Additionally, Mohr, Raisor and Thomas (2014) used student teachers' notetaking and writing practices to explore their content knowledge and to classify them according to their patterns of thinking. However, even though interest in qualitative approaches to measure SCK is evident in the literature, it is clear that such approaches are neither comprehensive, popular, nor well developed (Mohr et al., 2014).

Various qualitative methodologies – namely, lesson observations, review of teachers' lesson plans and follow-up interviews were used in this research study – to gain an insight into teacher's knowledge and demonstration of SMK as described in

Shulman's (1986) domains. Additionally, by employing a purely qualitative approach to research an issue that is typically and historically measured using quantitative approaches, the present study lends validity and credence to other research projects that eschew the use of quantitative instruments in measuring teachers' content knowledge. The decision to use qualitative methodologies to complete this project study rests on the observation made by Cooley (2013) who argued that a rejection of quantitative approaches in educational research is tantamount to a repudiation of the idea that complex educational issues can be addressed only by formulaic, scientific approaches that result in simple, unambiguous answers. Policy makers, Cooley argued, often want research which can be described as "science with some bulleted takeaways as recommendations for progress" (p. 256).

Data were collected over a four week period. Similar to the data collection method used by Kinghorn (2013), each participant was observed while teaching science lessons with duration of one hour each. Eighteen lessons were observed. Lesson plans for nine of the 18 lessons observed were analysed and each participant was interviewed. The data gathering techniques are outlined in Figure 1. The arrows in Figure 1 show the interconnectedness of the different data set as collected over the period.

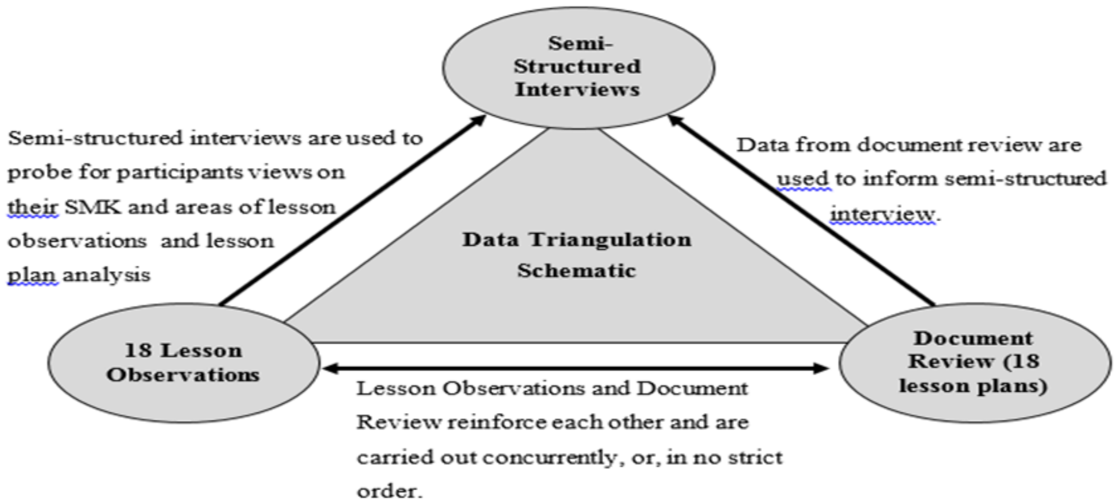

Figure 1. Data collection techniques used.

Lesson Observations in Qualitative Research

A review of the literature makes it apparent that lesson observation – either by itself or paired with follow-up interviews – is often used by researchers to gather data on teachers' pedagogy and content knowledge. Theoretical justification for the use of in-depth lesson observations and review of lesson plans was presented almost 50 years ago by Walcott (1973) who argued that an intimate, intensive look at a single school would reveal far more about the quality of public education, than surveys of multiple schools would. In keeping with this observation, many researchers have shown a preference for lesson observations over surveys and content tests as the former offer a far more detailed and meaningful study of teacher quality than the latter. For example, Glen and Dotger (2013) used lesson observations to collect data for a qualitative research study aimed at understanding how science teachers used writing in science lessons. In defending their methodology, they argued that "a small sample of teachers was selected because we wished to understand the research questions in depth, not to find out what is true of many teachers and schools" (p. 963). This idea was taken into consideration when planning the observation aspect of the data gathering process.

Despite the extensive use of lesson observations as a method of data collection, there is no evidence in the literature that any attempt has ever been made to validate its use among educational researchers. It is worth pointing out, though, that the reliability of lesson observations has been indirectly assessed by researchers before and the results seem to be at variance with the premium that the literature places on it. Hudson (2014), for example, attempted to measure how mentors give feedback to mentees and asked eight mentors to observe and evaluate the same lesson from a teacher. He found that mentors' perspectives varied about what constituted positive practices and that the teacher received conflicting and contrasting feedback from the eight observers. These inconsistencies in the observations and feedback associated with single a lesson (what would be considered in quantitative approaches "a lack of inter-rater reliability") are related to the different perspectives and insights that each observer has and which results in subjective observations being made. This is a drawback of using lesson observations as a data collection tool.

Notwithstanding this, however, lesson observation was used in this research study (see Figure 1). In heeding the advice of Hudson (2014), an observation tool was used in an effort to improve the reliability of the lesson observation (see Appendix D). The lesson observation tool was developed taking into account the seven domains postulated by Shulman (1986) in conceptualizing SCK. Lesson observations were conducted in the participants' home room. In most instances a copy of the participants' lesson plan was ascertained before the lesson commenced. Each lesson had duration of one hour. During the lesson, I made recordings of my observations on the observation instrument designed (see Appendix D). There was no communication between myself and the participants during the lesson delivery. Inferences drawn, questions to be asked of the participants and details that need to be clarified with participants were recorded on the section of the instrument that is designated for comments.

Lesson Observation Instrument

The instrument that was used to guide the lesson observation process was developed to identify aspects of Shulman's (1986) SMK and conceptual gaps that manifested themselves in the responses teachers gave to students' questions, in the instances when they explicitly and directly explain content to students and in cases where students' misconceptions are not corrected. I expected that, in some cases, teachers' knowledge of the fundamental connections of concepts would have been immediately apparent during lesson observation (such as when the teacher communicates or facilitates the sharing of misconceptions), while in other cases conceptual gaps may be masked by the teacher using avoidance strategies (for example, the teacher may avoid a student's question or terminate or discourage a discussion). In cases where evidence of the different domains of Shulman's (1986) SMK was observed an entry was made in the cell that corresponds with the domain (see Appendix D). Similarly, anecdotal entry was made in corresponding cells for cases where an incident allowed for inferring participants' demonstration of a domain. The lesson observation was executed in order to identify evidence of Shulmans (1986) seven domains of SMK:

1. Knowledge of subject matter
2. Knowledge of the skills embedded in the subject
3. Knowledge of educational context, history and philosophy of the subject
4. Knowledge of education context of the subject
5. Knowledge of the broad content base of the subject relating to pedagogical aspects of the subject
6. Knowledge of the learner
7. Knowledge of educational goals and purposes of the subject.

This framework, guided the construction of the lesson observation matrix that was used to highlight and disaggregate aspects of the seven domains of Shulman's (1986) SMK as is evident in science lessons (see Appendix D).

Document Review in Qualitative Research

Although classroom observations are useful in collecting data on teacher quality and content knowledge, they cannot be implemented at a large enough scale to get a clear idea of even a subset of teachers' classroom practices. "Another, more scalable and broader lens with which to measure teaching behaviours and the beliefs they evince" (Jacobs, Martin & Otieno, 2008, p. 1098) is document review which usually takes the form of critical analysis of teachers' writings such as lesson plans. Science lesson plan analysis has been used by researchers before (see, for example, Dotger & McQuitty, 2014 and McNeill & Knight, 2013), but no research could be found in the extant literature that shows that analysis of content area writing has been used to specifically measure teachers' SCK. Rather, the focus of existing research which used content area writing in science has been on defining a composite measure of teacher quality by considering, among other things, teachers' SCK. Or, as in the case of Dotger and McQuitty (2014, p. 74), to describe "teachers' systems of knowledge and practice in order to understand why their knowledge and practice were so different from" those of the researchers.

Teachers' lesson plans can offer meaningful insights into their SCK as they must make numerous decisions about selecting and sequencing content that depend on their knowledge of the subject area (Ferreira, 2015). According to Rusznyak and Walton (2011, p. 274), "knowing and understanding the content necessarily precedes the design of a learning process" and is inseparably intertwined with teachers' PCK (Shulman, 1986, 1987). In other words, content knowledge not only informs PCK but is also contained within it and, hence, can be discerned by examining teachers' pedagogical decisions within a lesson. During this project study teachers' lesson plans were analysed in order to identify overt and covert science content knowledge (SCK) aligned to Shulman's seven domains of SMK based on the following four areas:

1. Explicit statements (such as definitions and explanations) in the lesson plan that are vague, incomplete, undeveloped or that contain errors or misconceptions (Type I)
2. The selection and sequencing of content in the lesson plan that indicates that the teacher is unfamiliar with the hierarchical relationship among these concepts (Type II)

3. The pedagogical decisions that a teacher makes that are inconsistent with a deep and meaningful understanding of the concepts being taught (Type III)
4. Opportunities for making connections among related ideas that the teacher did not fully exploit (Type IV)

At the beginning of each lesson observation, participants were asked for a copy of the lesson plan for the science lesson being observed. Lesson plans were reviewed and findings recorded on the Science Content Writing Analysis Matrix (See appendix E). As with the lesson observations, areas for further probing with the participants were recorded on the instrument and addressed during the interview session. Science lessons were observed for all nine teachers during the four week period of data collection.

Interviews

Interviewing is a method of inquiry humans use to make sense of their experiences (Creswell, 2012; Merriam, 2009; Seidman, 2013). Furthermore, as Merriam (2009) stated, "interviewing is necessary when we cannot observe behaviors, feelings or how people interpret the world around them" (p. 88). The practise of conducting semi-structured interviews with teachers after observing lesson delivery in order to clarify what is observed is necessary (see Figure 2) as it also reduces the likelihood of misinterpreting the observed actions of the teacher (Diamond et al., 2013; Petty et al., 2012; Qu & Dumay, 2011). As such, each of the nine teachers participated in face-to-face interview sessions that were conducted individually. These interviews were semi-structured in design. A semi-structured interview is one in which the interviewer is allowed to ask probing questions in addition to a set of predetermined questions purposefully developed to guide the process (Augustine, 2014; Cetin et al., 2014; Cresswell, 2012; Merriam, 2009; Nguyen, 2015; Qu & Dumay, 2011; Seidman, 2013; Tripp & Rich, 2012; Wahyuni, 2012).

A very important feature of the semi-structured interview is that it facilitates participants in sharing their perspectives, knowledge, stories and experiences relating to the phenomenon that is being observed (Wahyuni, 2012). This semi-structured nature also allows the participants to answer questions from their frame of reference (Buldu, Buldu, & Buldu, 2014; Creswell, 2012; Merriam, 2009). The development of an interview protocol for this research study was done in a format similar to that of Kinghorn (2013) with similar introduction to the interview process and the number of questions outlined.

Creswell (2012) suggested that participants may experience fatigue if they are subjected to lengthy interviews. Therefore, guided by Kinghorn (2013) and Buldu, et al. (2014) the interview sessions lasted for a maximum of 40 minutes. While written notes were taken during the interview sessions, these sessions were also audiotaped with permission from the participants. Information from audiotaped interviews was useful as it provided me with a reliable data set long after the interview session (Buldu et al., 2014; Merriam, 2009; Tripp & Rich, 2012). Audiotaping of the interview sessions allows the researcher to interact with the data for longer periods after the interview (Lodico et al., 2010; Nguyen, 2015). It provides the researcher with an opportunity to capture information that could have been missed during the interview sessions (Angus et al., 2013; Bogdan & Biklen, 2007; Buldu et al., 2014; Lodico et al., 2010).

After conducting the interviews, the audiotaped recordings were transcribed in order to create a computer document for the purpose of analysis. The transcription of the audiotaped interviews and field-notes was done in a similar manner to the practice outlined in the literature (Buldu et al., 2014; Kinghorn, 2013). In order to facilitate the transcription process a hand-held Panasonic recorder which allowed for recordings to be played at a very slow speed was used. This slow speed allowed me ample time to transcribe the recordings without much difficulty (Lodico et al., 2010). Creswell (2012) recommended that margins be created on both sides of the transcribed document to facilitate the recording of notes and codes when the data is being analysed. In addition to the margins that were created, line spaces were used to separate my comments, as the researcher, from the comments of the participants. Importantly, the transcribed data was checked against the voice recordings to determine accuracy (Bogdan & Biklen, 2007; Kinghorn, 2013; Merriam, 2009; Nguyen, 2015; Tripp & Rich, 2012; Wahyuni, 2012). Furthermore, the chair on this research committee provided expert guidance for the transcription and also the interpretation of the data.

Additionally, the transcribed data gathered from each participant, along with the interpretation, were packaged and given to them. The participants were provided with instructions to read through the interpretations made of the data gathered and indicate whether the interpretations were accurate accounts of what they communicated during the interviews, lesson observation and in their written lesson plans. This was done on an individual basis. The participants were asked to return the packages to me within five days of receipt. All the participants returned the packages within the stipulated time.

Upon receipt of the feedback from the participants I perused each document to make note of any aspect that I may have misinterpreted. However, the participants wrote in the spaces provided that the interpretations made were correct. These processes enhanced the reliability and validity of the findings of this research study (Lodico et al., 2010; Merriam, 2009).

The Researcher's Journal

A researcher's journal was used throughout the data collection process. A researcher's journal is a reflexive tool that is widely accepted and used in qualitative research (Farrugia, 2015; Houghton et al., 2013; Lodico et al., 2010; Onwuegbuzie et al., 2012; Merriam, 2009; Venkatesh, 2013). Reflexive, as used in qualitative research, is the act of continuous questioning and contemplating of "self "as researcher in order to reduce researchers' bias and threat to the integrity of the data (Farrugia, 2015; Houghton et al., 2013; Qu & Dumay, 2011). Researchers are urged to talk about themselves, choices, experiences, biases and actions during the research process (Houghton et al., 2013; Merriam, 2009; Yilmaz, 2013).

The researcher's journal was used to record my actions, reactions to observations, decisions taken and rationale for taking decisions during the research process (Houghton et al., 2013; Tribe, Xiao & Chambers, 2012). Entries were made in the journal each day during the data gathering and data analysis process. Entries were detailed. Journal entries included information such as date and time of entry, my interpretation of observations made, opinions formed during data collection process, questions for participants and further actions to be taken.

Summary

The data collection techniques used (summarized in Figure 2), the data storage methods and the various means of ensuring reliability and validity have been used in previous research studies (Buldu et al., 2014; Cetin et al., 2014; Kinghorn, 2013) and have been effective in the investigation of aspects of teachers' science content knowledge. Additionally, these data collection methods used, and the methods used in preserving the data enhanced the credibility of the findings (Berger, 2015; Buldu et al., 2014; Cetin et al., 2014; Houghton et al., 2013; Lodico et al., 2010; Merriam, 2009; Onwuegbuzie et al., 2012). The data collection techniques and methods used provided adequate and reliable data for the following phase of the process which is the data analysis. Data analysis in qualitative research is a process which involves organizing, disassembling, segmenting, and reassembling the data collected in order to make meaning of the information (Augustine, 2014; Bogdan & Biklen, 2007). The data analysis process, as conducted in this project study is described in the following section.

Data Analysis

Data analysis was guided by Shulman's seven domains of SMK and the guiding questions. This is inclusive of data organization, open coding, axial coding and thematic development. Following data analysis, I presented the methods and strategies that were used to reduce errors and biases and thus enhance the trustworthiness of the findings emanating from the study. Additionally, the findings of this project study are outlined.

Data analysis is conducted in order to draw inferences from the raw data to be able to generate broad findings for the study and answers for the questions which guided the study (Augustine, 2014; Bogdan & Biklen, 2007; De Kleijn, Meijer, Brekelmans, & Pilot, 2015; Gioia, Corley & Hamilton, 2013; Merriam, 2009; Onwuegbuzie et al., 2012; Pierre & Jackson, 2014; Wahyuni, 2012; Wohlin & Aurum, 2015). Creswell (2007) stated, “During the data analysis the researcher follows a path of analyzing the data to develop an increasingly detailed knowledge of the topic being studied” (p. 19). As such data analysis in qualitative research is a process which involves organizing, disassembling, segmenting, and reassembling the data collected (Schreier, 2012). The purpose of the study along with the guiding questions should be used to guide the process of cutting and reassembling the data (Augustine, 2014; Bogdan & Biklen, 2007). Therefore, the transition from raw data to findings requires the interpretation skills of the researcher along with the different mechanisms that address the trustworthiness of the research (De Kleijn et al., 2015).

The process of analyzing qualitative data is an activity that should be done simultaneously with data collection (Gioia et al., 2013; Schreier, 2012). During this research process, data analysis increased in intensity as data collection progressed (Angus et al., 2013; Bogdan & Biklen, 2007; Buldu et al., 2014; Lodico et al., 2010). When data analysis is conducted simultaneously with data collection, saturation point is detected in a timely manner, thus reducing repetition (Bogdan & Biklen, 2007; Buldu et al., 2014; Lodico et al., 2010). Also, continuous analysis of data during data collection will guide, inform and refine data collection as the process progresses (De Kleijn et al., 2015; Schreier, 2012). This data analysis approach was used by Tretter et al. (2013) in an exploration of valid and reliable means of assessing science content knowledge.

Therefore, a similar approach was employed in conducting the data analysis of this project study. In order to analyze the data gathered in this project study, firstly, it was arranged systematically, secondly, a coding technique inclusive of open coding, axial coding, themes and the development of case narrative was used. These themes were developed based on Shulman’s (1986, 1987) seven domains of SMK. As such, chunking of raw data was grouped under Shulman’s seven domains of SMK based on the similarity, and recurrence of the words in the different domains. Figure 2 is a diagrammatic view of the coding process. Thus, Figure 2 shows the relationship of the open code with the axial code and the themes developed. Thus, the open codes are condensed to generate the axial codes and the axial codes further condensed to form broad themes.

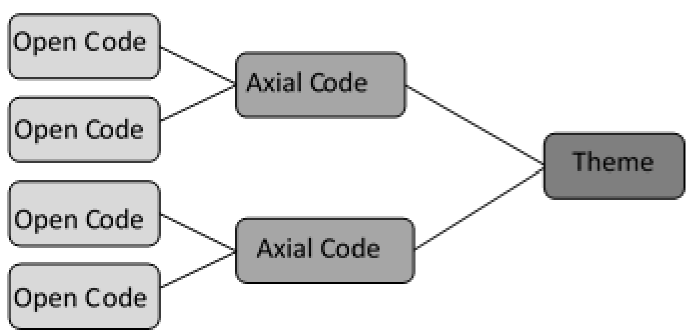

Figure 2. Data analysis structure showing open codes, axial codes and themes.

Data Organization

A structure for organizing and managing the data should be established at an early stage in the research process (De Kleijn et al., 2015; Vaismoradi et al., 2016; Wahyuni, 2012). A similar approach to the data organization as employed by Greene et al. (2013) and Kinghorn (2013) was used in this project study. The data gathered were transcribed to create computer text documents. The data included transcribed interviews, field notes from interviews, observation field notes and data from lesson planned reviewed. These documents were stored in files based on type such that all interview documents were stored separately from those documents generated from observations and lesson plan reviews. This level of organization enhanced the accessibility and retrieval of raw data and also reduced the possibility of misplacing important data sets (Onwuegbuzie et al., 2012). The systemic arrangement of data was done continuously and in a timely manner such as the same day the data was generated (Gioia et al., 2013). Additionally, the data was organized to include the time the data set was collected, assigning pseudonyms to participants from which data was collected and the setting where data were collected (Bogdan & Biklen, 2007; Buldu et al., 2014; Lodico et al., 2010). These processes proved to be important as they provided structure to the analysis process and also facilitated the peer review activities (Onwuegbuzie et al., 2012).

Open Coding

Open codes, as described by Onwuegbuzie et al. (2012) and Wahyuni (2012), is the first stage of data analysis which involves the assignment of descriptive words or phrases to segments of texts (see Figure 3). Merriam (2009) stated that a researcher is usually very open to numerous possibilities at this phase of the analysis process, thus the term ‘open codes’. Open coding can be done in various ways such as highlighting segments in color as suggested by Bogdan & Biklen (2007) and Buldu et al. (2014) or assigning descriptive words or phrases to the segments as done by Gioia et al. (2013). Harrigan (2014) described a similar method of searching the transcribed text and assigning descriptive words or phrases to segments based on meanings that are derived from these segments. Figure 3 is a diagrammatic view of the coding process. In this project study, the phrases that were used emerged form Shulman’s (1986) seven domains of SMK.

For this project study, an approach similar to that employed by Gioia et al. (2013) and Harrigan (2014) was used. This approach was used as the assignment of words and phrases was integral in creating the codes for the next phase of the analysis (see Figure 2). As such the assignments of phrases from different domains in Shulman’s (1986) SMK were used in creating the open codes for this initial phase of the coding. Phrases such as “knowledge”, “subject pedagogical content”, “content skill”, “science history”, “philosophy” and “process" skills emerged in the open code process. These phrases recurred throughout each document. This recurring of phrases provided an avenue for grouping of these phrases which was done in the next step of the analysis process. Furthermore, these phrases served as guides which were used as connections to the guiding questions; due to the fact that the guiding questions emerged from Shulman’s conceptual framework (Bogdan & Biklen, 2007; Buldu et al., 2014). This process was followed by axial coding which is discussed in the next section.

Axial Coding

Axial coding is the process which involves regrouping codes (see Figure 3) that are generated in the open coding (Bogdan & Biklen, 2007; Buldu et al., 2014; Wahyuni, 2012). This regrouping of open codes is done in a systematic and analytic way (Gioia et al., 2013). As such Wahyuni (2012) outlined that this activity is not descriptive but instead it is an activity that is the result of interpretation and reflection in order to generate meaning. In this project study meanings were generated in alignment with the seven domains of Shulman's (1986) SMK. Additionally, Harrigan (2014) outlined that during axial coding reexamination of the text was conducted in order to develop commonalities among the codes that were assigned in open coding. Thus, the sub-themes that were generated in the axial coding phase of this project study were derived from the open codes discussed earlier. These sub-themes are *subject matter, skills and science subject*, *philosophy and science* and *content and philosophy*'.

As described by Kinghorn (2013), the original document was cut in chunks based on similarities and meanings and pasted in a newly created document. In the newly created documents chunks that were merged based on similarity are pasted together. This activity was a physical regrouping of the document.

Thematic Development

Thematic development (see Figure 3) is the process resulting from the systematic and purposeful grouping of codes developed during axial coding (De Kleijn et al., 2015; Vaismoradi et al., 2016; Wahyuni, 2012). A theme represents broad response or meaning from the data that is related to the conceptual framework and guiding questions which guided the study (De Kleijn et al., 2015; Vaismoradi et al., 2016). As illustrated in Figure 3, these themes emerged from the process of refining the axial codes. The generation of these themes resulting from the process of open coding followed by axial coding is a highly inductive process (Augustine, 2014; Bogdan & Biklen, 2007; De Kleijn et al., 2015; Meijer et al., 2015).

Thus, the result, the assumptions and the inferences that are drawn from the process are strongly linked to the data as gathered in relation to the conceptual framework which guided the study (Wahyuni, 2012). The process of theme development was used by Kinghorn (2013) and Harrigan (2014) in conducting research studies. In the process of theme development, Kinghorn (2013) and Harrigan (2014) created physical files which were labeled with each theme as generated. As such the units of data which were compiled to generate these themes were placed in these files. A similar approach was used in this project study. The major themes used in this project study are the seven domains of Shulman's (1986) SMK. Thus, the sub-themes that emerged from the domains in Shulman's SMK were grouped based on meanings and similarity and placed in physical files with the themes which are the different domains in Shulman's SMK. Following the major themes in the analysis process, a case narrative was generated. This case narrative was guided by the conceptual framework and the guiding questions (De Kleijn et al., 2015; Vaismoradi et al., 2016; Wahyuni, 2012). As such Shulman's (1986) seven domains of SMK formed the major themes in the narrative for this project study.

Observations. All nine participants were observed teaching science lessons during the data collection period. As such 18 lessons were observed over a period of four weeks. The topics covered at the different grade levels during the period are shown in Table 1. All the participants in the three grade levels taught aspects of the same topic each week. However, I did not observe all the science lessons taught by each participant each week. I had the opportunity to observe more than one teacher teaching a specific topic in six occasions over the period (see Table 1). This occurrence, while it reduced the number of different topics observed over the period, allowed me to see the similarities that teachers have regarding SMK of these topics. Also, based on timetabling issues I was able to observe two teachers, Participant-4B and Participant-5C, once over the period while two teachers, Participant-5A and Participant-6C, were observed teaching science lessons three times. These participants invited me to observe follow-up lessons after I observed an initial lesson on a topic. Five teachers were observed two times during the period (see Table 1).

Table 1

Lesson topics for lessons observed

Topics for lessons observed	Grade level	Participant assigned code
Living and Nonliving Things	4	4A and 4C
The Tongue	4	4A and 4B
Why are Sense Organs Important?	4	4C
Friction	5	5A, 5B and 5C
Forces	5	5A
Matter	5	5B
Gravity	5	5A
Light and Reflection	6	6A
The Way Sounds Travel	6	6Band 6C
Sense Organ the Ear	6	6A and 6C
Sense organ the Eye	6	6B and 6C

Lesson observations were focused on the teachers' SMK as manifested in the way the teacher explained concepts, guided students' development of concepts with the use of probing and other questioning techniques, responded to students' questions, assessed students' understanding of concepts and facilitated discussions during science instructions. These observations were made in order to gather sufficient data to be able to respond to RQ1. How do teachers at Clarke Primary School demonstrate SMK of science as outlined in Shulman's (1986) seven domains when teaching science at the 4 - 6 grade level?

Lesson Plan Analysis. Lesson plans were requested at the beginning of all observation periods, however, only 9 of the 18 requests were honored. As shown in Table 2, two teachers, Participant-4A and Participant-6B, did not honor the requests made for the lessons plans as they indicated that they were unable to develop a plan for the lesson. However, three of the teachers were consistent with lesson plan submission over the period while four teachers were inconsistent. For example, Participant-5A submitted lesson plans for two of the three lessons observed and Participant-6C submitted lesson plan for one of the three lessons observed (see Table 2). The nonsubmission of lesson plans in nine instances resulted in no lesson plan analysis for the topics *Matter, Why are Sense Organs Important?* and *Sense Organ, the Eye*.

In all instances where lesson plans were not submitted, the participants communicated to me that they were unable to write the lesson plans despite exerting much effort in trying to do so. Lesson plan analysis focused on explicit statements (such as definitions and explanations) in the lesson plan that were vague, incomplete, undeveloped or that contained errors or misconceptions.

Table 2

Lesson plan submission

Teacher assigned codes	Topics	Lesson plan presented (√) Not presented (X)
4A	Living and Nonliving Things	X
	The Tongue	X
4B	The Tongue	√
4C	Living and Nonliving Things	√
5A	Why are Sense Organs Important	X
	Forces	√
	Friction	X
	Gravity	√
5B	Friction	√
	Matter	X
5C	Friction	√
6A	Light and Reflection	√
	Sense Organ the Ear	√
6B	The Way Sounds Travel	X
	Sense Organ the Eye	X
6C	The Way Sounds Travel	√
	Sense Organ the Eye	X
	Sense Organ the Ear	X

Note: Participants submission of lesson plans. √ signifies participants' submission of lesson plan while X signifies non-submission of lesson plan for a lesson observed.

The lesson plan analysis also focused on the selection and sequencing of content in the lesson plan that indicated the extent to which the teacher was familiar with the hierarchical relationship among these concepts, the pedagogical decisions that a teacher made that are inconsistent with a deep and meaningful understanding of the concepts being taught, the list of science skills in the plan, the assessment activities and the alignment with the objectives and the skills developed in the lesson and the opportunities for making connections among related ideas that the teacher did not fully exploit. This detailed analysis of the lessons plans was used to address the first and second guiding questions.

Interviews. All nine teachers were interviewed individually during the period of data collection. Two participants, Participant-4B and Participant-5C, were interviewed once while the seven other participants participated in follow-up interviews. Each follow-up interview was developed based on observations made during lesson delivery, observations made during lesson plan analysis, or reviews of notes from my research journal. In all instances the follow-up interviews were conducted on the same day the observations were made. Prior to each interview session; questions were formulated and recorded in my research journal. All interview sessions lasted for a maximum of 40 minutes. Data generated from interviews was used to answer all three guiding questions.

In the following section the data gathered in the lesson observations, lesson plan analysis and interviews were analyzed and discussed based on the Shulmans (1987) seven domains of SMK. These are:

1. Knowledge of subject matter
2. Knowledge of the skills embedded in the subject
3. Knowledge of educational context, history and philosophy of the subject

4. Knowledge of education context of the subject
5. Knowledge of the content of the subject relating to pedagogical aspects of the subject
6. Knowledge of the learner
7. Knowledge of educational goals and purposes of the subject.

Knowledge of Subject Matter

Shulman's (1986) SMK conceptual framework, the domain 'knowledge of subject matter' is associated with the units of facts and the organizing structure of a particular subject which defines the subject and set that subject aside from others. Aspects of the participants' demonstration of misconceptions and misrepresentations of knowledge of the subject matter as noted in the observations, lesson plan analysis, interviews and field notes outlined in table 3.

Table 3

Triangulation of the different data sources

Topics	Observation	Lesson plan analysis	Interview	Field notes
Living and Nonliving things	Participant-4A listed the word flowers on chalkboard in response to student's suggestion in a case where student meant ornamental plants.	Participant-4C Lesson plan Content notes – Nonliving things are things that are not alive.	Researcher: How differently could you have handled the student's suggestion in which the word 'Flowers" was used to refer to ornamental plants in order to clarify that misconception? Participant-4A: I did not pick up on that at all. Maybe it is because I do the same thing all the time. Once the plant is in the garden I call it flowers. Researcher: How would you differentiate between nonliving things and things that are dead? Participant -4C: I don't think there is a difference. There is no difference. You can't be a living thing if you are dead.	Most Jamaicans refer to ornamental plants as flowers. Teacher should have used the opportunity to clarify the misconception. Participant-4C has misconceptions regarding the phrases living things, alive, nonliving things and dead things. Nonliving things never lived.

(*table continues)*

Topics	Observation	Lesson plan analysis	Interview	Field notes
Matter	Student: Does the air around us have matter? Participant-5B: No class. Let's move on now. Pay attention everyone.	Participant- 5B submitted no lesson plan for this lesson.	Researcher: How could you have expounded on the student's question regarding the air around us and matter? Participant-5B: The truth is I don't think the air around us has matter because you can't hold it. For example this ball is made up of matter because it takes up space.	. Participant-5B could have used the opportunity to explain to the class that the air around us is the matter that occupies the spaces that seem unoccupied. Air/gas has mass and occupies space.
Friction	Participant-5C: Fluid fraction is referred to as the liquid gas that we have in cars.	Participant-5C Lesson plan content summary- Fluid friction is one of the frictional forces that acts on moving objects.	Researcher: What did you want the students to understand from the term fluid friction? Participant-5C: Students should understand that the fluid in terms of the gas in the car is what is used to cause the friction in the car and I think the students understand that. Researcher: So what would you say about other fluids such as gases? Participant-5C: I am not sure how those would come in.	Clarity is needed regarding fluid friction being referred to as liquid gas in car. Participant-5C is understand that friction fluid is a resistance force that acts on a body to retard the motion of that body such as the action of air a parachute in motion. Participant-5C lesson plan content summary indicated that fluid friction is one of the frictional forces that acts on moving objects but the action that is refers to is not defined.

(*table continues)*

Topics	Observation	Lesson plan analysis	Interview	Field notes
Gravity	Participant-5A explained to class that gravitational push acts up on an object while gravitational pull acts down on an object to keep that object afloat in water.	Participant-5A lesson Plan content no mansion was made of the actions of forces that resulted in an object floating or sinking.	Researcher: What did you want the students to leave the lesson with as it relates to what causes things to float? Participant-5A: I want the students to understand that for an object to float there has to be gravitational force acting upwards and gravitational force acting downwards on the object.	Participant-5A confuses gravitational force with upthrust force. Participant-5A's response in the interview is consistent with the lesson observation. Participant-5A also wrote on the chalkboard "An object <u>sinks</u> when the downward force of gravity is greater than the upward pull of gravity on the object and an object <u>floats</u> when these forces are equal." Participant-5A understands that a balance in the forces should be attained in order for an object to float.
Forces	Participant-5A: Gravity acts on the weight or the mass of the object and causes objects to fall to the ground.	Participant-5A lesson plan Content summary: Gravity is a force that acts on the weight of an object and causes it to fall to the ground.	Researcher: How do you want the students to conceptualize the terms weigh and mass? Participant-5A: Weight and mass are the same. So I want them to know that those two terms can be used interchangeably. Researcher: What do you know regarding the consistency of the weight of an object on Earth and its weight on the moon? Participant-5A: Based on your questioning I will need to do some research on that.	Participant-5A has the misconception that weight and mass are the things. This is a misconception that may be fostered by the way measurement of mass is taught in schools in Jamaica. Measure mass by weighing. This thing weighs 8Kg we never say 8N which would indicate that weight is a force.

(Table continues)

Topics	Observation	Lesson plan analysis	Interview	Field notes
Light and reflection	Participant-6A: Students are you sources of light? Students: No Miss. Participant-6A: Yes students we are all sources of light.	Participant-6A lesson plan content summary: "Do all light sources make their own light? Possible answer yes."	I noted that students were struggling with the idea that they are light sources after they responded in the negative and you corrected them. What do you want students to take away from this lesson regarding light sources? Participant-6A: We are sources of light that is how we are able to see each other.	Participant-6A response to the question in the interview was in alignment with the observation during the lesson however it contradicts the lesson plan summary notes that would indicate that all light sources make their own light.

Note: Triangulation of data from the different data gathering sources that connects to Shulman's (1986) knowledge of the content domain.

There were numerous areas of misconceptions cited from the different data gathering sources namely observation, interview, lesson plan analysis, and field notes (see Table 3). Additionally, misconceptions in the area of *Knowledge of the Content* from Shulman's (1986) domain were prevalent across a wide number of lesson topics as extracted from the different sources. In addition, the misconceptions spanned the three grade levels that were under investigation. Also, six of the nine participants exhibited evidence of misconceptions in this single domain (see Table 3).

As shown in Table 3, more than one teacher in the different grade levels displayed misconception in a common lesson topic. For example, in teaching the lesson on 'Living and Nonliving Things' Participant-4A displayed misconceptions by using the term 'flowers' when 'ornamental plants' would have been the correct term based on the context of the lesson. Additionally, Participant-4C displayed misconception while explaining the difference between 'living' and 'nonliving' and 'alive' and 'dead' while teaching the same concepts. During the peer review process, the reviewer communicated to me that this concept is highly philosophical and teachers at this level may not be familiar with it. I explained to him that nonliving thing cannot die, hence, a *dead bird* would be a *living thing* that is not *alive* as oppose to a *vase* that had never *lived*. However, he indicated that is hard to conceptualize especially if one is not a specialist in the area.

Some participants displayed misconceptions across different lesson topics. For example, in an initial lesson on *Forces*, Participant-5A demonstrated misconception in conveying to students the idea that the terms *weight* and *mass* are one and the same and in a follow-up lesson in which the same participant was teaching *gravitational force* the explanation given was that gravitational force acts up on an object which results in that object floating. Thus, the terms *up thrust force* and *buoyant force'* were not used in the lesson nor in the interview where further clarity was sought. I had difficulty interpreting the conception that Participant-6A held regarding human beings as a source of light. This difficulty resulted due to the fact that data from the interviews and the lesson observation are not concurring with what was written in the lesson plan developed by the said participant. In the interview Participant-6A said:

> We are all sources of light that is how we are able to see each other. I know that a lot of people have difficulty understanding that but that is the fact and my students will leave knowing that everything that can be seen is a source of light.

Based on Participant-6A's response during the interview, it provided enough evidence to suggest that there is a misconception that exists which convey that everything can be sources of light once it can be seen. However, the peer reviewer suggested that it is clear that Participant 6A is confusing light source with light reflection. Light is reflected from an object to the eye and so it allows us to discern what we are looking at.

From the findings of data collected during the observation, interviews and lesson plan analysis one can conclude that the participants hold misconceptions in the topics they are teaching. These misconceptions are seen in a number of concepts at all three grade levels. This finding is in line with the findings of previous studies such as Nowicki et al. (2013) which indicated "early studies of teacher science content knowledge suggested that elementary school teachers had limited content knowledge" (p. 1137). Trygstad, Smith, Banilower and Nelson (2013) suggested that elementary teachers are lacking in science content knowledge as a result of numerous factors, which include inadequate PD and the level of interest that teachers display in the subject.

Knowledge of Skills Embedded in the Subject

Knowledge of skills embedded in the subject is another domain of Shulman (1986) SMK. It refers to the skill-set that students must develop when exposed to a particular subject area. Also, it is critical for teachers to develop these skills in order to be able to demonstrate them to their students (Anderson & Clark, 2012; Shulman, 1986). Furthermore, students should be able to demonstrate these skills when necessary so as to provide evidence that they have developed these skills after exposure to the subject matter (Shulman, 1986, 1987). Based on the subject of interest in this project study, science skills were the focus of the observations, lesson plan analysis and the interviews.

In examining the raw data to properly examine the display of science skills the lesson plans were analyzed to identify the science skills listed along with other aspects of the lesson development to see the teachers' effort in the development of these skills and the teachers' ability to assess the acquisition of these skills. Additionally, data from the observations were analyzed to deduce evidence of teachers' knowledge of skills embedded in the subject. Findings are displayed in Table 4.

Table 4

Knowledge of skills embedded in the subject

Participants	Lesson Plan Topics	List of skills in lesson plan (lesson plan analysis)	Evidence of skills development in Lesson (Lesson Observation)	Evidence of skills acquisition assessment
4C	Living and Nonliving Things	No skills listed in the lesson plan	Students were asked to classify things into two groups living and nonliving things.	Assessment activity required students to place and assortment of items into groups labeled Living and Nonliving.
4B	The Tongue	Identifying explaining observing	Students listed the different functions of the tongue. Students identify from a diagram the areas of the tongue that detects sweet, salty, sour and bitter tastes	Students copy a set of notes from the chalkboard. No further assessment was administered for the lesson.
5B	Friction	Creating devices/ toys, describing friction	Students participated in activities such as rubbing stones together and rubbing sticks together. View information on a projected screen relating to frictional force	Students answered multiple choice questions relating to force.

(*table continues)*

Participants	Lesson plan topics	List of skills in lesson plan (lesson plan analysis)	Evidence of skills development in lesson (lesson observation)	Evidence of skills acquisition assessment
5C	Friction	No skills listed in the lesson plan	Students participated in rolling marbles and balls across the classroom floor. Discuss what they observed with each other in class setting.	Had a group of activities listed on chalkboard that were to be placed under either of the four types of frictional forces namely- Static Friction, Kinetic Friction, Rolling Friction and Fluid Friction.
5A	Forces	Experimenting Identifying magnetic fields	Students were asked to recall what force is. Students were asked to suggest different examples of force acting on different bodies.	Students participated in a quiz which was played with two teams. One team of boys and the other a team of girls.
5A	Gravity	Experimenting Identifying magnetic fields	Teacher demonstrated to students with the use of a bucket of water the actions of floating and sinking. Students observe as teacher walked around with the bucket containing the items to facilitate students' observation.	Students were asked to copy written notes from chalkboard which outlined the different forces that causes objects to float and sink.
6A	Light and Reflection	Investigating phenomena deducing relationships, Classifying objects.	Students participated in activity in which they classify objects as luminous or non-luminous. Students engaged in discussions with teacher and classmates to rationalize their classification.	Students were asked to write a definition for luminous and non-luminous objects that correctly communicate the difference between the two.
6C	The Way Sounds Travel	Read aloud, shared reading	Students participated in whole group reading of a passage describing the way sounds travel. This passage was read from class textbook.	Students were asked to answer questions based on the passage read.
6A	Sense Organ the Ear	No skills were listed in plan	Students watched video outlining how to care for the ear. Blindfolded students were to identify the student making a drumming sound based on the direction the sound is coming from	Students were asked to write five ways to take care of the ear.

Note. List of skills in lesson plans along with observed activities during lesson and skills assessment

Of the nine lesson plans reviewed, three had no skills listed in the plan (see Table 4). In some cases where skills were listed in the lesson plan, there was no activity outlined in the lesson plan to facilitate the development of those skills. For example, lesson plan with topic *Gravity* developed by Participant-5A had a list of skills inclusive of *experimenting and identifying magnetic fields*, however, the students did not participate in the process of experimenting, neither did they identify magnetic fields. Instead they were asked to observe and make inferences (see Table 4). Also, Participant-5A had the same set of skills for both the lesson titled *Forces* and lesson titled *Gravity*, however, the activities that the students did in both lessons did not account for the development of these skills. In both cases, the assessment activities that students did were not in alignment with measuring the development of those science skills. Additionally, the skills *Read aloud* and *shared reading*, as listed in the lesson titled *The way Sound Travel*, are not classified as science skills but rather reading skills (Chabalengula, Mumba & Mbewe, 2012; Haager, & Vaughn, 2013; Özgelen, 2012).

In some cases where the lesson plans had no skills listed, the students participated in activities that led to the development of skills. For example in a lesson delivered by Participant-5C the students conducted activities with marbles and then where asked to discuss their observation. Also, the assessment activity required students to classify activities in different groups based on the frictional force that is being applied. Observing, inferring, classifying and grouping are science skills that are widely used by scientists (Chabalengula et al., 2012; Özgelen, 2012).

During the interview sessions, all the participants were asked to identify the science skills that they wanted the students to develop during the session that was observed. Of the nine teachers, only one, Participant-6A, readily understood the term *science skills*. All the teachers said they are not aware of the scientific skills and asked that I provide examples of these skills. When Participant-6C was asked to justify the list of skills in the lesson titled *The Way Sounds Travel* which were *reading aloud* and *shared reading*, she said:

> I really was not thinking of science skills as I did not know about these science skills but what I really wanted was for the students to read about the way sounds travel so they could answer the questions I was going to give them. One of the challenges I am having is that some of these students are not reading at their grade level.

From the data gathered during the lesson observations, lesson plan analysis and the interviews, it can be concluded that teachers did not have purposeful intentions to teach students science skills that could have been developed in the lessons. This finding is similar to that of Chabalengula et al. (2012) who stated "the results suggest that this group of preservice teachers did not have sufficient conceptual understanding of science process skills to help their future students to understand them in a meaningful way" (p.174). It is important to note that the participants were trained as primary teachers with a minimum of two years teaching experience.

Knowledge of the History and Philosophy of the Subject

The history and philosophy of science is that aspect of the subject matter which covers the ways in which the subject evolves over time in relation to new approaches (Shulman, 1986). This aspect also speaks to knowing and understanding the *why* and the *how* in the body of knowledge (Anderson & Clark, 2012). Thus, it is that aspect of SMK that addresses the syntactic aspects of the subject (Anderson & Clark, 2012; Kleickmann et al., 2013; Klu et al., 2014). Therefore, when a teacher has a sound philosophical understanding of a particular subject, they can explain why concepts in the subjects are connected and also state how they are connected in order to provide a holistic viewpoint for students (Shulman, 1986). The topics covered in the lesson plans analyzed along with the lessons observed provided numerous opportunities for teachers to demonstrate knowledge of the history and philosophy of the subject. For example, in teaching the topics *Gravity* and *Force* Sir Isaac Newton could have been cited as a scientist who have made significant contributions in the area (Garik & Benétreau-Dupin, 2014). However, no mention was made of the scientist.

The participants gave similar responses to the interview question which sought to determine their knowledge of the history and philosophy of the subject. For example Participant-6C said “I don’t think I have the philosophical knowledge of the subject” while Participant-4A said “that is something I will need to think about.” And Participant-5A said “I never heard of the philosophy of science.” Nowicki et al. (2013) and Oh and Kim (2013) stated that teachers cannot communicate to their students that which they do not know. According to Anderson and Clark (2012), the syntactic subject matter knowledge which encompasses the history and philosophy of the subject can be facilitated in class discussions. As such, rich class discussions that can facilitate the demonstration of the participants' knowledge of the history and philosophy of science were missing from the lessons observed.

Knowledge of Education Context of the Subject

Knowledge of education context of the subject, as described by Shulman's (1986) SMK, addresses the contribution that this subject area should make to the broad sphere of education and academia. Knowledge of education context of the subject is critically important to the teachers as well as to students as it guides sequencing and matters of depth and breadth of the subject delivery at various stages (Kleickmann et al., 2013; Shulman, 1986). During the lesson observations conducted, there was no display by the participants of their knowledge of education context of the subject. However, the lesson plan analysis revealed that the teachers' lesson plans were in alignment with the Revised Primary Curriculum developed by the MOE (Ministry of Education, 2015). However, when the participants were asked to comment on their rationale for sequencing the lessons in the way they were sequenced they indicated that they simply adopted the sequence from the curriculum. Based on the observations made, the lesson plans analyzed, the interviews conducted feedback provided via member checking it is not clear to me if the participants possessed knowledge of the educational context of the subject.

Knowledge Regarding Pedagogical Content of the Subject

Knowledge regarding pedagogical content of the subject based on Shulman's (1986) SMK, addresses knowledge of the broad content relating to the pedagogical aspect of the subject. This aspect is aligned to teachers' ability to sequence, arrange, organize and explain the subject matter to students in an effective and appropriate manner (Anderson & Clark, 2012; Kleickmann et al., 2013; Shulman, 1986). Knowledge of the content relating to the pedagogical aspect of the subject also addresses teachers' ability to plan for students' learning and also the teachers' ability to assess the outcomes of the learning experiences (Kleickmann et al., 2013; Shulman, 1986). It was observed that teachers' ability to plan for students' learning was poorly demonstrated as only two of the nine teachers were consistent with lesson plan submission. Thus, of the 18 instances for teachers to submit lesson plans, only in nine of these instances did the participants submit lesson plans (see Table 2). When the participants were asked why they did not write the lesson plans they said they tried but were unable to write the lesson plans for the lessons. For example, when Participant 4-C was asked for the lesson plan for the lesson taught on 'Living and Nonliving Things,' the response was, "I tried to write that plan. I started and just did not know where to go with it".

During the lesson delivery, teachers did not demonstrate effective use of questioning and they did not encourage students to ask questions during lesson delivery. According to Meyer and Lederman (2013) one way by which teachers demonstrate effective pedagogy is with the use of questioning techniques that is used to guide students in making discoveries. Thus, during lesson delivery, teachers did not ask questions such as “any questions at this point, is everyone understanding, does anyone want to communicate their understanding of this concept?” (Meyer & Lederman, 2013).

In an instance where Participant-5B was teaching a lesson on the topic “Matter” a student ask “Does the air around us have matter?” Participant 5-B responded “No class. Let’s move on now. Pay attention everyone.” This was a good opportunity for the teacher to engage the students in a question and answer session so the students could come to realize that the air is matter. Also, Participant-5B could have engaged other students in the class to see what their opinions were regarding the student’s question. Participant-5B’s response of “Let’s move on now. Pay attention everyone” could be seen as an attempt by the teacher to discourage students from asking further questions. When the interpretation was communicated to the participant during the member checking process there was no contradiction to the interpretation.

A teacher’s ability to assess students’ learning is an indication of that teacher’s pedagogical knowledge and specifically, skills with assessment (Kleickmann et al., 2013; Shulman, 1986). In the lesson plan analysis, it was noted that there were misalignments among the objectives of the lesson, the skills being developed in the lesson and the assessment activities of the lesson. For example, in teaching a lesson entitled ‘The Tongue’, Participant-4B had students copy a set of notes from the chalkboard. Similar observations were made in a lesson taught by Participant-5A in which the students were asked to copy a set of notes from the chalkboard. When the participants were asked to comment on the effectiveness of the assessment activity for the lesson they both said they think the note taking activity is a form of assessment. Participant-5A said “the students can read through the notes, and it will become useful especially when test time comes around”.

In teaching a lesson titled *Friction*, Participant-5B outlined in the lesson plan that students will create designs, however, for the assessment activity students were asked to complete a set of multiple-choice questions. No activity was given to facilitate the creating of designs and no developmental activity catered to this skill. Findings from the lesson observations, the lesson plan analysis and the interviews conducted indicated that participants did not demonstrate knowledge of the content relating to the pedagogical aspect of the subject knowledge.

Knowledge of the Learner

Knowledge of the learner is important for both the teacher and the learner. Teachers should know and understand the diversity of students whom they are teaching along with the different strategies to cater to students’ varied learning styles (Sadler et al., 2013). Additionally, teachers should know how to sequence the body of knowledge in the subject area based on appropriateness for the group of students (Kleickmann et al., 2013; Sadler et al., 2013; Shulman, 1986). Participants were asked to describe the diversity of the group of students they were teaching and to say how they are catering to the diversity. In responding to this question the participants stated that they do have diverse classes but they also indicated that they do not usually cater for these diversities in science class. Participants indicated that these diversities are mostly associated with students’ reading abilities and, as such, these diversities are catered for in reading classes.

Based on the lesson plan analysis, there was not enough evidence to indicate that the participants were catering to the diversity in the students' population. For example, Participant-6C in teaching a lesson titled *The Way Sounds Travel* had the students read aspects of a textbook. Participant-6C also outlined that she was trying to help students develop the skill of reading. However, there was no differentiation during the lesson to indicate that the participant was catering to the diversity in the class as the students in the class read in unison and they all attempted the questions that were written in the text.

In the lesson titled *Sense Organs – the Ear,* Participant-6C engaged students in an activity in which some students were blindfolded and were asked to guess the name of the student who was making a drumming sound based on the where the students are seated in the class. When Participant-6C was asked what informed the choice of the students to be blindfolded she said, "Nothing really, I just choose at random, any student could have been chosen". Also, in teaching a lesson titled *Friction* Participant-5B had students rubbed sticks together and stones together to demonstrate the action of friction. When asked about the appropriateness of the activity for the set of grade five students and if she would have used the same activity with a set of grade one students Participant-5B said, "Now that I am looking back I could have given these students some activities that were more appropriate for their grade level." Based on the data collected during the observations, interviews and lesson plan analysis, it is perceived that the participants' knowledge of the students did not influence the activities that were engaged in during science instruction and in planning for the instruction.

Knowledge of the Goals and Purposes of the Subject

Knowledge of the goals and purposes of the subject, based on Shulman's (1986) SMK framework, addresses teachers' knowledge of the goals and purposes of the subject. This knowledge is important as it influences the teachers' ability to transmit these purposes and aims to the learners (Anderson & Clark, 2012; Sadler et al., 2013). This aspect regarding exposing students to the aims and purposes of the subject is usually beneficial to both the teacher and learner as it inspires the students to want to learn the subject (Shulman, 1986). During the lesson observations and lesson plan analysis, no evidence was provided by participants to indicate their knowledge of the goals and purposes of the subject. As a result, I made notes outlining how the participants could convey knowledge of the goals and purposes of the subject to the students. For example, my field notes for the lesson titled 'Light and Reflection' include the use of light in the field of arts, theatre, and film creation and the works of opticians. Field notes for the lesson titled *Sense Organ the Ear* include treatment of ear defects and contribution to the field of medicine.

During the interview sessions, participants were asked to comment on their knowledge of the goals and purposes of the specific topics taught and their efforts in communicating these to the students. All the participants, except Participant-5A, said they had a good idea of the goals and purposes of the subject. However, when they were asked to explain these goals and purposes they said they would need to get back to me with them. No participant came back to explain these goals and purposes with. I did not pose additional questions regarding these goals and purposes. Also, while the participants said they were familiar with the goals and purposes, they all admitted that they did not put effort in communicating these goals and purposes of the subject to the students. Additionally, the participants did not dispute the interpretation that I made regarding their knowledge of the goals and purposes of science during the member checking process. Consistent with the observations, lesson plan analysis and the participants' responses to the interview questions and member checking process, one could conclude that the evidence indicates that participants were not sufficiently able to communicate their knowledge of the goals and purposes of the subject.

Strategies to Reduce Bias and Errors

Elo et al. (2014) stated that "there has been much debate about the most appropriate term (rigor, validity, reliability, trustworthiness) for assessing qualitative research validity" (p. 2). However, reliability and credibility are two factors which any qualitative researcher should be concerned about while designing a study, analyzing results and judging the quality of the study (Augustine, 2014; Harper & Cole, 2012; Houghton et al., 2013; Lodico et al., 2010; Merriam, 2009). Therefore, the question "How can an inquirer persuade his or her audiences that the research findings of an inquiry are worth paying attention to?" (Lincoln & Guba, 1985, p. 290) is still relevant in every research study. Validity, which refers to the truth value and credibility of the research, is hinged heavily on the researcher's ability to accurately present the perspectives of the participants in the study (Houghton et al., 2013; Lodico et al., 2010; Merriam, 2009; Yilmaz, 2013).

According to Lincoln and Guba (1985) and Bryman (2012), trustworthiness in qualitative research can be broken down into four broad areas inclusive of credibility which is synonymous with validity, transferability, dependability and confirmability. Various measures were undertaken throughout the research process that are consistent with achieving trustworthiness in this project study. These include member checking, peer review, research guidance from a committee of expert researchers, and the maintenance of a reflexive journal (Farrugia, 2015; Harper & Cole, 2012; Houghton et al., 2013; Venkatesh, 2013). Findings from observations, lesson plan analysis, interviews and field notes were printed and a copy given to each participant with instruction to provide feedback in the margins provided on the document for that purpose. The feedback provided by participants indicated that the interpretations were correct.

A peer reviewer provides support by challenging the researchers' assumptions and asking questions about the rigour of the data collection mechanisms and the alignment of the collected data and the interpretations drawn (Lincoln & Guba, 1985). Permission was granted by IRB to engage a peer reviewer who examined the data collected and the interpretation of the data after the process of member checking. The peer reviewer was required to sign a confidentiality agreement form which outlined the conditions under which he would operate. The peer reviewer was an individual who has completed a research study at the doctoral level in a similar research paradigm in science education. This additional layer enhanced the trustworthiness of the research study as there was an agreement between myself and the peer reviewer regarding the interpretation of the data.

The reflexive journal was used to record my perspectives, opinions and feelings thus, keeping them separate from the data gathered from participants (Cope, 2014; Houghton et al., 2013). The interviews were audio-recorded to allow for repeated revisiting of the data in order to capture data that could have escaped notice during the interview. Also, audio-recorded data was revisited to check for overlooked themes (Vaismoradi et al., 2016; Wahyuni, 2012). These activities enhanced and emphasized the accuracy, uniqueness and the context of this research and added to the credibility of the findings.

The extracts from interviews, observation field notes and from lesson plan analysis were used in the narrative to validate the themes (Ellis & Armstrong, 2014). The data generated from the lesson plan analysis, lesson observations and interviews were triangulated to determine the common threads that ran across the data. The process of triangulation enhances the credibility of the findings when overriding themes are common to a wide variety of data sources (Creswell 2012; Lodico et al., 2010; Merriam, 2009; Vaismoradi et al., 2016; Wahyuni, 2012). In addition, expert practitioners on the research committee provided quality guidance throughout the research process. These processes combined, served to increase the credibility of the findings of this research study (Creswell 2012; Lodico et al., 2010; Merriam, 2009).

Reliability, which is concerned with consistency and dependability along with transferability, was also addressed in this project study (Lodico et al., 2010; Petty et al., 2012). Transferability in the qualitative research study refers to the level of applicability of a study to other settings (Bryman, 2012; Wahyuni, 2012). According to Lincoln and

Guba (1985), transferability can be achieved if rich and detailed explanation of the research sites and the characteristics of the case are provided. Thus, a transparent and clear description of the research site along with research process which accounted for information from proposal phases to the end are outlined. Additionally, the Walden University Institutional Review Board conducted a thorough review of the proposal to ensure that the data collection process was aligned to the university's standards. Challenges, decisions, themes were discussed with the chair of the research committee. These processes enhanced the consistency of this research study while, on the other hand, reduced biases and errors.

In the following section the analysed data is placed in context based on the guiding questions which guided the study. The guiding questions for this research study were:

1. How do teachers at Clarke Primary School demonstrate SMK of science as outlined in Shulman's (1986) seven domains when teaching science at Grades 4–6?
2. What aspects of SMK of science, as outlined in Shulman's (1986) seven domains are evident in the lesson plans written by teachers in Grades 4–6 at Clarke Primary School?
3. What are the views of the teachers at Clarke Primary School on their ability to teach the science content in Grades 4–6 at the primary level?

Research Question 1

How do teachers at Clarke Primary School demonstrate SMK of science as outlined in Shulman's (1986) seven domains when teaching science at Grade 4–6? In an effort to answer this research question, nine teachers at Grades 4–6 at the school were observed teaching science. An observation protocol (see Appendix D) was used to capture the information on the different domains as they were observed or inferred. Additionally, a follow-up interview was conducted with each teacher to clarify the observations and inferences drawn. The findings from the data analysis would indicate that teachers are not demonstrating SMK of science as outlined in Shulman's (1986) domains. This finding is similar to that of Nowicki et al. (2013) who reported that:

> Teachers struggled with misconceptions across a variety of topics including concepts of buoyancy, density, properties of matter, characteristics of solids and liquids, and the difference between size and mass. A number of teachers were confused about animal classification and habitat (e.g., snakes characterized as invertebrates and bats as insects), and a number of methods students and student teachers struggled to explain the defining characteristics of living and non-living things and the requirements for life. Some had misconceptions about the differences between rocks and minerals and soil and "dirt." In some cases, teachers began their lesson on firm footing, but then provided "real life examples" that were incorrect (p.1148).

It was observed that teachers did not correct students' misconceptions as in the case with Participant-4A and the use of the term 'flowers' (see Table 3) which should have been plant. Also, in the case when a student asked “Does the air around us have matter?” Participant-5B responded “No class. Let’s move on now. Pay attention everyone.” This response by the teachers could indicate that students are not encouraged to ask questions during lesson delivery. Additionally, teachers communicated erroneous content to students as demonstrated when Participant-5A who said “Gravitational push acts up on an object while gravitational pull acts down on an object to keep that object afloat in water.” Based on the findings from the data analysis, it is determined that teachers are not demonstrating the seven domains of Shulman’s (1986) SMK when teaching science at the upper primary level.

Research Question 2

What aspects of SMK of science as outlined in Shulman’s (1986) seven domains are evident in the lesson plans written by teachers in grade 4-6 at Clarke Primary School? In order to answer this question, lesson plans developed by teachers were analyzed and the notes recorded on the Science Content Writing Analysis Matrix for Lesson Plan Review (see Appendix E). In cases where the information in the lesson plans was inconclusive, the matter was raised with the teacher during the interview session. Lesson plan submission practices were also taken into consideration. During the period of data collection, teachers reported that they were unable to write the lesson plans in nine of the 18 instances when the request was made.

Lack of science content knowledge often limits teachers’ ability to plan effectively and deliver instructive science lessons (Nowicki et al., 2013; Oh & Kim, 2013). Teachers stated that they were unable to write lesson plans. For example, Participant-4C's response to why the lesson plan was not submitted was "I tried to write that plan. I stared and just did not know where to go with it." Additionally, the lesson plans analyzed contained gaps in alignment which indicated a deficiency in pedagogical content knowledge, knowledge of the skills embedded and knowledge of the learner. Additionally, findings from the lesson plans conveyed teachers' misconceptions of topics taught over the period. Based on the findings from the data analyzed, the different domains of Shulmans SCK were lacking in teachers' lesson plans.

Research Question 3

What are the views of the teachers at Clarke Primary School on their ability to teach the science content in grades 4-6 at the primary level? In an effort to answer this research question, teachers were asked to comment on their ability to teach the science content that is required at the current grade level. All the teachers communicated that they do not think they possess adequate science content knowledge to teach the science content required at the current grade level.

This finding is in keeping with the reports of other studies which communicated that science teachers who demonstrate poor competence in science teaching usually express that they think they are incapable of teaching the subject (Nowicki et al., 2013; Oh & Kim, 2013; Sodervik et al., 2014). In a study conducted by Nowicki et al. (2013), teachers expressed that they feel ill-prepared to teach some science topics, especially when they do not understand the content of the topic that they are required to teach. Based on the data collected and analysed, teachers' believe that they lack the ability to effectively teach the content associated with each grade level.

Assumptions

One assumption made is that all the participants' questions during the initial meeting session were adequately answered which prompted caused them to voluntarily participate in the study. This study was based on three assumptions: (a) Participants responded honestly to questions asked during the interview sessions; (b) The teaching was not significantly altered during the data collection process in order to give a false impression; (c) Teachers' responses to the interpretation of the data were honest and truthful so as to add credibility to the findings.

Limitations

The purpose of this study was to provide an understanding of teachers' science subject matter knowledge (SMK) as a component of teacher effectiveness at the Clarke Primary School. Thus, the sample size of this project study was nine teachers in Grades 4 – 6 at the Clarke Primary School. Also, the sampling strategy used in this project study was purposeful sampling. These are sampling techniques that are appropriate for qualitative research.

Scope and Delimitations

Teachers at Clarke Primary school assigned to Grades 1– 3 were not included in the study as science is planned and taught in an integrated way rather than in a discrete way at Grades 1–3. Additionally, teachers at Grades 4–6 who were not trained in primary education and who were teaching at the grade level for a period of less than 2 years were not included in the study because they did not fit the criteria for the study.

Summary

The purpose of this project study was to provide a deeper understanding of Clarke Primary School teachers' science content knowledge as a component of science teacher effectiveness. The procedures and processes outlined in this methodology were derived after reviewing the literature in both the qualitative and quantitative research paradigms. This review was conducted in order to make the most suitable decision based on the problem that was under investigation. Thus, the features of this methodology, the participants, research design, data collection procedures and data analysis are parallel to the findings from the literature reviewed. The activities conducted as outlined and discussed in this section are in line with the qualitative research methodology which employs a case study design.

The thematic approach was used in sharing the findings of this project study. This is an approach in which the text in the discussions is centred on themes identified in the analysis process (see Figure 2). An advantage of this approach is that it is quite flexible and can fit in a wide range of topics. An additional advantage is that it provided a guiding framework for me. In presenting the findings, quotes from interviews and observations along with notes from analysis of lesson plans were used to support and strengthen the development of themes.

In preliminary discussion of the findings with the Chair and the Second Marker on the Research Committee, the participants, the principal and senior teachers at Clarke Primary School, the option that was deemed most suitable to be used in addressing the misconceptions that emerged from the study is a PDP. As such the description of goals, rationale, review of literature, implications and evaluation of the PDP are outlined in Section 3.

Section 3: The Project

Introduction

This project is a PDP designed to address the gaps in science content knowledge of teachers at Grades 4–6 at the Clarke Primary School. The school's GSAT average over the last 5 years has remained below 40%., which is very low compared with the school's average in mathematics and language arts, which are both above 65%. Clarke Primary's science average in the GSAT remains below the national average, which has been above 62% over the last 5 years. This low performance in science prompted discussions with administrators, teachers, and other stakeholders at the school.

Discussions with stakeholders at the school revealed that teachers had concerns about their knowledge of science content as well as their ability to effectively deliver science instruction in Grades 4–6. A review of the science lesson plans conducted at the school by the NEI team, revealed erroneous content and abnormalities in lesson plan submission (Ministry of Education, 2015). Given the school's GSAT scores, empirical evidence from the NEI report, and the concerns of administrators and teachers at Clarke Primary, I was prompted conduct a qualitative case study in order to provide a deeper understanding of the teachers' science content knowledge

A study was conducted at the Clarke Primary School, which involved nine teachers who were deployed at Grades 4–6. Data were collected over a period of 4 weeks in November, 2016. The study was guided by Shulman's (1986) SMK concept. The guiding questions focused on teachers' ability to (a) demonstrate Shulman's SMK concept during science teaching and (b) write lesson plans that demonstrated Shulman's

SMK, and (c) their views on their ability to cater to SMK demands at Grades 4-6. Data gathering tools included lesson observations, lesson plan reviews, and interviews. Data analysis was conducted with the use of open coding, axial coding, and thematic development. Findings revealed that (a) the participants held misconceptions in some topics taught at Grades 4 – 6, (b) the participants' lesson plans indicated less than adequate SMK, and all participants believed that they lacked proficiency in teaching science at the grade level to which they were assigned.

Upon completion of the data analysis, preliminary findings were shared with members of the Clarke Primary School Community, including the principal, grade supervisors, and participants. All agreed that a PDP would be most suitable in addressing the gaps, including my research committee and peer reviewer. Suggestions and recommendations offered from the various groups and individuals prompted the decision to design a PDP to address the gaps. The purpose, rationale, goals and outcomes for the PDP are outlined and discussed in this section.

Purpose of This Project

Anecdotal data regarding teachers' poor delivery of science instructions as reported by the NEI (Ministry of Education, 2015) and information gathered from the principal and teachers at the school prompted a study which was conducted in order to develop a deeper understand of the teachers' science content knowledge. Findings revealed that teachers had misconceptions in some concepts taught at the Grades 4 – 6 level and they failed to demonstrate proficiency in writing lesson plans which convey their understanding of the different domains of Shulman's (1987) SMK. Consequently, the purpose of this project was to develop a PDP to address the gaps identified in planning and teaching science concepts at the Grades 4 – 6 levels (Al-Balushi & Al-Abdali, 2015; Earley & Porritt, 2014; Perez & Furman, 2016).

Goals of the Project

This project study was designed to gather information on the science content knowledge of nine teachers at Grades 4 – 6 at the Clarke Primary School. Findings from the study revealed that these teachers held misconceptions in some concepts that are taught at the grade level to which they were assigned. Additionally, these teachers displayed an inability to write lesson plans that are consistent with Shulman's (1986) SMK. Also, they expressed that they feel inadequately prepared to teach the science content that is to be covered at the Grades 4 – 6 levels. As such, this project is a PDP designed to address the gaps identified in the study by these nine teachers.

Effective PD is a calculated comprehensive sustainable mechanism, designed to enhance educators' ability to create the environment needed to increase students' achievement (Sun et al., 2013). Hence, the goal of this PDP is to cater to the broad areas of science education inclusive of conceptual development, effective lesson planning and the development of professional learning circles. These goals are:

- To build teachers' capacity in writing science lesson plans that exhibit the domains of Shulman (1986) SMK in order to enhance students learning outcomes.

- To build teachers' capacity in the pedagogical and conceptual understanding of the science concepts taught at the 4 – 6 grade level in order to enrich students' learning experiences and learning outcomes.

These goals are in line with those articulated by Greene et al. (2013) in a two-week long PDP designed to enhance the science content knowledge of 34 science teachers at the University of Oklahoma. This PDP was designed and implemented in order to enhance these teachers' science content knowledge so they can positively impact students' learning outcome (Greene et al., 2013).

In order for teachers to achieve these goals they will participate in a PDP titled 'Empowering Teachers in Science: Empowering Students' Future' (ETSESF). This PDP will be implemented over 3 days with duration of 5 hours each day. The calendar developed by the MOE allows for 3 days of profession development each year (Ministry of Education, 2015). These days are spread across the three academic terms in the school year. The PDP is broken down into three broad areas:

- Building conceptual understanding in science
- Strategic planning for optimum students learning outcomes in science
- Establishing and maintaining viable learning communities for teachers of science

Each of these areas are broken down into smaller component sessions and discussed in the following section.

Expected Learning Outcomes

The PDP, Empowering Teachers in Science: Empowering Students' Future (ETSESF), will be implemented over a period of 3 days. Each day the teachers will participate in sessions that are planned to cater for a specific aspect of their content knowledge in the area of science. As such the learning outcomes are directly linked to the goals of the project. On Day 1, teachers will cover the aspects of the program that are designed to build conceptual understanding of the concepts that are covered in Grades 4 – 6. Providing that the teachers have successfully completed the sessions on Day 1 they should be able to:

- Develop an appreciation for the concepts as outlined in the Grades 4 – 6 level of the curriculum
- Identify misconceptions in the concepts taught at the Grades 4 – 6 levels from various sources (students, textbooks, etc.)
- Use various strategies to correct misconceptions that students have.
- Apply the most suitable strategies and skills in teaching science at the Grade 4-6 level.

On Day 2, teachers will participate in sessions that are designed to provide guidance in the area of strategic planning (Maye, 2013). It is expected that these sessions should enhance the teaching experience for both teachers and students. Providing that teachers successfully complete Day 2, they should be able to:

- Plan science lessons that reflect the different domains of Shulman's SMK and are also appropriate for the intended grade level.
- Analyze science lesson plans to determine their quality in terms of alignment, cohesiveness of the different areas, suitability for the grade level intended and diversity in the grade level intended.

On Day 3, teachers will participate in the development of a program that will be institutionalized in order to facilitate the sharing of effective practices in science teaching. This program, when institutionalized will enhance the resourcefulness of each teacher in the program to be able to teach science effectively at the upper grade level in primary schools. Therefore, if teachers successfully complete the sessions developed for day three, they should be able to

- Establish a viable learning community among themselves to enhance their capabilities in science teaching
- Maintain a viable learning community among themselves to enhance their skills in teaching science
- Engage in strategic and collaborative planning to build the capacity of the learning community.

Providing that these teachers successfully complete the different sessions that are developed to see to the achievement of the goals outlined in the ETSESF, it is hoped that their ability to plan and execute conceptually sound science lessons will be greatly enhanced. As such, the rationale for the development of the ETSEF program is outlined in the following section.

Rationale

A PD project was considered the most suitable option to address the gaps identified in the study as there are numerous benefits to be derived from the process (Desimone, 2011; Kisa & Correnti, 2015; Saunders, 2012). These benefits include the opportunity to engage teachers in sessions to improve their ability to develop appropriate lesson plans to teach science lessons, providing teachers with the skills to identify and address misconceptions in science, providing the environment for the development of teachers instructional strategies and pedagogical practices, fostering lasting collegial networking, sharing of best practices and ultimately creating the platform for promoting improved students' performance (Desimone, 2011; Saunders, 2012; Sun, et al., 2013). Furthermore, effective PD should result in a change in teacher behaviour, which should eventually fuel students' learning (Burke, 2013; Kisa & Correnti, 2015; Sun, et al., 2013). Lumpe et al. (2012) stated that "Well-designed and well-implemented PD activities have the potential to increase teachers' beliefs about teaching science" (p. 164). There is an urgent need for teachers to change the way they plan for, think about and teach science. This is essential consequent to the findings of the study which revealed that teachers hold misconceptions about the concepts they are teaching and expressed that they lack the capacity to teach science (see Table 3).

Additionally, PD was used in a number of cases to build teachers' capacity in science content knowledge. For example, Greene et al. (2013) reported that teachers demonstrated marked improvement in science content knowledge after participating in a PDP which lasted for two weeks. Similarly, Zwiep and Benken (2013) completed a study in which 52 science teachers assigned to Grades 4 – 9 participated in a week long PD session which was designed at building teachers' science content knowledge. Findings from the study indicated that teachers' knowledge of science content along with their perceptions regarding their ability to teach science increased significantly.

The Ministry of Education's annual calendar of events designates three days for PD and training; these days, however, are often used to build teachers' capacity in the areas of numeracy and literacy. As such, there is not a designated PD session that is earmarked for the development of science teaching. This is similar to the findings of Greene et al. (2013) who also indicated that mathematics and language are the focus of many PD activities due to accountability issues with which school administrators must contend.

The preliminary findings of this study were communicated to the principal and grade supervisors at Clarke Primary along with the participants of the study. The members of the groups unanimously recommended that a PDP be designed to address the gaps and the malpractices that were discovered. Additionally, the research reviewer and members of the research committee also agreed that a PDP would be most suitable in addressing the weaknesses discovered.

Findings from the study revealed that teachers held misconceptions in science areas such as *classifications of living and non-living things*, *mass and weight*, *force of gravity* and *light and reflection*. Additionally, participants did not demonstrate pedagogical skills in engaging the students in discussions and questioning. For example, in a lesson a student asked the participant "Does the air around us have matter?" The teacher responded "No class. Let's move on now. Pay attention everyone". As a result of these findings, the sessions developed for day one of ETSESF will be focused on addressing areas of misconceptions in science. Thus, facilitating the development of pedagogical techniques that will enhance teachers' skills in identifying misconceptions, correcting misconceptions, identifying and selecting quality assessments and facilitating the development of science process skills.

The participants wrote nine lesson plans for submission during a period when 18 plans should have been submitted (see Table 2). In the nine instances when teachers did not submit the lesson plans, they indicated that they had difficulty writing these lesson plans. Also, in cases where teachers submitted lesson plans, the elements in the lesson plans were not correctly aligned. In one lesson plan, a participant listed a set of science skills which included ‘experimenting and identifying magnetic fields’, however, the students did not participate in the process of experimenting; neither did they identify magnetic fields. The sessions planned for day two of ETSESF are designed to guide teachers in strategic and meaningful planning in order to respond to the gaps identified in teachers’ ability to plan lessons. As such teachers will engage in activities to analyze and critique lesson plans, sequence topics in science to show continuity and cohesion, and collaboratively plan lessons. These sessions are designed to see to the achievement of teachers’ learning outcomes and the project goals as outlined.

In the study conducted, the participants all expressed that they considered themselves inefficient to teach science at the grade level assigned. Therefore, the sessions planned for day three of ETSESF will focus on the development of teachers’ ability to help each other to develop as resources for teaching science. As such, the sessions include activities built around self-evaluation, collaborative planning and research sharing. These activities will enhance continuous PD within the staff and can expand to include individuals from within the wider school community. Based on the findings, the suggestions and the recommendations, PD is deemed to be the most suitable strategy to be used in correcting the shortcomings identified in the participants' ability to plan for and teach science lessons that are conceptually sound.

Review of the Literature

In this section, a comprehensive review of the literature was conducted to show the current thinking about and the attitude towards the ideas and issues that are germane to the research. The aim of this section is to outline the procedures documented in the extant literature on how the concept studied in this research have been conceptualised and studied by others and its applicability in addressing the weaknesses observed in science teaching as displayed by the participants. This section has implications for sections to come as the research methodology, design and the various decisions related to instrumentation and operationalization of the concept is determined in large parts by convenience and expedience but also by the conceptual framework developed and outlined in this study. In addition, the findings of this research will ultimately be placed in their proper perspective by making comparisons with the extant literature.

The issues involved in this research are all intertwined and converge around the underlying issue of professional development (PD). Given that PD has long been seen as important (Hilton, Hilton, Dole & Goos, 2015), there is an abundance of research on PD with the bulk of the work in the extant literature dedicated to examining the ideal design of PD and the impact that such PD may have on teachers' practice and, by extension, student outcome. Despite the preponderance of research on PD, however, according to DeChenne et al. (2012), the field has "lacked a comprehensive theory and is characterized by research that often relies on case studies, professional judgment, or self-report" (p. 4). These researchers also bemoan the lack of replication across studies operating within different contexts and the failure of research to demonstrate an unambiguous empirical nexus between PD, classroom practice and students' achievement and the further inability of research to support intuitive and hypothesised relationships. This literature review, therefore, seeks to satisfy the following aims:

- Delineate the meaning, components and nature of PD
- Establish precedence in the literature for employing PD to improve teachers' science content knowledge even while giving due regard to the shortfalls of this approach
- Outline the factors that mitigate against (and the conditions that enable) the implementation of lessons learnt from PD
- Explore the interplay, in the literature, among PD design, impact on instruction and students outcome.
- Identify, from the extant literature, teachers' attitudes towards and beliefs about PD and the resultant impact that this has on its likely effectiveness
- Analyse the theories of change employed by previous researchers and prepare the groundwork for the proposition and justification of the theory of change that guided this research.

This literature review is centred on PD as a means of improving teachers' pedagogical skills in an effort to enhance students' learning outcomes. Saturation for the literature review was achieved after researching peer-reviewed journals in the education databases: ERIC, Academic Search Complete, Educational Research Complete, SAGE Premier and ProQuest Central. The following terms were used in the search : *professional development, models, history, adult learning, content, knowledge, pedagogical, impact, needs, student achievement, effects, collaborative learning, learning circles, science instruction* and *effective professional development*.

Professional Development – An Educational Endeavour

PD has long since been recognised as a non-negotiable prerequisite for effective teachers and has been a feature of the education system in one form or another for decades (Capps, Crawford & Constas, 2012; Patton et al., 2015; Saunders, 2012). Speaking on a very broad level, PD is seen as a vast range of activities and interactions that can increase the knowledge and skills, improve pedagogical practices and ultimately contribute to the professional, personal, social, and emotional growth of educators (Desimone, 2011; Kisa & Correnti, 2015; Lumpe et al.., 2012; Marrongelle, Sztajn, & Smith, 2013; Saunders, 2012). PD has evolved rapidly in the last decade and as such it is now quite varied in design (Bailey, 2011; Kisa & Correnti, 2015; Lumpe et al.., 2012). These designs range from formal, structured seminars on in-service days to informal hallway discussions with other teachers on a day to day basis (Marrongelle et al., 2013). The activities associated with PD can take the form of a workshop delivered locally, national or international conferences or a college course (Saunders, 2012). This educational endeavour is embarked on as a means toward the development of teacher quality and a way to leverage change in student learning outcomes (Saunders, 2012).

This current research has shown that participants possessed significant inadequacies in the way they understanding fundamental concepts in elementary science (see Table 3). In addition, many indicated that they lacked enabling, positive self-efficacy beliefs about their ability to teach science and, hence, actively avoided planning and delivering science lessons (see Table 2). PD, the literature has shown, is one of the most effective ways to address misconceptions in science held by teachers, such as those revealed in the current research. Lee (2011), for example, used a series of school-based, collaborative PD activities to affect increases in teachers' PCK and to refine their knowledge of key concepts in science. These findings were confirmed by Pecore, Kirchgessner and Carruth (2013) who used novel PD activities to improve teachers' content knowledge and to clarify their misconceptions.

While the primary aim of PD is improving teachers' content knowledge and instruction, there is evidence in the literature that PD has been used to target teachers' self-efficacy (Althauser, 2015; Morrison, 2014), values and attitudes (Ekanayake & Wishart, 2015) and beliefs about science and how to best teach it (McKeown, Abrams, Slattum & Kirk, 2016). These are all issues that the current research highlights as areas of concern. A major issue, for example, with which researchers have concerned themselves is that of scientific inquiry and how teachers can be led by PD to better appreciate its meaning and how to promote it within the classroom. Sullivan-Watts, Nowicki, Shim and Young (2013) found that teachers engaged in inquiry-based classrooms during their teacher training or student teaching year outperformed their counterparts who did not have the benefit of this experience. Also, Morrison (2014) has shown that when teachers engage in authentic PD activities – attending a summer program at a research facility where they shadowed and interviewed scientists – they develop more wholesome beliefs about science and were able to successfully implement scientific inquiry in the classroom.

Without prejudice to the general consensus that continuing PD is an important element in supporting teachers' professional growth and development, investment in PD must be evaluated and parsed to ensure that meaningful benefits are indeed earned from these activities. This observation comes against the background that PD requires an enormous investment of time on the part of the teacher and a significant financial investment on the part of the school or educational authorities that are tasked with the responsibility of funding it (Hilton et al., 2015). The question as to whether PD is a futile activity is further fuelled by the fact that in a study of Turkish primary school teachers, carried out by Gokmenoglu, Clark and Kiraz (2016), it was discovered that, aside from cursory interest in guidance and special education, teachers indicated little need for or interest in participating in-service training. The issue of teachers' interest in PD is not a settled matter, however, as El-Deghaidy, Mansour, Aldahmash and Alshamrani (2015) and Friedrichsen, Linke, and Barnett (2016) found that the vast majority of primary teachers identified that science content knowledge was an issue in which they would benefit from additional PD. This discord in the literature needs not be surprising because, as Lewis, Baker and Helding (2015) pointed out when they warned about the importance of PD implementation fidelity that it is idiosyncratic thus, it is difficult to make global claims about all PD.

Theory of Change

PD as a tool for improving teachers' practice is based on a sequential set of interdependent actions that predict how PD impacts teacher's growth. Linear and simplistic theories of change such as that proposed by Guskey (1986) and Desimone (2009) and later adopted and tested by Qablan, Mansour, Alshamrani, Aldahmash and Sabbah (2015), posit that if teachers experience effective PD, then their knowledge is increased and their attitudes and beliefs are improved. This results in adjustments to their instruction or improvements in their content (or both) and these new instructional strategies result in increased student learning. However, as our understanding of teacher change and teacher learning has evolved, these traditional models have been called into question for the inability to recognise the cyclic nature of the process of teacher change. (Hilton et al., 2015). One model that has been suggested by Clarke and Hollingsworth (2002) is the Interconnected Model of Teachers Professional Growth (IMTPG), which argues that teacher change occurs through teachers actions and reflections in four domains – the Personal Domain (teachers' knowledge, beliefs and attitudes); the Domain of Practice (comprised of all professional experimentation, planning and practice); the Domain of Consequence (the result attendant with teachers' actions and inactions); and the External Domain (sources of information or stimulus that exists external to the teacher).

DeChenne et al. (2012) also proposed a theory of change that argued that teacher learning must be conceptualized as an intricate system, identified within variables that are characterised by the teachers' background and learning environment. Their model placed a premium on the fact that specific PDPs, processes, and initiatives cannot be assessed in any meaningful way without also examining those complex interplay of teacher along with those environmental variables that contribute to teacher performance. This is an idea that appears consistently in the work of Lewis et al. (2015), who have argued that learning environments are similar in nature to an ecosystems, subcultures, communities of practice, places of social reproduction, and microcosms of the communities within which they are situated. Against this background, responses to PD are expected to be dissimilar from one teacher to the next, based on the beliefs (about teachers and students) that are promoted by the specific classroom ecosystem. There is evidence in the literature, however, to suggest that school context may not play as significant a mediating role in teacher change as previously believed. This is evidenced, for example, by Glover et al. (2016) whose research showed that teachers had similar expectations of – and experiences with – PD, even when they taught under vastly different settings in rural versus urban areas.

A theory of change model developed by Trygstad, Banilover, Smith and Nelson (2014) adopts a linear approach that Guskey (1986) and Desimone (2009) suggested, but introduced instructional materials as an intervening factor since the implementation of lessons that teachers learnt from PD is usually hampered by scarcity of high quality instructional resources. This lack of provision of complementary resources to facilitate teacher change is related to the traditional view of teacher change that Hilton et al. (2015) described. Their review of the research literature led them to conclude that teacher change has been variously portrayed as something imposed on or done to teachers through engagement with experts, as something that occurs through experience or adaptation in the classroom despite the fact that many PD programs failed to satisfactorily consider the processes that bring about teacher change.

A review of the literature supports this view. The primary interest that has driven the flurry of research in PD has been a singular focus on the features that make PD successful (see, for example, Kanadl & Saglam, 2016; Mansour, El-Deghaidy, Alshamrani & Aldahmash, 2014; Minor, Desimone, Lee & Hochberg, 2016; Qablan et al., 2015). On the contrary – and counterintuitively – little is known about the variables and factors that promote individual teachers' professional growth during PD programs (Hilton et al., 2015). The advice of Clarke and Hollingsworth (2002), however, should prove useful in the design of PD that promotes meaningful, sustainable teacher change. They argued that teachers should be able to access and interact with many channels and domains (personal, professional, external, etc.) through which change is possible. Furthermore, they argue that it would be useful to identify the factors that facilitate or hinder teacher change so that the design of PD may make the best use of these.

Impact of PD on Instruction

The importance of PD as a means of driving quality education has been underscored by Guskey (1994) who observed that it is impossible to improve schools without effectively cultivating the requisite skills and competencies of the teachers within them. The support for this claim lies in the vast number of studies that, over time, have demonstrated the noticeable, significant and remarkable positive impact that PD has on instruction and student outcome (Birman, Desimone, Porter, & Garet, 2000; Boydak &

Dikici, 2001; Carver & Katz, 2004; Desimone, Porter, Garet, Yoon, & Birman, 2002; Easton, 2008; Jonson, 2002; McCaughtry, Martin, Kulinna, & Cothran, 2006; McLaughlin & Talbert, 2006; Moir & Gless, 2001). More recent studies have also confirmed these earlier findings by showing that PD has improved science teachers' strategic use of classroom discourse (Kanadl & Saglam, 2016); strengthened their use of scientific inquiry and empowered more open lesson plans (Perez & Furman, 2016); facilitated statistically significant improvements in teachers' ability to design and deliver creative lessons (Al-Balushi & Al-Abdali, 2015); improved their attitude to technology for teaching science (Bang, 2013; Ekanayake & Wishart, 2015); empowered them to plan for and promote problem- solving and higher order thinking in the classroom (McKeown et al., 2016), and built their confidence in executing research for science teaching (McKeown et al., 2016).

The net effect of the aforementioned findings is that there is general consensus that PD that has been designed with due regard to research-based effective practices has the potential to significantly impact instruction and, ultimately, students' outcome. This happens through what Pella (2015) described as pedagogical shifts that teachers make once they have been exposed to meaningful, effective PD. Pedagogical shifts are "characterized by a teacher's transformation of content knowledge into forms that are pedagogically powerful and adapted to fit the students" (Pella, 2015, p. 84). In her research, she found that a practice-based PD model afforded teachers with multiple opportunities for making pedagogical shifts, which were catalysed by *pedagogical reasoning and action* – a concept developed by Shulman (1987) – and that these shifts were sustained (and even improved) well beyond the period during which the PD is offered. The importance of teachers reflecting – contemporaneous and otherwise – and talking with their colleagues about their pedagogical actions is also a source for teacher change. Ekanayake and Wishart (2015) found evidence that offered undeniable support to the importance of teacher talk and Parise, Finkelstein and Alterman (2015) concluded that teachers' collaborative talk is the most important source of teacher growth and change.

In this vein, it appears that PD that encourages collaborative inquiry and practice-based designs is most likely to have a significant impact on instruction (Pella, 2015). Consistent with this, researchers have explored how lesson study, mentoring and professional learning communities have been able to facilitate teacher change. Tan (2014), for example, used lesson study among a group of four Biology teachers at grades 9 – 10 to show how a theory-framed lesson study enhanced a discourse of teacher inquiry that was centred on student learning. Also, Kelly and Cherkowski (2015) offered professional learning communities (PLCs) as a significant source of PD, arguing that "professional growth for teachers is catalysed through peer observations, trying new things, testing different perspectives, and developing intellectual curiosity about teaching and learning" (pp. 6 – 7). While researchers have uncovered general support for collaborative, practice-based approaches to PD, they have also shown that there are limitations in using these approaches. Parks (2008), for example, found that teachers lack experience with collaboration and hence do not benefit as much as they should from engaging in a PLC or in a lesson study activity. In addition, Saito, Hawe, Hadiprawiroc, and Sukirman (2008) argued that, during lesson study, teachers place a disproportionate focus on refining every detail in a lesson during the lesson preparation stage – a process that Tang and Shao (2014) described as ‘*lesson polishing*’ – instead of focusing their attention on students learning process. This limits the extent to which teachers are likely to benefit from lesson study.

In addition, schools’ ethos, cultural practices, leadership and teachers’ individual personality determine the extent to which collaborative, practice-based PD will be impactful. This view is supported by Tang and Shao (2014), who argued that while teachers in the same school district may feel comfortable sharing teaching stories and giving advice when asked they usually practice in isolation and have no initiative to be part of interdependency when it comes to teaching.

Notwithstanding these concerns, however, Tang and Shao (2014) concluded that while truly collaborative PLCs remain elusive to most teachers, their engagement in these communities presents significant benefits especially if efforts are made to attend to the climate that accounts for the feeling of support, care and respect. These views are echoed by Mosha’s (2015) assertions that learning communities are crippled by the lack of resources made available to them to support teachers’ PDP effectively and efficiently.

Despite the overwhelming evidence to support the assertion that PD is useful for enhancing instruction, there are findings that seek to question this. In Blank, De las Alas, and Smith’s (2008) rigorous and comprehensive study of PD activities carried out among mathematics and science teachers in America between 2004 and 2007, no observed changes in teachers practice were observed and it was not clear how to conclude with certainty how PD impacted practice. These findings are supported by Lewis et al. (2015) who carried out a two year investigation of how secondary teachers of science responded to PD aimed at building their competence in promoting scientific discourse within the classroom. They concluded that even with explicit PD activities on the integration of writing in science lessons teachers rarely engage students in formal scientific writing during science instructions. In addition, they found that during science instructions teachers rarely provide an opportunity for differentiation during instruction nor do they exert deliberate efforts to bridge language and culture gaps with science.

Other researchers have also turned up results that cast doubt on the efficacy of PD to create pedagogical shits. DeChenne et al. (2012), for example, concluded that coaching as a form of PD had a significant and positive impact on science teachers' practice but not on their beliefs about attitudes the subject and students. This seeming contradiction raises questions about the extent to which these instructional changes are sustainable if they are not buttressed by changes in affect. Sullivan-Watts et al. (2013) who investigated whether the teaching practices of 27 beginning elementary school teachers was affected by PD offered through mentoring, found that teachers' science content knowledge predicted their teaching competence, but that mentoring was not predictive of their instructional capacity.

In summarising the literature, Capps, Crawford and Costas (2012) offered that despite general alignment between PD and the suggestions from research, "no reported study has connected participation in inquiry-based PD with all the desired outcomes of teacher PD: enhanced teacher knowledge, change in beliefs and practice, and enhanced student achievement" (p. 292). These views are expressed by Hilton et al. (2015), who stated that the factors that have meaningful impact on the efficacy of teachers' PD are varied and inconclusive.

Leveraging PD for Greatest Impact

Perhaps the single most important task to carry out in this literature review is an analysis of the factors that enhance or hinder the utility of PD for the purpose of pedagogical shift. This is needed so that the researcher can better understand how to design PD for the purpose of enhancing teachers' science content knowledge. This issue of the design of PD for science teachers has received significant attention in the extant literature with most researchers eschewing traditional approaches to PD (see, for example, Belland, Burdo & Gu, 2015; Beyar, 2014; Hemphill, 2015; Rahman, Abdurrahman, Kadaryanto & Rusminto, 2015; Shymansky, Wang, Annetta, Yore, Everett, 2012, and Smith, 2015). Traditional approaches to PD usually take the form of one-off workshops delivered by an expert and is usually not linked to the immediate needs of teachers. The extensive use of this approach indicates that the providers of PD are inclined to perceive it as an external top-down initiative provided by an outsider rather than an insider bottom –up perspective that is based on teachers' needs analysis (EL-Deghaidy, et al., 2015)

In response to this and other similar criticisms, there is a large body of work aimed at providing an understanding of the factors that improve the effectiveness of PD. While the suggestions are wide and varied, they can perhaps be summarised by DeChenne's et al. (2012) recommendation that effective PD should move away from the ‘sit and get’ approach, which “does not focus on the background knowledge, teacher characteristics, transfer to instructional activities and cultural instructional context.

Wilson (2013) outlined five key aspects of teacher PD that have been identified over time by researchers. These include (a) a sharp focus on specific content that is immediately relevant to the issues and needs of teachers, (b) an engagement of teachers in active learning, (c) an environment that facilitates the collective participation of all teachers, (d) deliberate steps taken to ensure organisational and institutional coherence, by aligning PD objectives with other school practices and finally, (d) sufficiency of duration by ensuring that teachers benefit from appropriately intensive encounters for an acceptable length of time. Smith (2015), in assessing the extent to which these features matter in designing effective PD, found that institutional coherence was not readily identified by teacher as an important element, though they placed premium on the other features. Smith also sought to elevate suitability of content knowledge over the other features of effective PD, by arguing that identifying the content of PD may easily be the most significant decision to make when developing PD programs. The underlying principle he argued, though, that should guide the design of PD programs for teachers is a concern with teachers’ knowledge of the subject matter and an awareness of how students learn that subject matter.

The context within which PD is offered has also come in for some attention in the extant literature. It is generally regarded that PD offered to teachers outside of the school setting decontextualizes learning and, therefore, where possible, PD should be offered in-house and should be initiated by teachers and make use of material that they develop and present (El-Deghaidy et al., 2015). In addition, PD is most effective when teachers' participation is voluntary (Stewart & Houchens, 2014) and when the principles of andragogy are given due regard (Lewthwaite, Murray & Hechter, 2012). The issue of context has been explored at great extent in the literature with some researchers, such as Stewart and Houchens (2014), exploring the importance of embedding PD in the immediate classroom context with which teachers are familiar while others, such as Morrison (2014) have analysed the role of authentic, field-based, and industry-driven experiences as a vehicle for PD. Both approaches to the issue, however, have arrived at the same conclusion, which is that couching PD in real contexts that teachers find immediately useful – whether in the classroom or within industries – is tremendously beneficial in improving teachers' pedagogy.

Effectiveness of PD is also enhanced by giving considerations to teacher factors – their personality, preferences, and interests – since successful PD programs are those that are deeply and personally meaningful to teachers (Mokhele & Jita, 2010). As an example, Ciampa & Gallagher (2015) studied the extent to which blogging could be used to support teachers' PD. They found that teachers' personality played a significant role in how they responded to and benefited from blogging. Specifically, they found that teachers who were shy had a preference for the online setting, which increased their confidence to participate as they developed an online identity. In addition, the research of Saka (2013) provides evidence of the importance of teachers' demographic variables such as sex, age and the level at which they teach, in determining their interest in PD.

This led him to conclude that “teacher demographics” should be decisively considered as one of the important facets when preparing a PD program.

Supporting Teachers’ Implementation of PD

Regardless of how effective PD is at changing practice, even more crucial is the issue of post-PD implementation and actions. Despite this, barriers to implementation are an issue that has not received significant attention as evidenced by the dearth of research on the issue in the extant literature. Research done by Lewis et al. (2015) is one of the few entries in the literature that explicitly examined barriers to PD implementation. It revealed that teachers usually identify barriers to implementation as factors that exist outside of their locus of control and which are generally related to factors such as availability of material, support from school leadership and students’ readiness to learn. Incidentally, from Lewis’ et al. study, teachers identified more sources of support than obstacles to implementation. The researchers conceded, however, that when teachers assigned weight to the factors, a negative factor may be sufficient to prevent teachers from implementing what they were taught and what they learn in a PD program.

Sources of support may easily become obstacles to PD implementation – based on how they are organised at the school level. Typically, though, researchers have identified five factors that may enable or hinder PD implementation – administrative support, level of collaboration among teachers, curriculum, instruction, parental support and the students’ attitude and beliefs (Lewis et al., 2015). Researchers have recommended the inclusion of school leaders in PD activities as a useful strategy for ensuing that post-PD actions have school-wide support (Hilton et al., 2015). The involvement of school leadership in the actual PD activities is expected to encourage the development of a professional learning community, and to foster collaboration and reflective dialogue regarding practice, both of which accounts for learning on an individual level as well as at the group level. Unfortunately, the role of school leaders in promoting the implementation of PD has not been precisely defined in the literature except, perhaps, by Hilton et al. (2015) who identified two key areas in which school leadership influences the professional growth of teachers. These two areas includes; providing opportunities for teachers to attend PD programs and the encouragement they provide teachers to experiment in their classrooms (Hilton et al., 2015). In addition, school leaders have the ability to create the logistical framework within which teachers operate and hence can offer support in terms of the provision of resources and material, the organisation of the teachers' timetable to make more time available for implementing strategies, the deployment of teachers to take advantage of new training that they have received, the development of mentorship and coaching programs, as these are all factors that affect the extent to which PD is implemented (DeChenne et al., 2012; Morrison, 2013; Qablan et al, 2015).

Indeed, a recurring theme in the literature on the implementation of PD is the issue of support for teachers. As Qablan et al (2015) noted that trained teachers do not have the ability to adjust their classroom teaching practices as there are several obstacles that get in the way of science instruction. Teachers often identify the design of the PD program, the time allocated for participation and implementation and their teaching and social responsibilities as factors that determine the extent to which they participate and implement PD (Qablan et al., 2015). Indeed, implementation is threatened when there is a mismatch between the reality of the classroom and what teachers learn in PD. As an example, consider this observation from Qablan et al.: "the small classroom and [large] number of students in each classroom overwhelm teachers and distract them from utilizing new teaching strategies" (p. 626). These classroom sizes forces teachers to place greater focus and energy on disciplinary issues and class management instead of implementing new teaching strategies developed during PD (Qablan et al. 2015).

To support implementation, the literature has made some useful suggestions. Teacher coaching, for example, has been shown to increase implementation of PD strategies from 15–85% of the time – though coaches for science are rare when compared to mathematics and literacy. Belland et al. (2015) has also made suggestions for a blended approach to PD – where face-to-face delivery is augmented by online delivery – in order to address some of the logistical challenges that teachers have with accessing PD. Also, such an approach has greater potential for scaling and for providing post-PD support to teachers by making each teacher a part of a large virtual community. Lee and Choi (2015) interviewed and observed six elementary teachers of science in an effort to understand the characteristics of PD that influence implementation. From their research, three themes emerged. Firstly, they discovered that PD implementation was enhanced when the PD was singularly focused on a particular issue that all participants have in common. A common goal ensured that the participants received the necessary social and psychological support that helped them to maintain their thrust when facing challenges to implementation (Lee & Choi, 2015). The second factor that enables implementation according to Lee and Choi is the empowerment of teachers to be producers of knowledge so that they are able to solve unanticipated problems during implementation. Finally, ensuring that teachers are provided with a continuous authentic learning experience will allow then to trial their PD lessons while still enrolled in the PD program.

Teachers' attitude, beliefs and values have also been shown to impact the implementation of lessons learnt from PD. Teachers with low self-efficacy beliefs about teaching science are less likely to believe that they can effect change in students' behaviour and hence are not likely to adjust pedagogy post-PD (Morrison, 2013). Additionally, Lewis et al. (2015) found that the extent to which post-PD implementation takes place is surprisingly dependent on the socio-economic status (SES) of students – with lower implementation occurring in schools attended by students with low SES when compared to schools with students of high SES. The reasons for this, according to Lewis et al. (2015) is that when teachers are of the belief that students are unwilling and unable to engage in critical thinking they fail to provide such opportunities, thus limiting students' access to a standards based science education. As such some teachers may need to be exposed to PD which is geared at explicitly addressing teachers' dispositions toward equity in the classroom (Lewis et al., 2015).

More support for the important role played by teachers' attitude, beliefs and values is also alluded to by Lewis et al. (2015), who argued that PD which requires extensive fidelity in implementation is not likely to be implemented, given the difficulty teachers have with adopting and accommodating changes. Belland et al. (2015) also lends support to the role of teachers' beliefs and attitudes by "showing that teachers who have much experience in more teacher-directed forms of instruction often think that their former approach worked well and that students will resist taking on more responsibility for their own learning" (p. 282). These teachers are not likely to implement PD which requires changes in their pedagogy.

Summary of Literature Review

Despite some research to the contrary, there is overwhelming support for the view that PD is able to change science teachers' attitude, beliefs, knowledge and pedagogy and that these changes are likely to result in improvements in students' outcome. PD impacts pedagogy through a complicated theory of change, which is viewed as a linear chain of reaction by some researchers but is perhaps best conceptualised as a more complicated, iterative web of connections among various factors – the teachers' external environment, the teachers' own personal beliefs and values and the accountability framework within which the teacher operates. Given the various positive impact that PD has on individual elements of teachers' practice – their creativity while teaching, their ability to pose meaningful problems, their use of scientific inquiry, for example – the cumulative effect of PD on teachers is expected to be pedagogical shift.

Given our understanding of how pedagogical shift takes place – through reflection and communication – there is renewed interest in PD that focuses on collaborative-inquiry or that is action-based. As a result, PLCs, mentoring and lesson studies have become popular mechanisms for PD and have been shown to offer significant advantages to traditional, workshop style, one-off PD activities. PD can be leveraged to offer significant impact if strategic attention is paid to its design – in particular, by focusing on the content of the PD, the duration and the type of engagement to which teachers are exposed. In addition, ensuring that PD is delivered within meaningful context, and that it takes into account teachers' interest and unique circumstances is also likely to enhance its effectiveness. Finally, the implementation of lessons learnt from PD can be encouraged by ensuring that school leadership is involved in PD, teachers receive support and that teachers' beliefs and values are addressed.

Description of Project

This project study, titled ETSESF, was designed to address the gaps identified in a study conducted at the Clarke Primary School which had an aim of developing a deeper understand of science content knowledge of teachers in Grades 4 – 6. This project is designed for the nine teachers that were participants in the study, however, all the teachers at the institution can benefit from the content of the project since all the teachers teach science. The PD project will be conducted on the three PD days designated by the Ministry of Education in the academic year 2017/2018. These three days span the three terms in the academic year. The sessions will be conducted by science educators in the Core Curriculum and Professional Development Unit of the MOE. A PowerPoint presentation will be used in the initial session to communicate the purpose, background, rational, aims and objects and overview of the individual sessions. The resources, potential barriers and solutions and the implementation timetable are discussed in the following sections.

Needed Resources

In order to effectively conduct the PDP as designed, there are needed resources that must be secured (Trygstad et al., 2014). Time is an important resource that must be accounted for in the design (Beyar, 2014; Hemphill, 2015). The program will be delivered over three days. These days are designated PD days by the Ministry of Education. Each day, participants will be engaged in PD activities for duration of five hours. These sessions will be conducted at the Clarke Primary School.

One other important resource that must be accounted for is the person that will facilitate the sessions (EL-Deghaidy et al., 2015). An individual from the Core Curriculum Professional Development Unit with expertise in science education will be recruited to conduct the sessions. A letter will be written to the Assistant Chief Education Officer of Core Curriculum Unit to request a trained specialist to facilitate the training. This person should have a comprehensive knowledge of the science content that is taught at the different grades at the primary level. Additionally, this person should possess presentation skills that will enhance the quality of the sessions and keep participants active and mentally engaged (EL-Deghaidy, et al., 2015).

Other important resources needed for the program are sample lesson plans, computer and projector, handouts, PowerPoint presentation, evaluation forms and stationery. The lesson plans, inclusive of prototypes and non-examples of good plans, will be developed by the resource person. Handouts will be given to teachers for reinforcement purposes. Each session will be evaluated, as such; each participant will be given an evaluation form to be completed at the end of each session. All the other resources will be provided by the institution.

Existing Support

The support that is available is the principal's commitment to see to the facilitation of the PD training. As such, the principal has pledged to release the teachers from teaching duties for the three days. Also, the principal has committed to make financial allocations for the budget of the program providing that he can identify the money in the school's coffers.

Potential Barriers

It is important to identify the potential barriers in the planning phase of a project so that alternative plans can be put in place to address these barriers (DeChennes et al., 2012). One important barrier that may threaten the effective delivery of this program is funding (DeChenne's et al., 2012; Trygstad et al., 2014). All sectors and ministries in Jamaica, including the Ministry of Education have experienced a reduced budget as a result of the country's endeavor in satisfying the International Monetary Fund (IMF) requirements (Maple, 2015). As such, the monies that were formerly allocated to PD are now redirected to other areas.

One other potential barrier that may affect the effective and efficient administration of the PD sessions is the availability of a trained science specialist. Currently, one trained science specialist is employed to the Core Curriculum Unit. This Science Education Officer has the task of providing professional development for the entire island which is consisted of 14 parishes. These situations may prove to be major barriers to PDP.

Potential Solution

One possible solution to the lack of funding that is a potential barrier is for the principal to identify monies in the schools coffers that may be used to fund this venture. As such the principal through the Board of Management of the school can write to the Ministry of Education Regional Officer and ask permission to *vire* funds for the purpose of conducting the ETSESF program. As it relates to the availability of a training science educator to administer the training I am trained, capable and will be available to do the training. Additionally, I have had interactions with the participants and the administrators at the school and would have gained their trust over the period.

Proposal for Implementation and Timeline

The PD plan will be delivered over three days. Each session is designed to meet the stated goals as discussed in the earlier sections. The 3 days activities are outlined in Table 5.

Table 5

Sessions schedule for ETSESF program

Days	Title	Rationale	Time
Day 1	The Program: Empowering Teachers in Science to Empower Students Future	To communicate the goals, purpose and objectives of the PDP to participants	09:00-10:30
	Science Content Knowledge: The seven Domains	To explain to participants Shulmans seven domains of SMK and to make the connections to science teaching.	10:45-12:15
	Addressing Common Misconceptions in	To discuss with participants some common misconceptions,	01:15-03:15

	Science Topics Taught in Grades 4-6.	ways to identify misconceptions and strategies to correct these misconceptions	
Day 2	Lesson Planning: The Importance of Alignment and Sound SMK	To communicate to participants the importance of sound Conceptual knowledge in the lesson planning process.	9:00 am - 10:00am
	Lesson Plan Critique: Spotting the Prototype	To allow for the vetting and analysis of lesson plans critique of lesson plans	10:15 - 11: 30
	Lesson Plan Development, Alignment and Content	To provide participants the opportunity to develop lesson plans guided by the prototype provided.	12:30- 02:00
	Presentation of Lesson Plans Developed	To provide an opportunity for participants to discuss lessons developed with their colleagues	02:00- 03:15
Day 3	Science Teachers Learning Club: The Benefits	For participants to develop an appreciation for the importance of the science teachers learning club.	09:00- 10:30
	Establishment of the Science Teachers Learning Club	To empower teachers through the establishment of a science teachers learning club.	10:45- 12:15
	Strategies for Maintenance of the Science Teachers Learning Club	To develop and communicate strategies on the maintenance of the Science Teacher learning Club.	01:15- 03:15

Roles and Responsibilities of Students and Other Stakeholders

The students at Clarke Primary School do not have an active role to play in the PDP. My role as researcher is to design a PDP that is comprehensive and appropriate in addressing the needs identified in the qualitative aspect of the project study. Additionally, I am to ensure that the administrators of the institution are in receipt of the PDP in a timely basis so that adequate preparation can be made for the implementation. Similarly, the participants have a critical role to play in the process. They are required to attend all the sessions; furthermore, they are to actively participate in these sessions so that the identified goals of the PDP can be achieved. One other role that the participants have is to provide timely feedback regarding the quality, suitability, design and relevance of sessions to the facilitators. It is expected that evaluation forms (see Appendix A) will be completed in an honest and truthful manner so that the feedback can be used to inform the sessions as the PDP progresses.

The principal of Clarke Primary School also has some responsibilities that are critical to the implementation of the PDP. The principal is responsible to organize for the preparation of the venue for hosting the sessions. Also, the principal has the responsibility to release the teachers from normal teaching duties on the scheduled training days so they can access the PDP.

Project Evaluation Plan

The evaluation of a PDP is an important but challenging part of the process (Kisa & Correnti, 2015; Lumpe et al., 2012; Simpson, 2013). This is important as it provides information on the effectiveness, the value and the impact of the PDP (Beaudoin, Johnston, Jones & Waggett, 2013). Additionally, the findings from formative evaluation can be used to inform any modification and refining that may be needed during the implementation phase of the program (McKeown et al., 2016; Wilson, Sharrad, Rasmussen & Kernick, 2013). Data collected from summative evaluations can be used to inform future PDPs for the same participants or for different participants in similar contexts (Simpson, 2013; Wilson et al., 2013). Thus, the evaluation plan for a PDP should be in alignment with the goals and objectives of the program (Beaudoin et al., 2013; Kisa & Correnti, 2015; Lumpe et al.., 2012; Simpson, 2013; Wilson et al., 2013). Conversely, evaluation plans that are not supported by the objectives of the PDP might not provide information that is reliable and valid about the program (King, 2014; McKeown et al., 2016).

The evaluation plan for this PDP involves both formative and summative evaluation activities (see Appendix A) that are aligned to the goals and the daily expected learning outcomes of the program (Pella, 2015; Saunders, 2012). As such, at the end of each day, the participants will complete a formative evaluation of the sessions (see Appendix A) in which they participated (King, 2014; Simpson, 2013). This formative evaluation will be analysed by the facilitators and the findings documented and used to inform the activities in the PDP as the sessions progressed (King, 2014; McKeown et al., 2016; Pella, 2015; Simpson, 2013). Additionally, participants will complete a summative evaluation of the PDP (see Appendix A). The data from this evaluation will be analysed to determine the impact of the program on the teachers' ability to effectively teach the science content at the 4 – 6 grade level (King, 2014; McKeown et al., 2016; Simpson, 2013). Importantly, the impact of the PDP on students' outcome is invaluable (King, 2014; Simpson, 2013; Wilson et al., 2013). As such, an evaluation of the impact on students' outcome will be conducted (see Appendix A).

Project Implication and Social Change

The ETSESF PD is designed to remedy the gaps identified in some areas of science teaching at the Clarke Primary School. Findings from the study indicated that there are elements of misconceptions in some areas of the science content taught at the 4-

6 grade level. Additionally, teachers are inconsistent in writing science lesson plans for some topics taught at Grades 4–6. Furthermore, lesson plans developed were lacking in key alignment features. Thus, the objectives in some lesson plans were not in alignment with the teaching activities and the assessment activities outlined in the lesson plans (see Table 4). During the PD sessions teachers will be exposed to strategies to enhance lesson planning and lesson delivery (Beyar, 2014; Hemphill, 2015). Additionally, these teachers will be engaged in activities that will result in the development of professional learning circles (Hemphill, 2015; Wilson (2013). Ultimately, students' academic achievement in science should improve with time. This PDP, when implemented is intended to have a positive effect on all the stakeholders groups that are affected by the teachers' inadequacies highlighted in the findings of the study.

Importance of Project to Local Stakeholders

This project is intended to bring about positive social changes by addressing the quality of science teaching at the Clarke Primary School. The program is designed to that the teachers that access this PDP will show improvement in their ability to identify and correct misconceptions in science. Furthermore, it is believed that as a result of the program, the teachers will be able to plan lessons that are comprehensive and appropriate to address the curriculum requirements for Grades 4–6. Additionally, the students should experience positive social change from this PDP. Students' performance in science at the Grades 4–6 should improve. It was noted that students' performance in the GSAT, which is content based exit exam, stood below 40% for the last five years. It is expected that the implementation of the ETSESF program will ultimately lead to improvements in students' achievement in this exam. Improvement in students' science performance at the Clarke Primary School will contribute to an improved performance in science regionally.

Importance of Project to Broader Stakeholders

It is expected that this PDP will have a positive social change on stakeholders that are outside of the boundaries of the Clarke Primary School. The ETSESF, as outlined in Appendix A, is a comprehensive PDP that can be adopted to be used in other contexts that are similar to that of Clarke Primary School. Furthermore, the ETSESF is designed to respond to the needs of science teaching. However, it can be adapted and use in other subject area. It is hoped that this ETSESF will be used by other schools that are having similar challenges with science teaching and students achievement in science. Ultimately, this ETSESF might contribute to improved outcomes in instructional practices, science teaching and science education nationally.

Summary

The purpose of this project study was to provide a deeper understanding of Clarke Primary School teachers' science content knowledge as a component of science teacher effectiveness. Findings from the study revealed that the participants believed that they lack proficiency in teaching science at the grade level assigned. Additionally, the participants held misconceptions in the topics taught at 4-6 grade level and planned lessons that lacked key lesson plan elements such as science skills and appropriate assessment activities. After an evaluation of the possible remediating options, it was decided by the researcher, stakeholders from Clarke Primary School and the Walden University assigned committee that a PDP would be most suitable in addressing the gaps identified in the study. Thus, a review of literature was completed and the findings used to inform the development of the ETSESF, as presented in Appendix A. An evaluation plan and the prospective for positive social change are also discussed. In the following section, the strength and limitations of the project along with possible social change and analysis of me as a scholar, practitioner and project developer are discussed.

Section 4: Reflections and Conclusions

Introduction

The purpose of this project study was to provide a deeper understanding of Clarke Primary School teachers' science content knowledge. Findings from the study revealed that the participants held misconceptions in the topics taught at the 4 – 6 grade level. Furthermore, the participants said they felt incapable of writing lesson plans for some topics taught at the grade level to which they are assigned. In cases where lesson plans were written, essential elements such as science skills were not included and the assessment activities were not in alignment with the objectives of the lesson. Subsequently, a PDP was designed to address the gaps and were identified in the research process (see Appendix A). In this section, I outline the strengths and limitations of the project and discuss recommendations that can address the limitations. Additionally, I examine my roles as a scholar, practitioner, and project developer. This section concludes the implications for social change, suggested applications, and directions for further research.

Project Strengths and Limitations

Project Strengths

This PDP was designed to address the needs identified in science teaching at the 4 – 6 grade level at the Clarke Primary School. After consultation with a science specialist in the Core Curriculum Unit of the Ministry of Education, research participants and educational administrators at Clarke Primary School, a thorough review of literature was conducted. This informed the design of the PDP.

This PDP has many strengths. First, it was developed based on the concept of effective PD as proposed by King (2013) and Earley and Porritt (2014). According to King (2013) and Earley and Porritt (2014). PDPs should focus more on the impact of the program on students' outcome rather than on the execution of the program. It was noted that the evaluation process for many PDPs is sometimes unstructured and as such is greatly underused in many cases (Earley & Porritt, 2014; King, 2014; Simpson, 2013). Based on the aforementioned, an evaluation program was developed to assess the implementation of this PDP, the evaluation of teachers' use of learnt strategies during science instruction and also the impact of the program on students' outcome (see Appendix A). This robust evaluation program should be able to generate adequate, valid, reliable and relevant data in order measure the efficacy of the PDP.

Second, this PDP was designed to address the different facets of science teaching and specifically the gaps identified at the Clarke Primary School. According to Earley and Porritt (2014), PD should enhance teachers' effectiveness and should be designed to address targeted areas of deficit (Beaudoin et al., 2013; King, 2014; Simpson, 2013; Wilson et al., 2013). Thus, the areas of lesson planning, lesson plan analysis, identifying and treating misconceptions in science and the development and maintenance of a professional learning circle are embedded in the program. Therefore, teachers who are exposed to the sessions in the program should be able to construct lesson plans that include the requisite components of a sound lesson and should be able to execute lessons that are conceptually sound and cognitively engaging.

Third, the supporting documents and presentations for the PDP were all developed and presented in Appendix A. These documents have been developed with the guidance and expertise of a science specialist assigned to the Core Curriculum Unit of the Ministry of Education. This expertise enhanced the quality of the documents developed to support the program. The program strength is attributed to the robust evaluation plan, its embedded concepts, and the documents that have been developed to support the program. Notwithstanding, some limitations are associated with the program as developed.

Limitations

The PDP was designed to address the gaps identified in teachers' science content knowledge at the 4 – 6 grade level at the Clarke Primary School. The participants of the study that provided the baseline data for this PDP are nine teachers. Hence, the program was designed to address the areas of gaps that emerged in the study conducted with the nine teachers. This sample of nine teachers may be considered small for the level of participant interaction that is needed to enhance the execution of the program. Furthermore, the evaluation of the program will be completed by these nine participants. This number of participants is considered inadequate to provide the volume of data that can be considered reliable and valid from which information to make decisions can be deduced. Additionally, the findings from this small volume of data will be limited and not generalizable.

According to Earley and Porritt (2014), PDPs are most effective when they are executed over a long period of time. A lengthy period for execution of a PDP allows for adequate reflection by the participants (Capps et al., 2012; Earley & Porritt, 2014). It also creates an avenue for the participants to test their ability to apply the new learning in teaching experiences with their students during the process of engaging in the PDP (Capps et al., 2012; Earley & Porritt, 2014; Patton et al., 2015). However, this PDP would be conducted over 3 days. This duration is short and will not allow for the benefits that can be achieved if it were administered over a longer period.

There is a shortage of science specialists employed by the Ministry of Education Jamaica. As a result, there is a shortage of science specialists to conduct and facilitate PD sessions in the area of science education. Additionally, all schools across the island will be participating in PD sessions on the same 3 days. As such it is highly likely that a science specialist may not be available to facilitate the training on these designated days.

Recommendations for Alternative Approaches

One alternative approach for the administration of the PD session is to have all the teachers who are deployed in Grades 4–6 at the school participate in the sessions instead of only the nine teachers who participated in the study. This will increase the number of participants and account for dynamics in participants' interactions which are an important element of the program. This adjustment will also account for an increased number of participants who will complete the evaluation activities. Findings from evaluation completed by large number of participants are said to be more reliable than findings from evaluations completed by a small number of participants (Button et al., 2013).

One alternative approach that could be used to increase the possibility of having a science specialist available to administer the session is to conduct the PD sessions on days that are not earmarked by the Ministry of Education for PD activities. A written request outlining the challenges and proposing alternative days could be made to the Permanent Secretary in the Ministry of Education. Additionally, the school can make an early request to the Core Curriculum Unit of the Ministry of Education for a science specialist to be reserved and assigned to the school on the designated days. It is hoped that with these modifications the program will be successfully implemented.

Scholarship

This journey was a dynamic and interesting one. I learnt a number of meaningful lessons along the way. Having completed this project study, I now have an appreciation for the importance and relevance of the use of baseline data when designing targeted PDP. In this project study, the findings from the data analyzed were essential in informing the structure, content and scope of the PDP that was designed to address the gaps identified in the areas of teachers' SMK and science teaching. Outside of the available findings, a PDP might have been designed that did not address the gaps and weaknesses that were negatively impacting the teaching of science at the Clarke Primary School.

During the process, I was compelled to conduct an exhaustive review of literature. This review of literature informed all aspects of the project study. It was essential as it provided critical information on what other scholars have discovered in my area of interest over time. Also, through the review of literature, I gleaned information regarding the most suitable and trustworthy tools and methods to be used in the data collection and analysis process in light of the local problem that I was investigating. The use of the insights gleaned from the body of scholarly work reviewed contributed significantly to the trustworthiness of this project study.

In order to get this document to the standard that is considered appropriate for publishing, I completed a minimum of 23 drafts. This was a task that was physically, mentally and psychologically draining. However, having seen my professional and personal growth reflected in the many successive drafts over the period, and as I reflect on the many mistakes – methodological and otherwise – that I have made and from which I have learnt, I am certain that the effort was well worth it. As such, I now have an appreciation of the writing process and its importance in scholarly writing.

Parallel to the number of drafts that were necessary for this project study to reach a high standard, was also the requirement to write in order to respond to the varying viewpoints of the different members of the committee. Due to the varying backgrounds, philosophical underpinnings and perspectives of the members of my Research Committee, I was sometimes faced with the challenge of having to respond to contradicting feedback. This aspect of the process was overwhelming. However, my reflections led me to appreciate this as a normal part of scholarly work. Also, I think that going through the rigors of meeting the standards of these varying perspectives has contributed to the trustworthiness of the work. This project study will be published and may become useful to a number of other scholars in different ways; as such, the different perspectives and experiential background of the members of the committee were warranted. Indeed, the process provided the experience that is important in the development of a scholarly writer.

Project Development Leadership and Change

I have had the opportunity of serving my community and country in the area of education for a period exceeding twenty years. During this period I was involved in the development of two major projects that were implemented nationally to enhance the teaching of mathematics. As such, I was able to transfer the skills developed on those project to the development of this project study. It was not difficult to identify the problem to be researched in this project study as the principal and other constituents expressed concerns regarding science content knowledge of the teachers at the school in a frequent manner. However, I faced one major challenge in completing Section One of the project due to the fact that there was a paucity of peer reviewed journals that addressed the matter locally. As a result I had to rely heavily on anecdotal data provided by the stakeholders of the school locally and nationally. This data set enhanced and strengthened the background of this project study.

Data collection was a dynamic aspect of this project study. This was so because when I started the project study I was unknown to all the participants and they were unknown to me. Thus, a purposeful effort was exerted during the period to earn the trust of the participants so they would feel free to communicate with me in an unreserved manner. The researcher-participant relationship that was forged over the data collection period was phenomenal. The participants offered information that was related and unrelated to the topic under investigation, they made themselves available for interviews, they accommodated follow-up meetings when I needed clarity after interview sessions and they responded in a timely manner during the member check activities. I now have a greater understanding and appreciation of the importance of a healthy researcher-participant relationship.

After gathering and analyzing the data, a collaborative approach was used in making a decision regarding the most suitable approach to address the gaps identified in the findings. The design of the PDP was undertaken with guidance provided by the chair of my research committee and also specialists in science education who are currently assigned to the Core Curriculum Unit of the Ministry of Education. This collaborative approach was beneficial as it enhanced the high quality of the project that was developed.

Positive change usually results when different stakeholders are aware of their role and are inspire to play their role well (Sharma & Good, 2013). Schools need strong leaders who can initiate and guide the process of positive change (Furlong, 2013). Teachers are important leaders in the education arena who have great responsibilities (Furlong, 2013; Sharma & Good, 2013). My engagement in this research process has caused me to broaden my perspective of the roles of the different leaders in the education arena and the importance of a collaborative approach in order to bring about positive change.

My experience in conducting this project study has caused me to examine myself as a leader and an advocate of positive social change. When I started this project study, I realized that I would be engaging in data gathering activities that called for many attributes of a good leader such as being trustworthy, objective, understanding, sensitive and creative. Also, I see the need to develop competences such as good oral and written communication skills, listening skills and organizational skills. Importantly, there was a pressing need to be able to work on my own initiative. I must admit that I did not possess all of these skills and attributes of a leader. For example, I had difficulty expressing an understanding of the situation in cases where teachers do not have prepared lesson plans to teach their lessons. However, when the participants of the study communicated to me that they spent many hours unsuccessfully trying to develop lesson plans to teach those science lesson, I saw the need to help these teachers. I think good leader should know when to emphasize and reach out to build professional capacity that may result in positive social change.

Analysis of Self as a Scholar

The term “scholarly writing” was not one that I had given serious thought before I started the project study. However, in order to complete this journey I had to develop the skills of a scholarly writer. During the period I had to analyze numerous pieces of scholarly work that are relevant to my area of study. It was a laborious task to read these articles in an analytical way in order to determine their relevance and appropriateness to the study that I was doing. I also learnt how to examine the context and the setting of the studies conducted in my area of research so that I can accurately compare them to the setting in which I was conducting the study.

As a scholarly writer, it is important to examine study and analyze current and past research studies that are conducted in my area of study. This will help to identify gaps in the body of research and also provide information for making recommendations for further study. Over the period, I have developed as a scholar and I now have a full appreciation and gratitude for scholars who preceded me so I could have their work to validate the work that I have completed. Similarly, I have grown to appreciate the writing process and the need to have experienced scholars review my work and provide feedback for its improvement. I have grown as a scholar throughout the process, as such; I will continue to do scholarly work so that others may benefit from my expertise.

Evaluation of Self as Practitioner

I have always seen myself as a practitioner because of the passion with which I approach my work and the impact I have had in my chosen field on a local and a national scale. I started teaching at the age of 17. Over the years I have inspired my students and fellow colleagues by the demonstration of my desire to learn so that I can continue to make a difference in the educational landscape of Jamaica. Having completed this body of work; I feel the desire to continue to learn and to develop as a practitioner so that I can continue to influence positive social change in this developing country; Jamaica.

Analysis of Self as a Project Developer

It is interesting that I have always seen myself as a practitioner because of the dedicated approach that I take to science education, in general, and the teaching of science, specifically. However, I have never described myself as a project developer even after working on two major projects for the Ministry of Education, Jamaica in the earlier years of my professional career. Nevertheless, after completing this project study, I feel that I have every confidence to describe myself as a project developer. The process was a difficult one which required technical knowledge that I did not have. Thankfully, I had a skillful and experienced support group working with me. This support group was very instrumental in helping me with the design and the content of the sessions in the program, allocation of the resources such as time, the logistics of the sessions and the development of the deliverables as outlined in Appendix A. I am thankful for the experience garnered. I now feel empowered to start the development of a new project and also to help others who may need my expertise in this area.

Reflection on the Importance of the Work

This project study was conducted in order to develop an understanding of the science content knowledge of teacher deployed to the 4-6 grade level at Clarke Primary School. Findings from the study indicated that teachers' hold misconceptions in some areas of science at the grades 4 – 6 level. Additionally, teachers expressed having difficulty writing lesson plans for some topics that they teach and they are of the view that they lack the competence to teach science at the 4 – 6 grade level. This finding led to the development of a PDP that was deemed most suitable in addressing the gaps that were identified.

It is believed that the teachers at Clarke Primary School will improve in the area of science teaching as a result of their participation in the PDP. Additionally, it is expected that students' achievement will improve as a result of teachers' improvement in the area of science. Though, it was designed to addressed teachers' at the 4-6 level, it is hoped that the PDP can be shared with and modified to address similar needs that are found in other schools.

Implications for Social Change, Applications and Directions for Other Research

This project study was conceptualized and developed to bring about social change, locally and nationally. It is hoped that the PDP will enhance and improve the science content knowledge of the teachers at Clarke Primary School. Additionally, the PDP can be modified to address similar gaps in teachers' science content knowledge at other primary schools in Jamaica. It is the belief that when teachers' knowledge of the content in a subject increases there is also an increase in their students' performance (Diamond et al., 2014; Nowicki et al., 2013). As such, it is expected that at Clarke Primary School, the students' performance in GSAT science will increase to exceed 40% in the coming years.

This professional develop program has a comprehensive evaluation plan that is designed to examine the teachers' application of the lessons learnt during the program and the impact the PDP had on students' performance. This evaluation plan can be tailored and used by the MOE to evaluate the impact of PDPs and other initiatives at the national level. The information garnered from these instruments could guide the MOE in providing more targeted PDP which will result in an improved education system and ultimately positive social change.

One recommendation for further research is to investigate in-service teachers' science content knowledge in a large number of schools across a wider section of the Jamaica. I would recommend the use of a mixed method approach in such a study, as this approach could yield a comprehensive data set. The findings from such a study could be used to inform PDPs that could be disseminated nationally. Also, findings from the study could be used to inform and enhance the curriculum and training programs at the teacher training colleges in the country. A similar study could be conducted to assess the science content knowledge of pretrained teachers. Findings from such a study could be used as baseline data when designing programs at the teacher training institutes.

Conclusion

This project study was designed to examine the science content knowledge of the teachers at Grades 4 – 6 at Clarke Primary School. Findings from the study revealed that the participants held misconceptions in some topics taught at Grades 4 – 6. It was also observed that teachers lacked the skills to plan suitable lessons to guide lesson delivery at the grade level assigned. Additionally, the participants believed that they lacked proficiency in teaching science at the grade level assigned. These findings were used to inform the design of a PDP that may address the gaps identified.

Effective implementation of the PDP should result in improved teacher effectiveness. It is hoped that improved teachers' science content knowledge should result in improved students' performance in science. This improvement at the teacher and student level should contribute to positive social change.

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Appendix A: The Project

Day 1 of the ETSESF Professional development Program

Day 1: Building Conceptual Understanding in Science

ETSESF sessions for Day 1 will be held Thursday, October 12, 2017 at the Clarke Primary School.

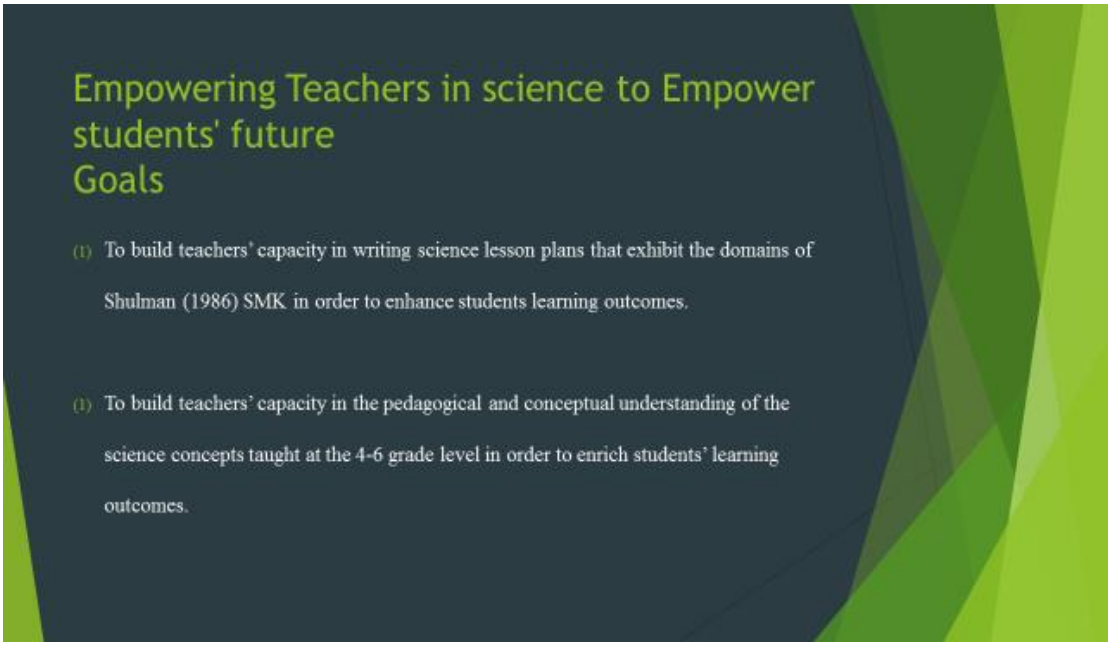
DAY ONE AGENDA

Time	Session	Activities
8:30 – 8: 45	Registration and Devotion	N/A
8:45- 9:00	Welcome and Opening Remarks	N/A
9:00 – 10: 30	Empowering Teachers in Science to Empower Students Future	N/A
10:30 – 10:45	BREAK	
10: 45- 12:15	Science Subject Matter Knowledge: Shulmans (1986) Seven Domains	Participants will complete a work sheet activity to demonstrate their understanding of the different domains of Shulman's (1986) SMK.
12: 15- 1:15	LUNCH	
1:15 -3:15	Addressing Common Misconceptions in Science Topics Taught in Grades 4-6.	(A) Complete activity in groups to develop strategies to address misconceptions that are identified. (B) Discuss and critique strategies that are identified to address misconceptions
3:15- 3:30	EVALUATION AND DISMISSAL	

Day 1: Session One

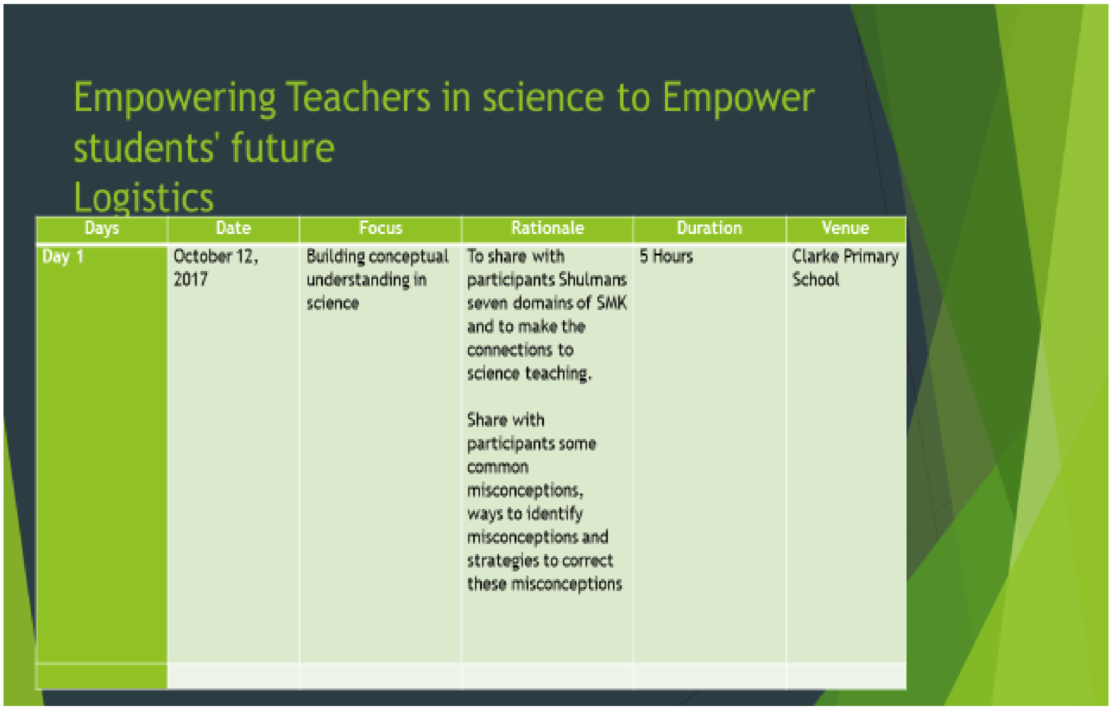
Empowering Teachers in Science to Empower Students Future

The first activity on Day 1 is the presentation to participants which conveys the overview of the ETSESF professional development program. In this presentation, the facilitator will discuss with participants the goals of the professional development program. The following PowerPoint Presentation will be used to guide the session.



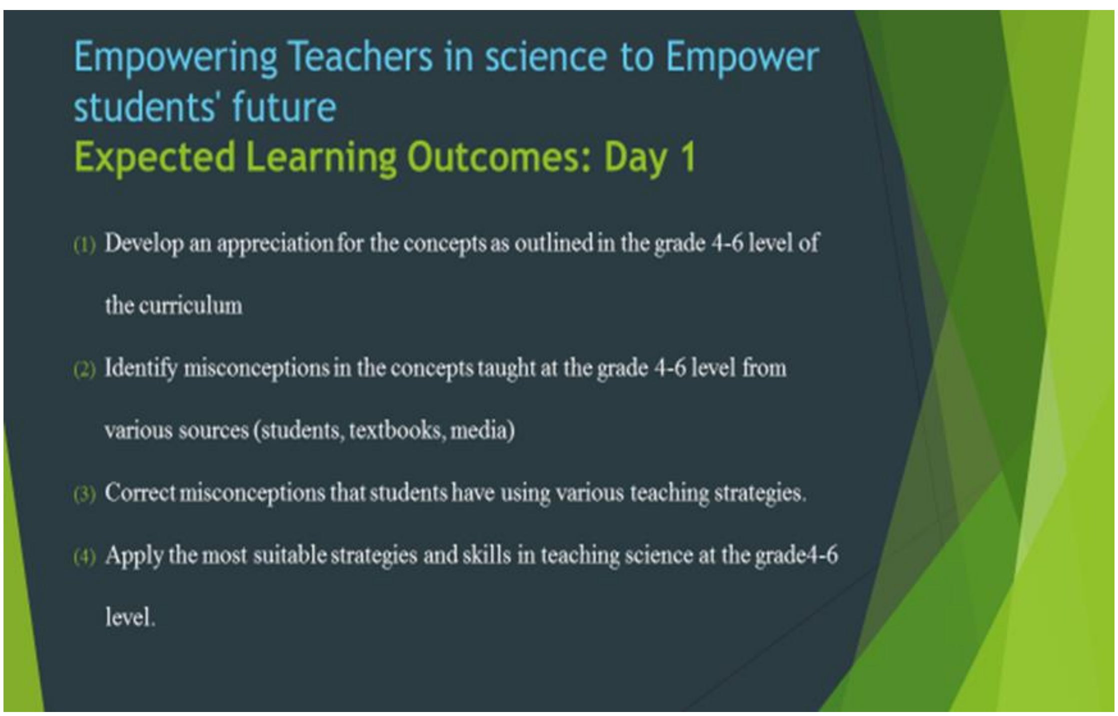
Facilitator: One goal of this professional development program is to build and enhance teachers' ability to write lesson plans that exhibit the domains of Shulman (1986) subject matter knowledge in order to enhance students learning in science. Shulman's subject matter knowledge domains provides a comprehensive approach to subject matter knowledge. Thus, when his domains of subject matter knowledge are highlighted in the lesson planning process students will be exposed to the broad range of subject matter knowledge. The end product of this exposure to a broad subject matter knowledge is improvement in students learning outcome.

Facilitator: The other goal of this professional development program is to build teachers' capacity in pedagogy and concept development in science. When teachers have the capacity to teach and they have a deep understanding of the concepts they are teaching students usually display optimum performance in the subject.



Days	Date	Focus	Rationale	Duration	Venue
Day 1	October 12, 2017	Building conceptual understanding in science	To share with participants Shulmans seven domains of SMK and to make the connections to science teaching. Share with participants some common misconceptions, ways to identify misconceptions and strategies to correct these misconceptions	5 Hours	Clarke Primary School

Facilitator: The program will be executed over 3 days. Day 1 (today) we will be focusing on building teachers conceptual understanding in science. Shulman's seven domains will be explored and we will examine some common misconceptions in science and discuss ways by which they can be identified and corrected.



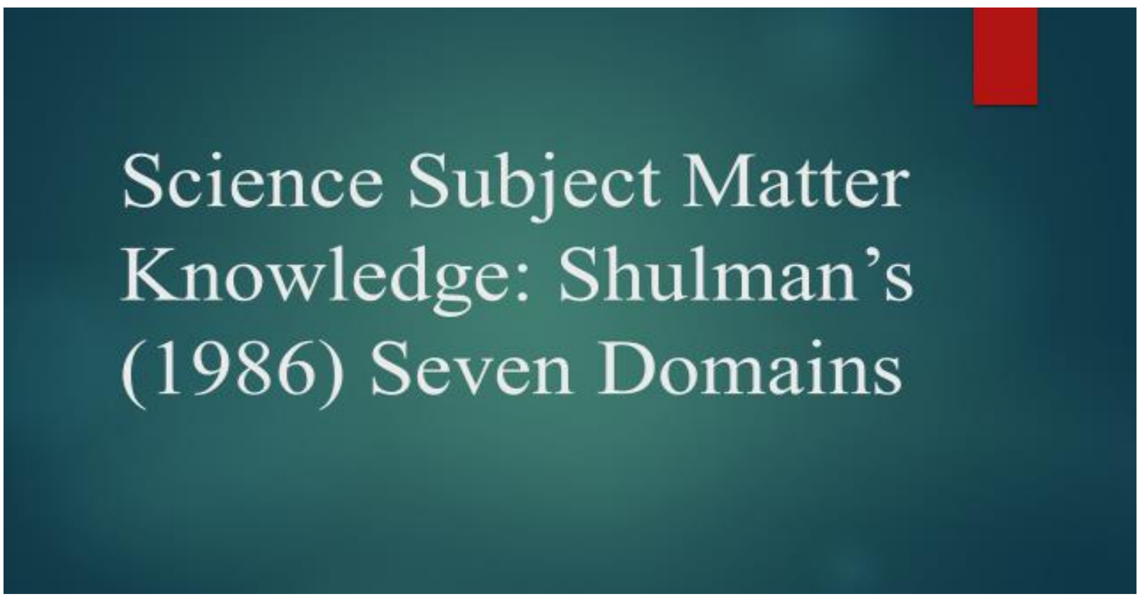
Facilitator: The learning outcomes for today are to:

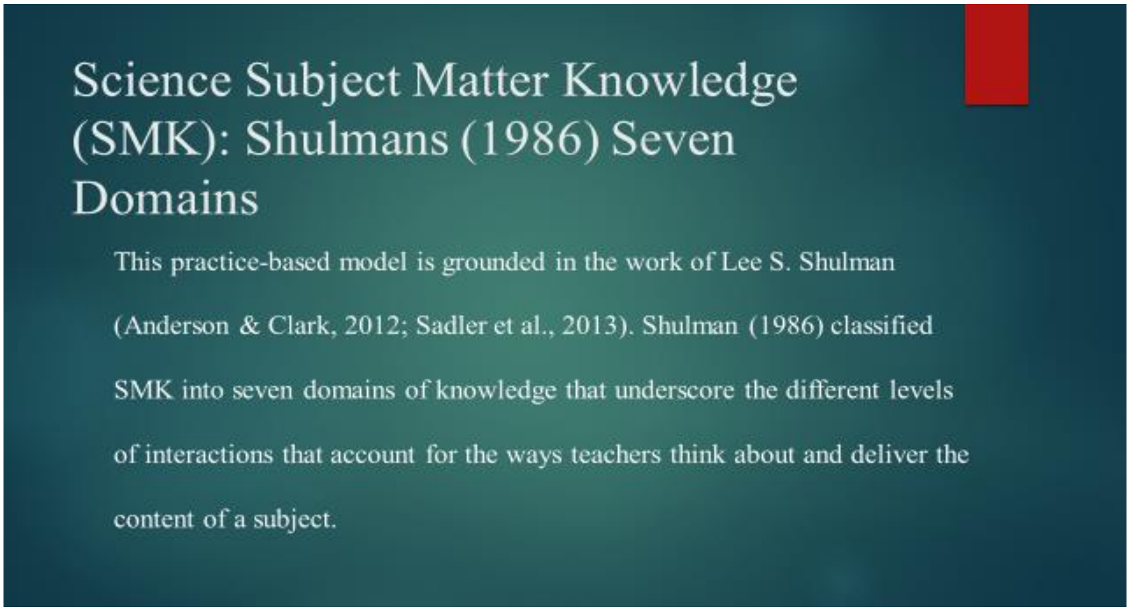
1. Develop an appreciation for the concepts as outlined in the grade 4-6 level of the curriculum
2. Identify misconceptions in the concepts taught at the grade 4-6 level from various sources (students, textbooks, media)
3. Correct misconceptions that students have using various teaching strategies.
4. Apply the most suitable strategies and skills in teaching science at the grade4-6 level.

Day 1: Session 2

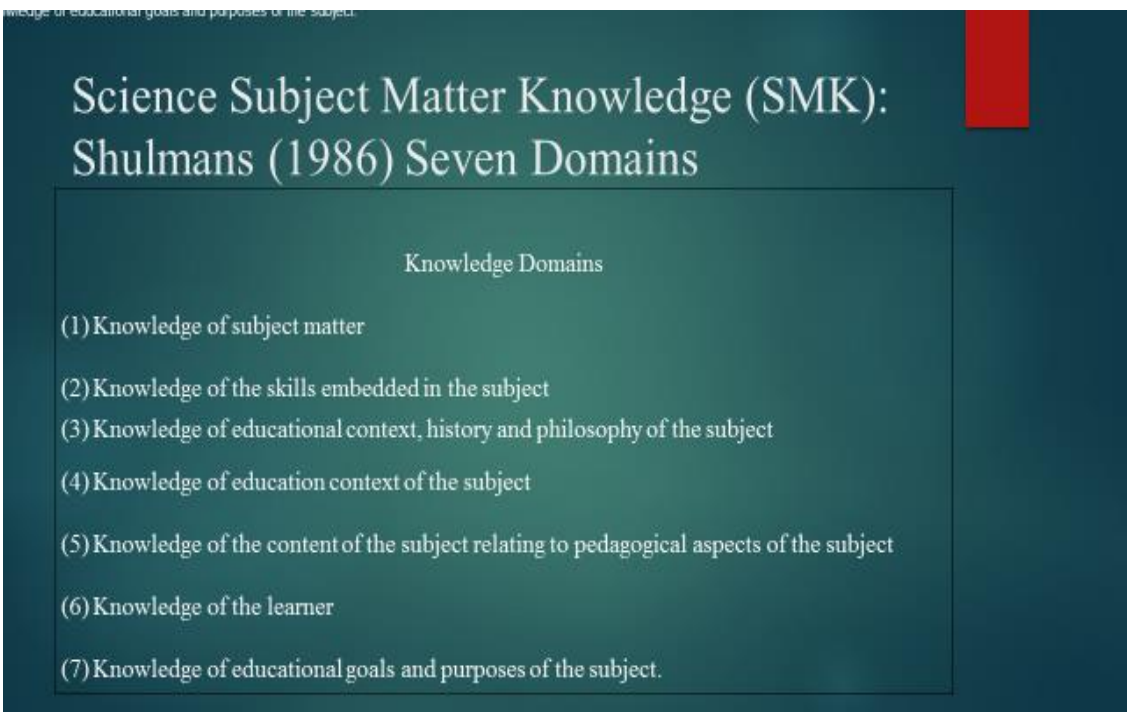
Science Subject Matter Knowledge: Shulmans (1986) Seven Domains

The second session of Day 1 is based on Shulman's (1986) subject matter knowledge. The facilitator will discuss each of the seven domains with participants and in doing so state the applicability to science teaching at the primary level. The following presentation will be used to aid this session of the professional development program.



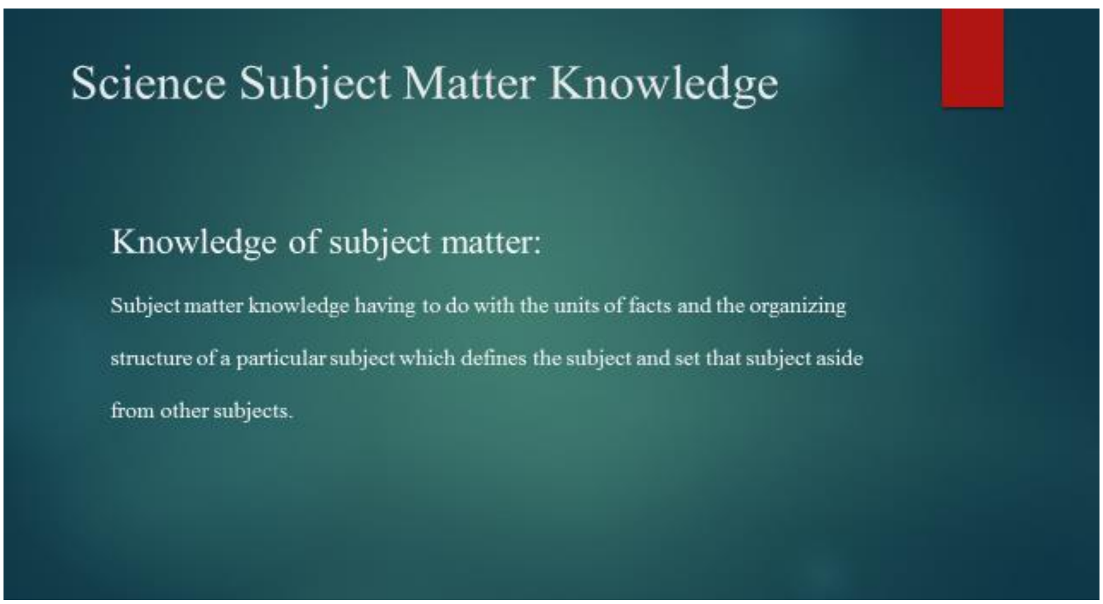


Facilitator: Shulman classified subject knowledge in seven domains that encompasses all aspects of content knowledge. All the domains are considered curtail to the process of lesson planning and lesson delivery in science.

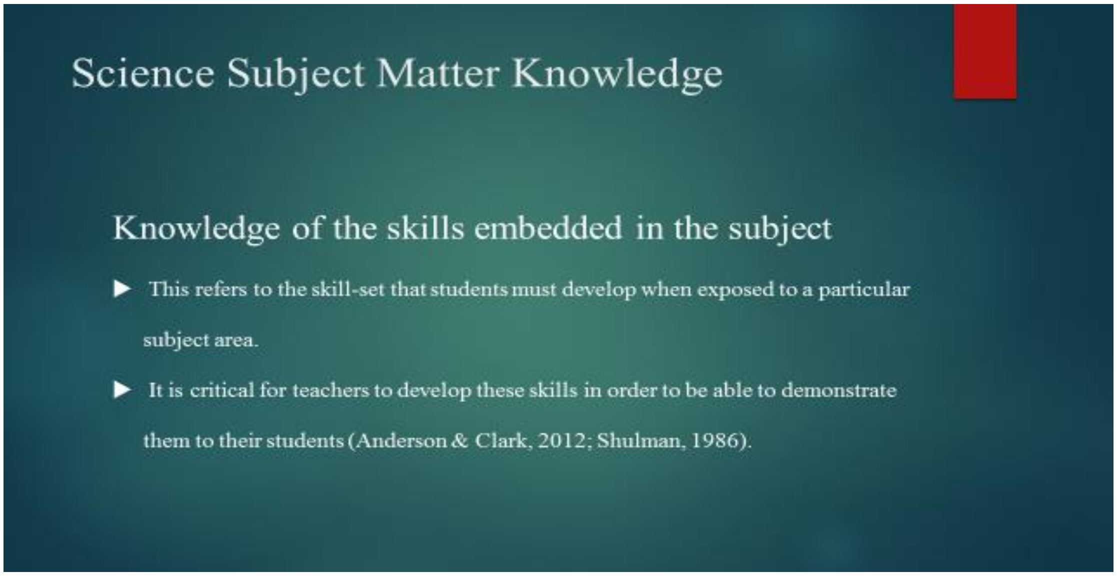


Facilitator: These are the seven domains of Shulman's subject matter knowledge. We will discuss each of these with an emphasis on the implications for science teaching.

These domains encompass all aspects of a subject in any discipline and contributes significantly to teachers' effectiveness. By using this concept, teachers can construct knowledge that is relevant to a subject when they have a chance to engage in discussions and develop strategies to display this knowledge (Hoffman, & Ralph, 2013; Tretter et al., 2013). Thus, this conceptual framework is widely used to guide teacher education in a wide array of subjects inclusive of science, mathematics and modern languages (Anderson & Clark, 2012; Kleickmann et al., 2013). Furthermore, it forms the framework for professional development programs which address areas of content matter relevance, structure and development in science along with other subject areas (Anderson & Clark, 2012; Klu et al 2014).



Facilitator: This domain 'knowledge of the subject matter' are those facts that cause the subject to stand out from other disciplines. As such, technical terms, when used in the subject, usually have specific meanings that are sometimes different from the use of the same term in a general sense. For example, the term 'fruit' when used in science has a technical meaning related to the process of reproduction, while in other settings it can be an important element in the human diet.



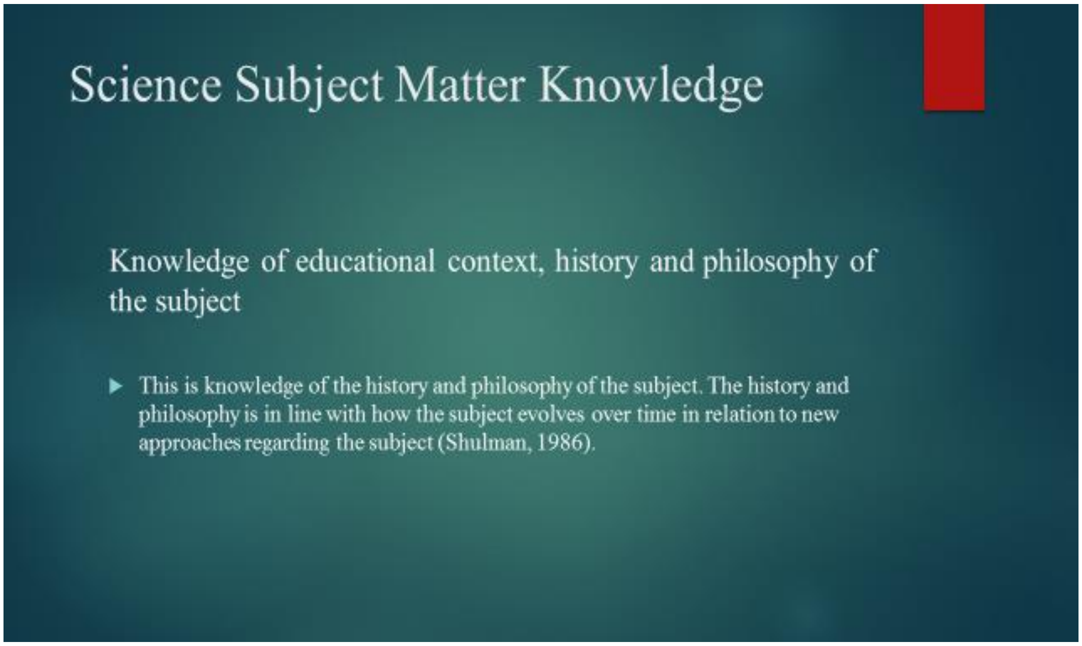
Facilitator: Knowledge of the skills embedded in a subject refers to the skill-set that students must develop when exposed to a particular subject area. It is critical for teachers to develop these skills in order to be able to demonstrate them to their students (Anderson & Clark, 2012; Shulman, 1986). Furthermore, students should be able to demonstrate these skills when necessary so as to provide evidence that they have developed these skills after exposure to the subject matter. For example, measuring is a science skill that students must develop. Therefore students should be engaged in the real practice of measurement in order to demonstrate to their teachers that they have developed this skill.

Facilitator: May you list some skills that our students must develop during science instruction.

Expected Responses: Experimenting, designing experiments, hypothesizing, classifying, extrapolating, inferring, researching, organizing, sequencing, drawing

Facilitator will make a list of the skills as they are suggested by the participants. These will be written on a chart and displayed.

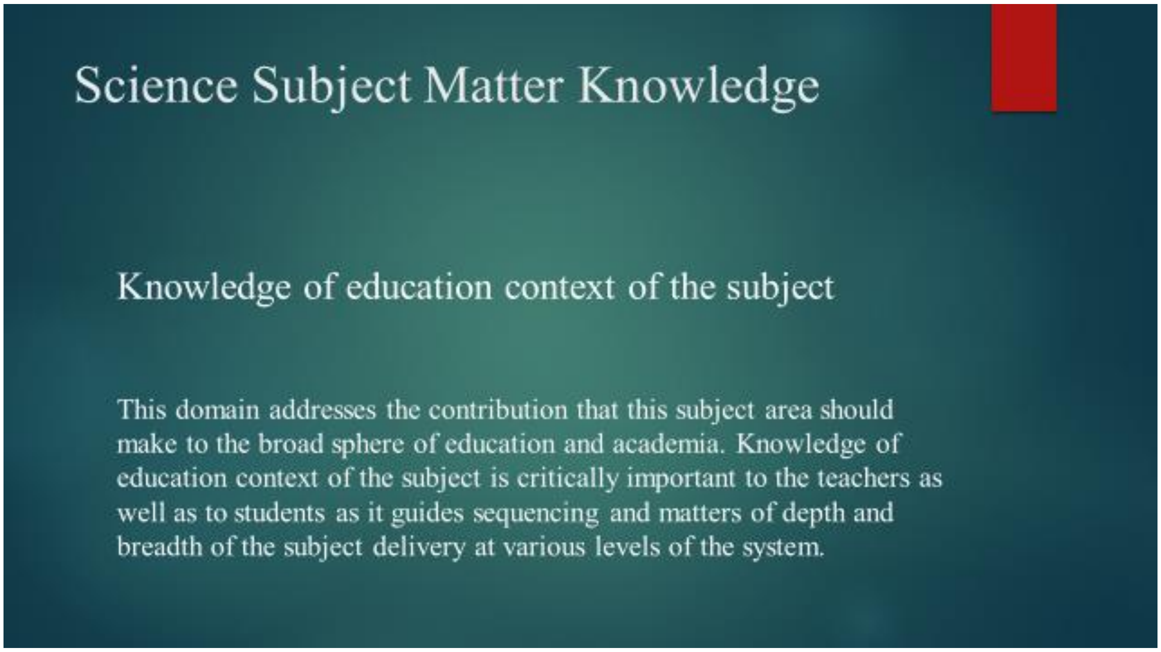
(Participants will make reference to the chart in a later session on lesson plan writing).



Facilitator: The history and philosophy of subject matter knowledge is in line with how the subject evolves over time in relation to new approaches to delivering the subject (Shulman, 1986). This aspect also speaks to knowing and understanding the *why* and the *how* in the body of knowledge (Anderson & Clark, 2012; Kleickmann et al., 2013; Klu et al., 2014). Therefore, when teachers have sound philosophical understandings of a particular subject, they can explain why concepts in the subjects are connected and also state how they are connected in order to provide a holistic viewpoint for students.

Facilitator: For Example a teacher may have a set of students conduct a food test. Having done that food test students can determine the nutrients that are in the food item. They can now make connections to highlight how this food item helps the body. Further connections can be made by determining the deficiency disease that will result if there is a lack of such nutrients in the diet. Further connections can be made by identifying the specific organs that are affected which result in the deficiency disease. Next students can be guided to research the different specialists that may be called on to treat the disease.

The facilitator can use other examples as appropriate.



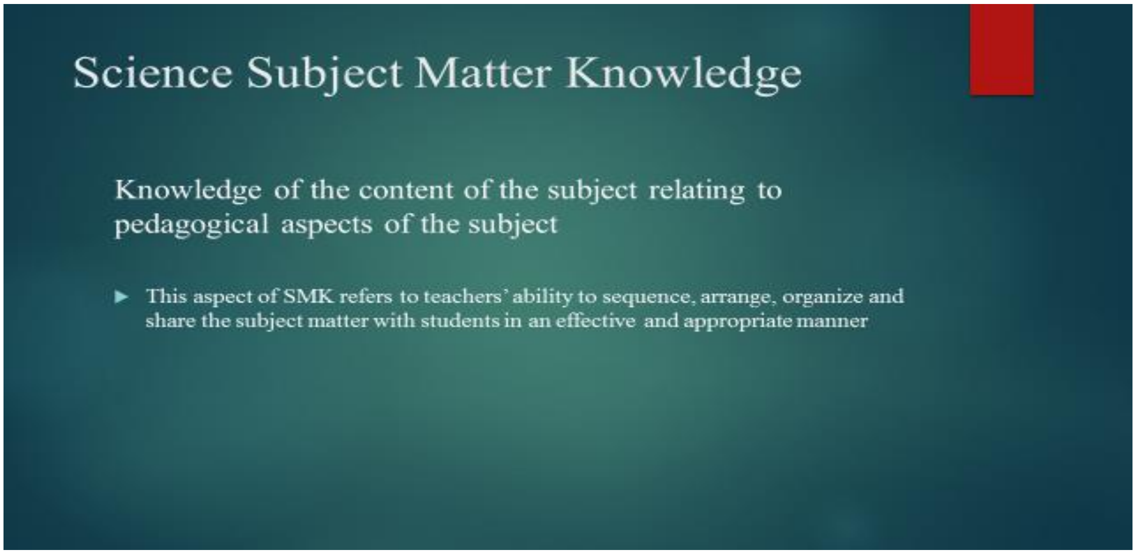
Facilitator: Knowledge of the education context of the subject addresses teachers' ability to spiral and sequence the content of the subject in order to get students to understand the content appropriate to the grade level. A teacher should be able to rationalize for their planning purpose the reason for teaching the concept of *matter* before teaching *heat transfer.*

Facilitator: Can someone explain to the group the rationale for that sequencing?

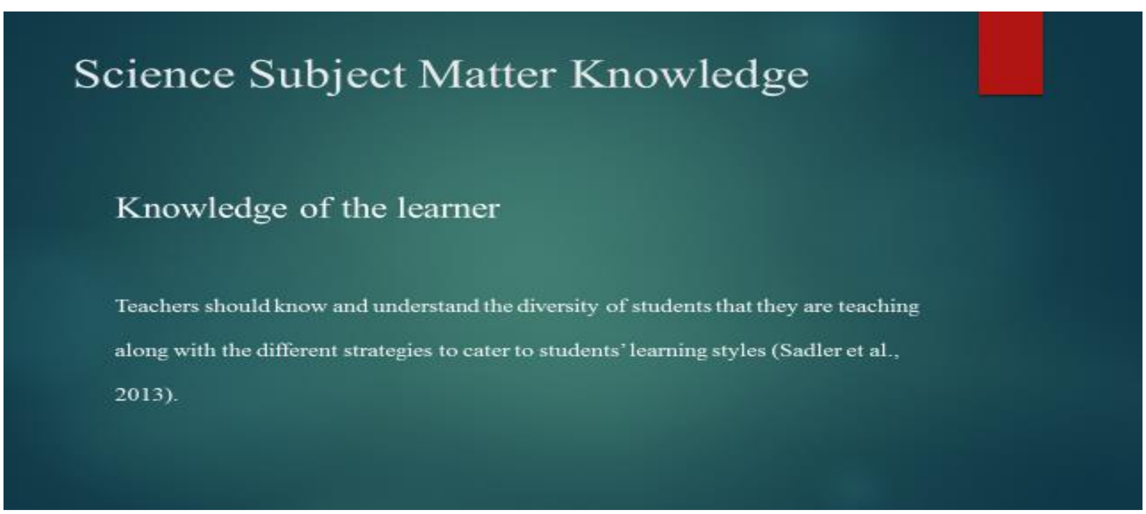
Expected Response: Students must understand the arrangement of the particulate nature of matter before they can conceptualize the different forms of heat transfer. This is because heat transfer in a type of material or fluid is dependent on the arrangement of the particles that make that material. The particles in an iron rod are closely packed thus the method of heat transfer is condition. In liquid the particles have no fixed position so they move about. Thus, the form of heat transfer is conduction.

Facilitator: It would be difficult for students to readily understand conduction if they do not understand the arrangement of the particles in solids.

Other examples can be used to illustrate this point.



Facilitator: Knowledge of the content relating to the pedagogical aspect of the subject also addresses teachers' ability to plan for students learning and also the teachers' ability to assess the outcomes of the learning experiences (Kleickmann et al., 2013; Shulman, 1986). Therefore, in planning for students learning teachers must take into consideration the different skills that must be developed, the different attitude that students need to develop, and the different ways that the students can be engaged so that they understand the concepts. Teachers should also determine how to assess the lesson to determine if the objectives of the lessons were met.

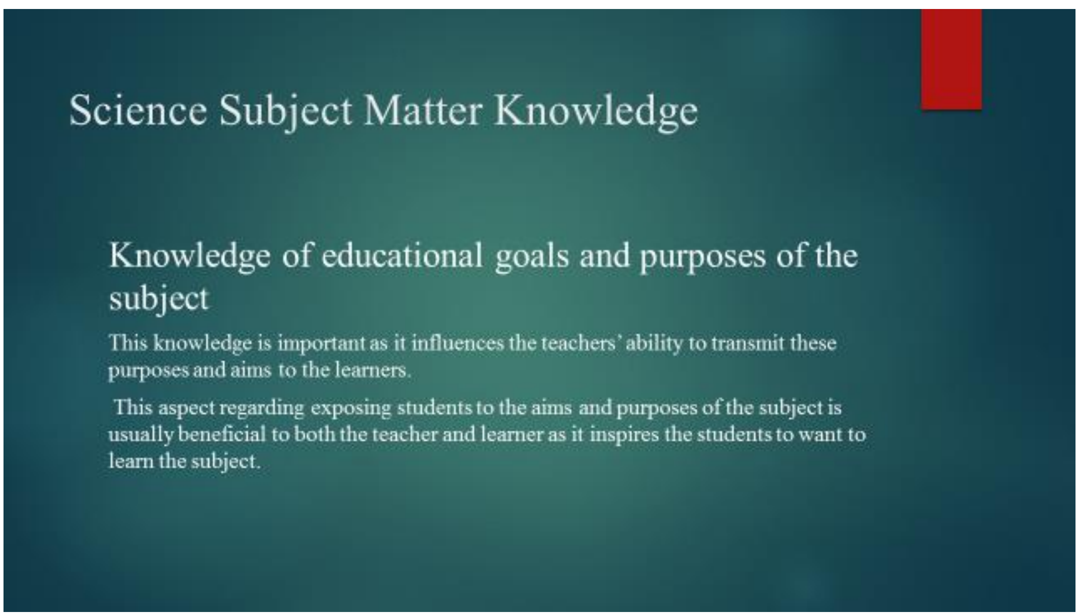


Facilitator: Knowledge of the learner seeks to address how the teacher knows the students so that planning and lesson delivery is appropriate for all the students. As such teachers should know the interest of the students, the different learning styles of the students and students' cognitive level. This knowledge is important so that the lessons and lesson delivery are not inappropriate for the set of students.

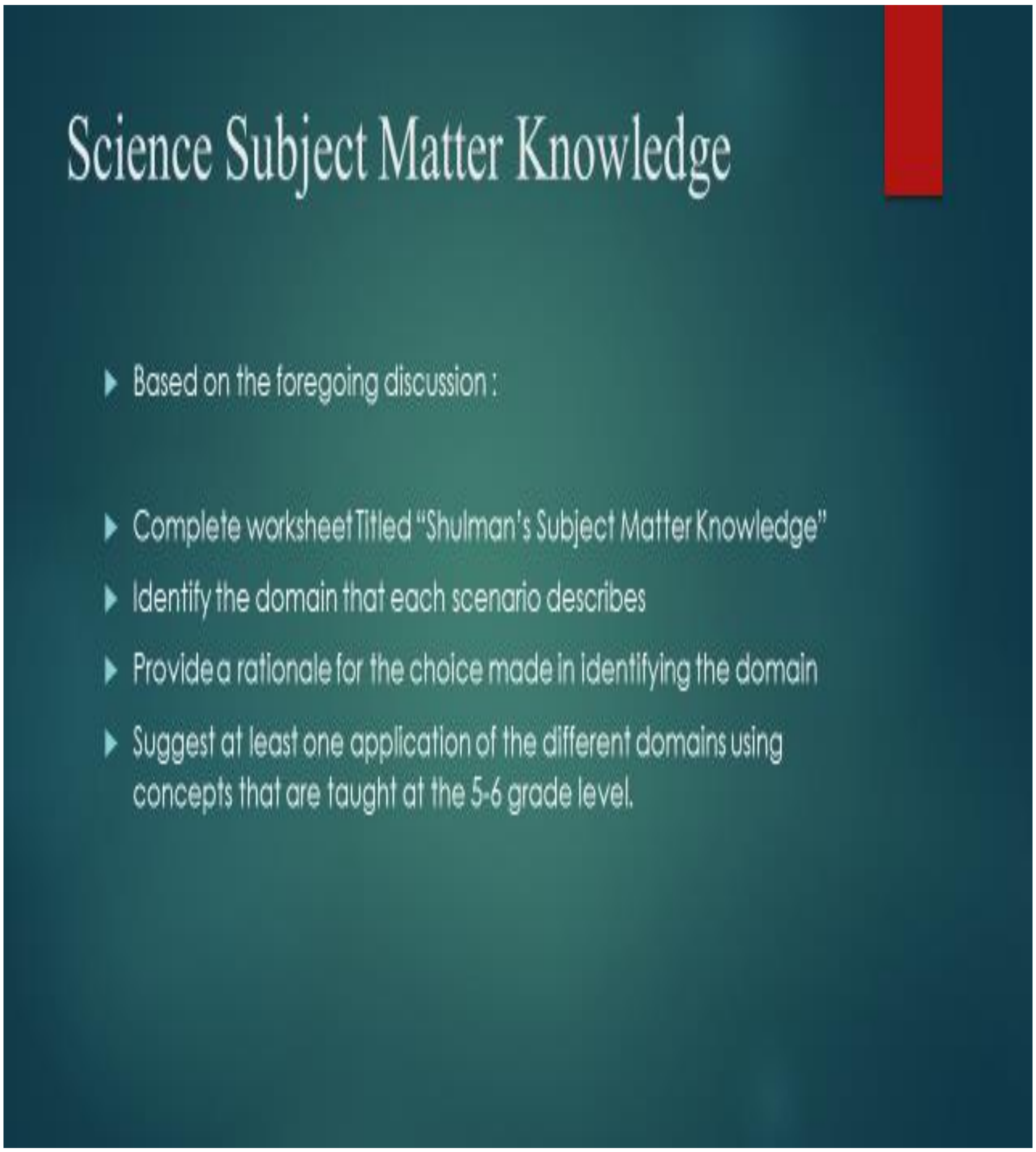
Facilitator: What are implications for learning when a teacher does not have knowledge of the students they are planning lesson for?

Expected Responses:

Students may demonstrate lack of interest in the lesson, students may underperform in the subject area, students may leave the classroom setting with misconceptions, students may develop the feeling of underachievement and there may be an increase in students' absenteeism.



Facilitator: Knowledge of educational goals and purposes of the subject helps the students to connect the concepts they are learning to the applicability in the wider society. This knowledge is important to teachers as they can use the information on the goals and purposes of the subject to inspire students' interest in the subject. A teacher can explain to student while they are studying 'Light and Reflection' the importance of this concept to the areas of arts, theatre, and film creation and the works of opticians. In doing so, students who have an interest in these areas will exert every effort to understand the concept.



Shulman's Subject Matter Knowledge

Instruction: Identify the domain of Shulman's Subject Matter

Knowledge that corresponds with the scenario in Column A

Column A Scenario	Shulman's subject matter knowledge domains	Rationale for selecting the domain
Students are asked to measure the temperature inside and outside the classroom		
Students complete activities on the benefits of learning about the sense organs		
Teacher provides explanation to students as to the reason human beings are classified as animals.		
In a lesson on plant reproduction teacher assess students by having students draw a diagram of a flowering plant		
Teachers have boys in class design article to float in air and have girls write an article to describe the designs		
Teacher have students conduct further research to determine how to correct protein deficiency protein in the diet of a strict vegetarian		
Teachers have students compare the human arm with a simple machine		

Response to Participants worksheet

Shulman's Subject Matter Knowledge

Instruction: Identify the domain of Shulman's Subject Matter

Knowledge that corresponds with the scenario in Column A

Column A Scenario	Shulman's Subject Matter Knowledge Domains	Rationale for selecting the Domain
Students are asked to measure the temperature inside and outside the classroom	Knowledge of the skills embedded in the subject	Knowledge of the skills embedded in a subject refers to the skill-set that students must develop when exposed to a particular subject area
Students complete activities on the benefits of learning about the sense organs	Knowledge of educational goals and purposes of the subject	This helps the students to connect the concepts they are learning to the applicability in the wider society
Teacher provides explanation to students as to the reason human beings are classified as animals.	Knowledge of subject matter	Those facts that cause the subject to stand out from other disciplines. As such, technical terms, when used in the subject, usually have specific meanings that are sometimes different from the use of the same term in a general sense
In a lesson on plant reproduction teacher assess students by having students draw a diagram of a flowering plant	Knowledge of the broad content base of the subject relating to pedagogical aspects of the subject	Aspect of the subject which addresses teachers' ability to plan for students learning and also the teachers' ability to assess the outcomes of the learning experiences.
Teachers have boys in class design article to float in air and have girls write an article to describe the designs	Knowledge of the learner	This address how the teacher knows the students so that planning and lesson delivery is appropriate for all the students.
Teacher have students conduct further research to determine how to correct protein deficiency protein in the diet of a strict vegetarian	Knowledge of education context of the subject .	spiral and sequence the content of the subject in order to get students to understand the content appropriate to the grade level
Teachers have students compare the human arm with a simple machine	Knowledge of educational context, history and philosophy of the subject	This shows how concepts are connected in order to provide a holistic viewpoint for students

Facilitator will divide participants in groups of three to complete the attached worksheet. This activity will last for 45 minutes. After completing this worksheet, each group will discuss their findings with the whole group. Facilitator will guide a discussion based on the presentations by the different groups.

Facilitator: In groups you will discuss the scenarios in "Column A" of your worksheet and decide on which of the seven domains of Shulman's SMK it is depicting. Having done so provide a rationale for the choice that the group made. Each group should show the application of a domain using a concept that is taught at the 4-6 grade level. You have 25 minutes to complete the task. Following the completion of the worksheet each group will be allowed to discuss the findings with the other participants for critique and comparison of rationale with that of other groups.

Day One: Session Three

The facilitator will display chart with common misconceptions and engage participants in a discussion to define the term misconceptions. Participants will be allowed to discuss freely their understanding of the term. The group will discuss each of the misconceptions on the chart stating how they can be identified and strategies that can be used to correct them.

Facilitator: What are misconceptions?

Expected responses: Misconceptions are alternative understandings about concepts and phenomena that learners have formed, or scientifically incorrect interpretations that learners believe (McConnell et al., 2013; Nowicki et al., 2013).

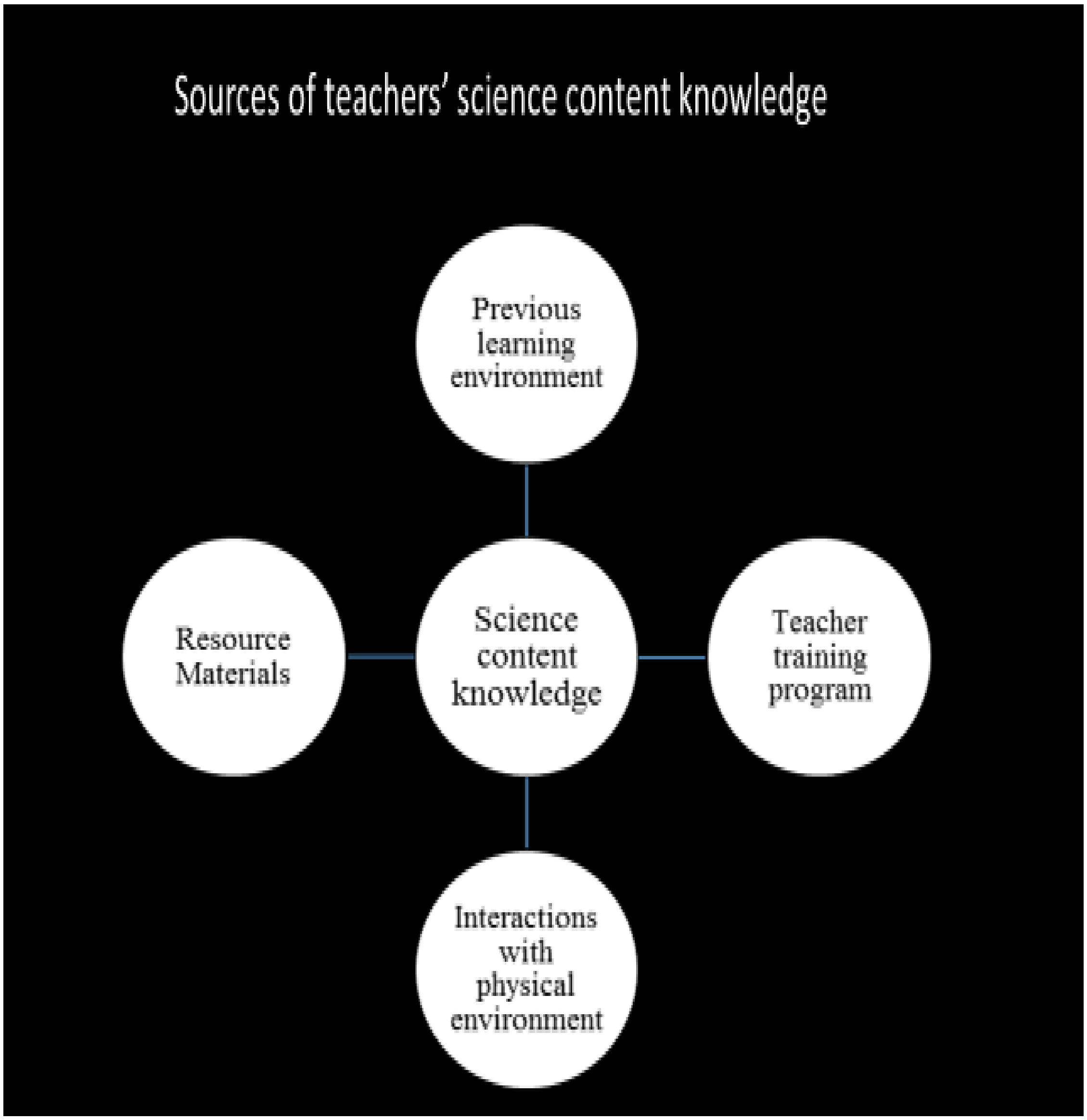
Facilitator: Now let us examine this chart captioned "Common Misconceptions at the Primary Level" we will discuss each misconception and state how each can be identified and how each can be corrected. Additionally, you can discuss with the group misconceptions that you have encountered or that you had, so we can add it to this list.

Common Misconceptions at the Primary School Level

1) Water is the food that plants feed on to grow.
2) Birds, insects and humans are not animals.
3) Ejected and undigested materials are considered and listed as products of excretion.
4) All plants used for ornamental purposes are flowers.
5) A fruit is considered to be such only if it is edible by human beings.
6) The terms mass and weight have the same meaning and can be used interchangeably.
7) Work is done once energy is used up in a process even in cases where no distance is moved
8) The sun cannot be considered a star because of its size.
9) Water on the outside of a container of ice is as a result of the water inside seeping out through microscopic holes in the material that makes the container.
10) The end of a metal rod that is away from a heat source will eventually get hot because the particles that are at the end closer to the heat moves away from the heat source.
11) Plants make food only in the light reaction phase of photosynthesis. Plants rest in the dark reaction phase.
12) Breathing and respiration are the same hence the terms can be used interchangeable.
13) Plants breath in carbon dioxide and breath out oxygen
14) Animals inhale oxygen and exhale carbon dioxide
15) All blood vessels are veins

Facilitator will display chart showing some possible sources of misconceptions. The group will discuss the ramifications of the practices that may unknowingly create misconceptions during lesson delivery and other interactions with students.

Facilitator: In light of the misconceptions discussed let us now examine some possible sources of misconceptions as outlined on this chart.



Facilitator: Having examined theses sources of misconceptions is there any other that you would add?

Additional responses from participants will be added to the chart.

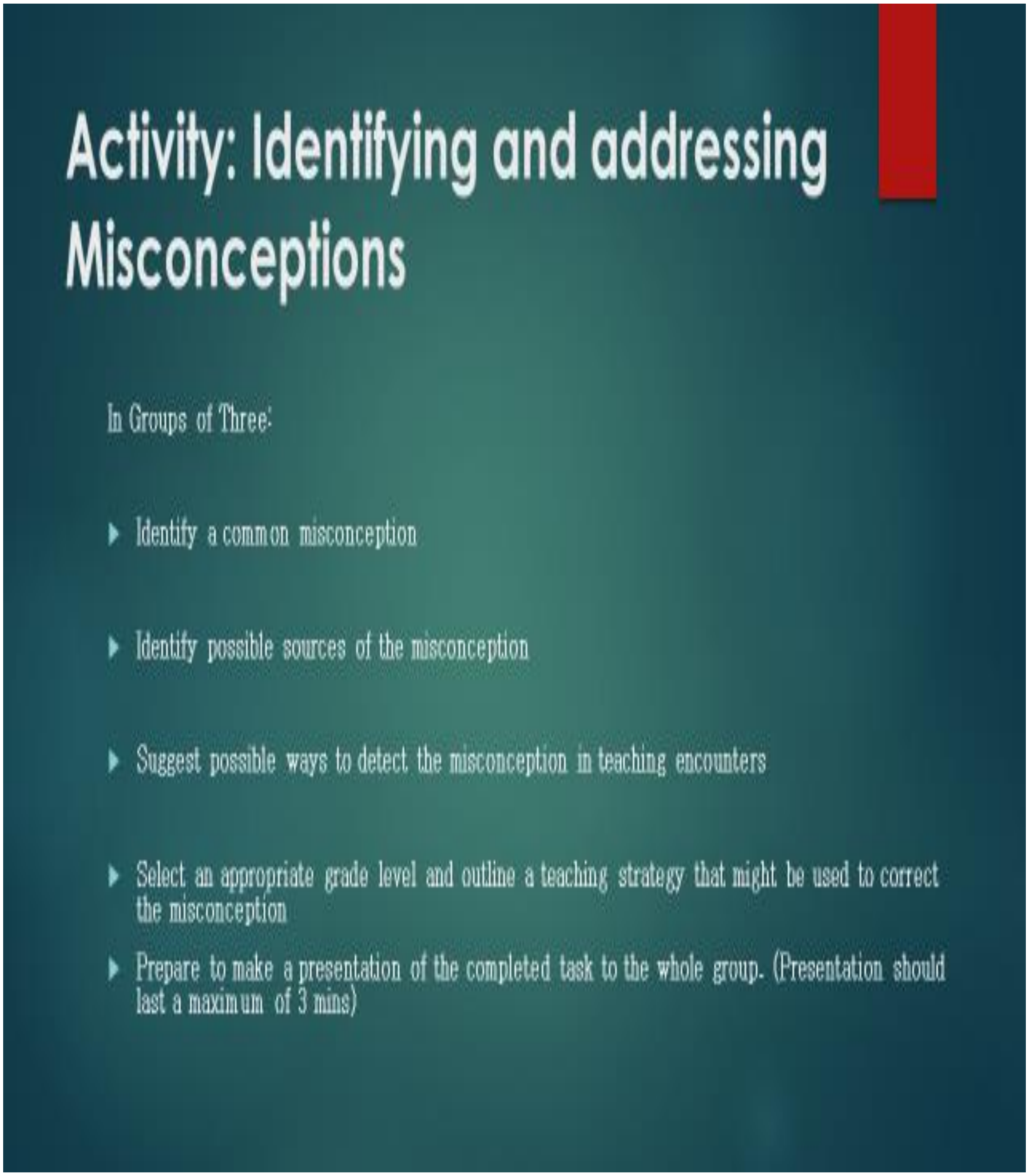
Participants will receive a copy of the charts with the common misconceptions and the possible sources of misconceptions.

Facilitator will distribute the activity sheet to each group along with a sheet of blank display paper and markers. The facilitator will then discuss the activity sheet with participants and state the duration of time within which to complete the activity. This activity should last 30 mins.

Facilitator: Having discussed some common misconceptions found at the primary level and along with the sources of the misconceptions in you groups you will choose a common misconception; this can be listed on the chart or it could be one that your group identified. You will then identify possible sources of the misconception. For example; if you choose the misconception “water is the food for plants” possible source of this misconception would be students’ interaction with the physical environment. They may have observed a wilting plant regained turgidity after it was watered and so they came to that conclusion. Having recorded the source of misconception you will then discuss ways by the misconception can be identified. Having done so you will determine a teaching strategy the correct the misconception. Let us look at this example sheet.

Facilitator will display the completed example sheet and discuss the example with the participants.

Facilitator: Each group will be asked to display and make a presentation on the work of the group. At the end of the presentation the other participants will ask questions and make suggests for improvement where necessary. We have 30 minutes to complete this task.


Activity: Identifying and addressing Misconceptions
In Groups of Three:
Identify a common misconception
Identify possible sources of the misconception
Suggest possible ways to detect the misconception in teaching encounters
Select an appropriate grade level and outline a teaching strategy that might be used to correct the misconception
Prepare to make a presentation of the completed task to the whole group. (Presentation should last a maximum of 3 mins)

Identifying and Correcting Common Misconceptions in Science

Common Misconception	Possible sources of misconception	Possible ways to detect this misconception	Teaching strategy to correct misconception

Response Example

Identifying and Correcting Common Misconceptions in Science

Common Misconception	Possible sources of misconception	Possible ways to detect misconceptions	Teaching strategy to correct misconception
Example: Water is the food that plants feed on to grow.	Students' interaction with the physical environment. Students may observe a wilting plan regained turgidity after it was watered.	Teacher can place a wilting plan in a container with water and have students observe plant for a period. After students observation teacher can pose direct questions to students: What do you think happen to the plant for it to look turgid again? Do you think the water helped the plan? How did the water help the plant?	Teacher may have students observe plants that are exposed to different conditions such as One plant may receive water but receive no sunlight; one plant placed in a transparent plastic bag, receive water and placed in the sun. Students will make a note of their observation over a week period. Students may observe that the plants will die after the observation period even though they were receiving water. Through guided discussion teacher will help students to come to realize that other elements are needed to provide nourishment for the plant.

Evaluation Activity

Evaluation for Professional Development Session - Day One

Date: ____

Select the number which best indicates your views on the session.

SA- Strongly Agree, A- Agree, U Undecided, D Disagree, SD Strongly Disagree

		SA	A	U	D	SD
1	The objectives outlined in the session responded to your training needs.	4	3	2	1	0
2	The information received was clearly outlined and easy to follow.	4	3	2	1	0
3	The materials used were relevant.	4	3	2	1	0
4	The materials incorporated in the training sessions were and effectively used	4	3	2	1	0
5	The time allotted to the session was sufficient for exploration of the concepts explored.	4	3	2	1	0
6	You are satisfied with the overall training experience	4	3	2	1	0

How has the professional development session enabled you in becoming better at your duties as a teacher of science?

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What recommendations would you make regarding the professional development sessions in helping teachers develop further mastery of science content?

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Day 2 of the ETSESF Professional development Program

Day 2: Strategic planning for optimum students learning outcomes in science.

ETSESF Day 2 will be held Tuesday March 13, 2018 at the Clarke Primary School Day Two

Day 2 Agenda

Time	**Session**	**Activities**
8:30-8:45	Registration and Devotion	N/A
8:45-9:00	Welcome and Opening Remarks	N/A
9:00- 10:00	Lesson Planning: The Importance of Alignment and Sound SMK	N/A
10:00-10:15	BREAK	
10:15-11:30	Lesson Plan Critique: Spotting the Prototype	Participants will use a lesson plan checklist to assess lesson plans in a group setting.
11:30- 12:30	LUNCH	
12:30-2:00	Lesson Plan Development, Alignment and Content	Participants will develop science lesson plan using the lesson plan checklist and Shulman SMK
2:00-3:15	Presentation of Lesson Plans Developed	Participants will present lesson plans developed to the groups of participants for the purpose of analysis, critique and feedback.
3:15-3:30	EVALUATION AND DISMISSAL	

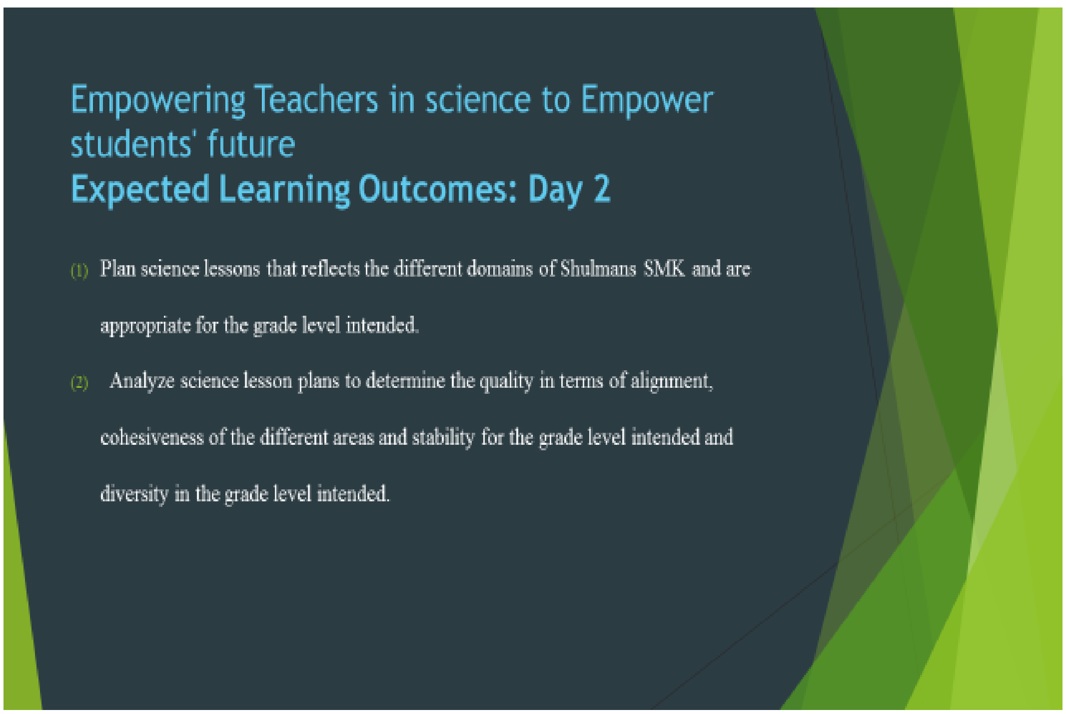
Day 2: Session One

Lesson Planning: The Importance of Alignment and Sound SMK

Facilitator will present to the participants the learning outcomes for the day.

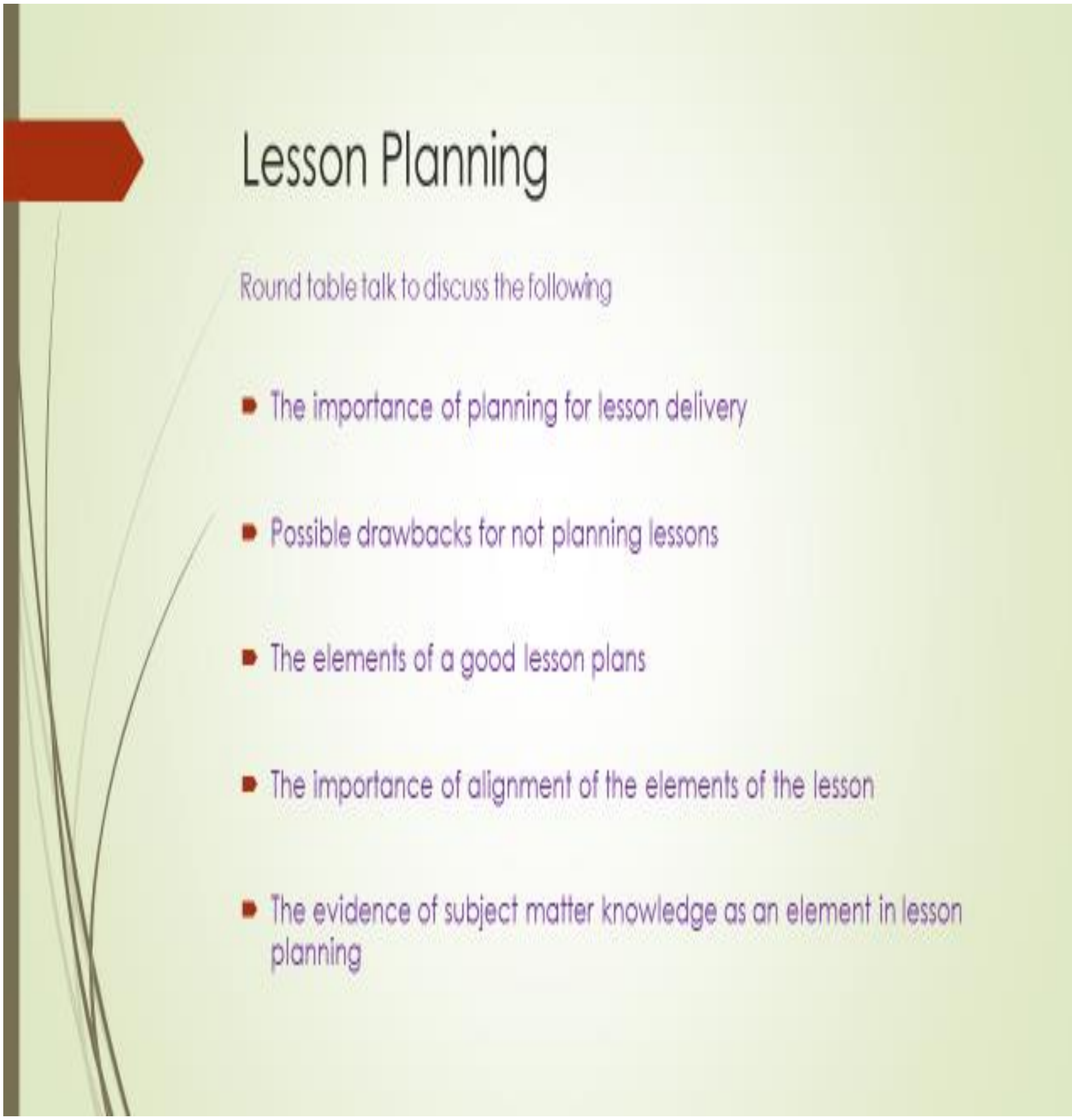
Facilitator: The expected learning outcomes for today are: 1) plan science lessons that reflect the different domains of Shulmans SMK and are appropriate for the grade level intended.

2) Analyze science lesson plans to determine the quality in terms of alignment, cohesiveness of the different areas and stability for the grade level intended and diversity in the grade level intended.



Following the expected learning outcomes, the facilitator will organize the participants in groups to discuss the following areas under the broad topic lesson planning. With the use of flip charts, markers and scissors each group will create a design for display. Each group will discuss and respond to the topics on the chart listed below. This activity will last for 45mins.

Facilitator: Participants in your groups you will discuss and make notes regarding the following: the importance of planning for lesson delivery, possible drawbacks for not planning lessons, elements of a good lesson plans, the importance of alignment of the elements of a lesson, the evidence of subject matter knowledge as an element in the lesson. You have 20 mins to complete this task.



Expected Response:

Importance of planning lessons: Lesson plans provide smooth flow for transition in the lesson, lesson planning process provides the avenue for teacher to conduct research on the topic and lesson planning provides the environment for collaboration amongst colleagues. Lesson planning also presents an opportunity for the teacher to cater for the different learners in the class.

Failure to plan: Failure to plan may result in poor lesson delivery, inappropriate activities employed in lesson delivery, disjointedness in lesson flow.

Elements of a good lesson: Elements of a good lesson include: clearly written objectives, researched content, appropriate activities that are aligned to objectives, skills to be developed are embedded in the activities of the lesson, lesson plan facilitates a variety of learning styles and abilities, assessment activities are appropriate and evidence of the different subject matter knowledge are embedded in the plan.

Importance of alignment of the elements of a lesson plan: The opportunity is created to measure the objectives of the lesson, activities are appropriate for the learning needs, assessment is designed to measure objectives of the lesson and learning is facilitated.

Each group will mount their design and present to the whole group their response to the item on the chart. The facilitator will guide the discussion so that the salient points regarding lesson planning are highlighted.

This aspect of the session should last for 45 mins. The mounted displays will form a montage under the broad topic: Lesson Planning.

Day 2: Session Two

Lesson Plan Critique: Spotting the Prototype

Each group will be given a science lesson plan and a lesson plan checklist. The members in the group will analyse the lesson plan based on the criteria on the lesson plan checklist. Each group will assign a rating level to the lesson plan that is critiqued. This activity should last for 45 mins.

Sample Lesson Plan

Subject: Science

Unit Title: Sense Organs (Eye and Ears)

Focus Question: How do materials affect the behaviour of light and sound?

Attainment Target: recognize that the property of the materials an object is made of affects how light and sounds and transmitted through it.

Objectives: students should be able to:

1. State the relationship between light and the eye.
2. Distinguish between objects that are luminous non-luminous
3. List some luminous and illuminated objects
4. Infer that light travels in straight line
5. Demonstrate the behaviour of light with selected material dull/ shiny/ transparent

Key Vocabulary/ Concepts: light sources, luminous, illuminated, transparent, translucent, opaque, refraction reflection.

Activities: Students will:

1. Be asked to state the association between light and the eyes based on previous knowledge.
2. Be involved in various activities to confirm answers given in Activity 1. The activities done will be discussed thoroughly and the importance of light will be highlighted.
3. Talk freely about where they think light come from
4. Carry out an activity that will allow them to classify light sources as being either luminous or non-luminous and state the definition of same.
5. Say whether they think the sun is a luminous or illuminated object. Students will observe and listen carefully as teacher explains (with the aid of diagram) why the sun is considered to be a luminous object and why the earth is illuminated.

6. Work in their groups to identify five objects that are non-luminous. Students will discuss their work with class. Corrections will be given where necessary. From answers given teacher will construct a table on the board to reflect same.
7. Read additional information from text about what was look at in previous activity.
8. Carry out simple investigations to prove that light travels in a straight line
9. In small groups, using different objects made from three different materials, investigate how the properties of materials affect light by focusing a light on each object, using the same light source.
10. Read information from text about the investigation done in previous activities. Based on reading done students will classify objects used as being transparent, translucent or opaque. They will then take note regarding same.

Assessment:

Students will write a paragraph to explain the connection between light and the eye.

Lesson evaluation

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Facilitator: Now that we have examined the elements of lesson plans and the importance of alignment we will now conduct reviews of some lesson plans. You will use the checklist provided to guide the review process. Each group will present the findings to the other participants and give a rationale for assigning the particular grade. The rating levels to be used are: poor, good, excellent. Other participants can challenge or support the rating based on the justifications and rationale given. This activity should last for 45 mins.

Lesson Plan Checklist

ITEM	EXPLANATION	Rating
Evidence of Data Driving Instruction & in Evaluation	Reference to at least one established data set from internal or external assessment e.g. External: GSAT Internal: Mid Term Test, End of Unit Test	
Appropriateness of Objectives	Appropriateness to age, class, grade, domains, scope and sequence, etc.	
Objectives written provide a clear focus on instructional outcome	The objective is measurable and evidence can be generated to determine if objectives are met.	
Content of the lesson is researched and outlined	Lesson plan has a summary of content that is accurate.	
Content Appropriate	Adequate, age, content, topic,	
The different domains of Subject Matter Knowledge are observed in the lesson plan	The different component of the lesson has evidence of the different domains of subject matter knowledge	
Lesson plan is written to accommodate different learning styles/needs	Different learning styles Visual/ auditory/tactile learners are catered for.	
Learning Activities Appropriate	Appropriate for age, objectives, content, learning needs, (data/Assessment)	
Methodology Appropriate	Appropriate to age, objective, content,	
Assessment activities appropriate	Assessment activities are aligned to the lesson objects	
A variety of assessment is used to measure students achievement of the stated objectives	Students are provided with a number of stimuli that can allow for teachers to determine if objectives are met.	
Accommodations & Evidence of Differentiated Instruction	Are low performing, high performing and average students catered for? Are multiple intelligences catered for? Are physically challenged students catered for? Are children who learn at different paces and in different	

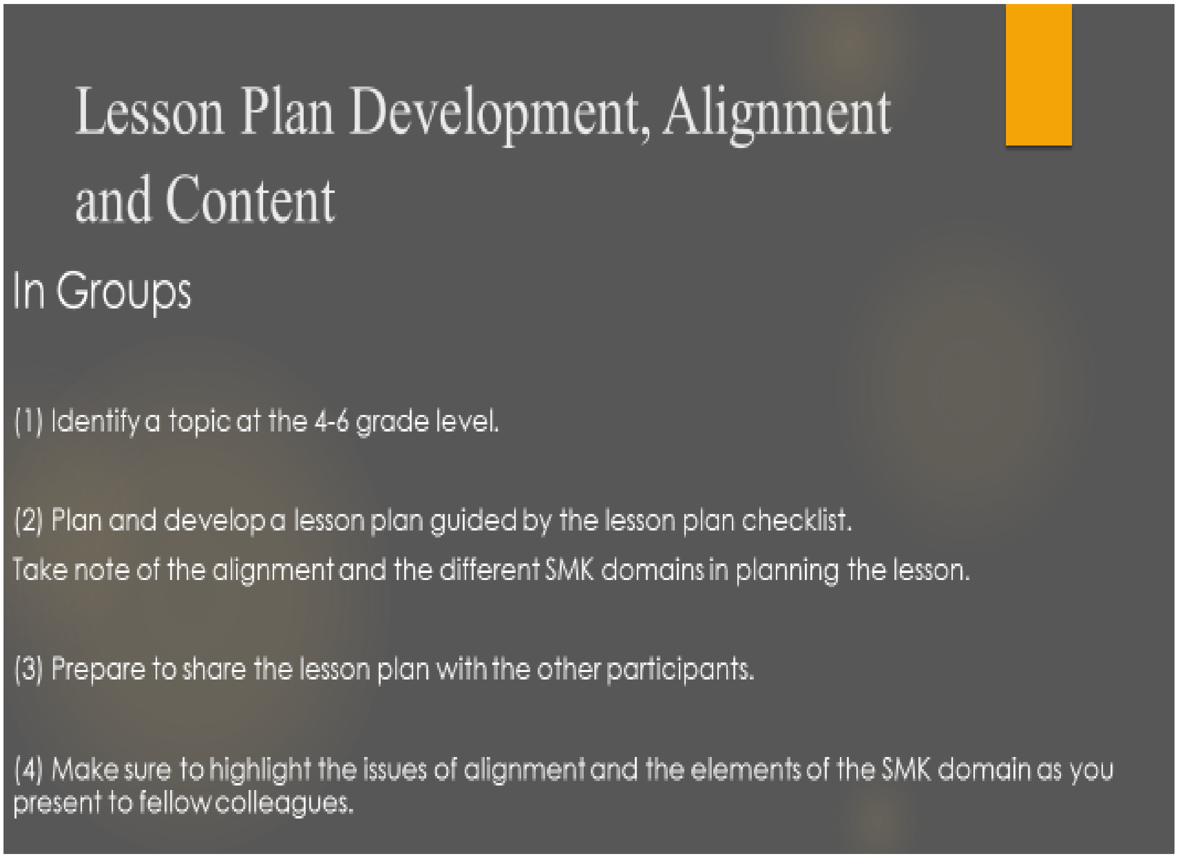
	ways catered for? Is each gender catered for? These should be evident in the activities, assessment and homework sections of the lesson.	

Day 2: Session Three

Lesson Plan Development, Alignment and Content

In this session the participants will develop a lesson plan using the strategies that were discussed in the previous session.

Facilitator: Teachers now that we have reviewed the lesson plans you are now required to write a lesson plan. As such in groups you will be engaged in designing and the development of the lesson plan. Each group will design a lesson plan using a topic that is covered at the 4-6 grade level. You will use the lesson plan checklist as a guide in the development of the lesson plan. Also, the elements of alignment of the lesson objectives, the lesson activities, skills to be developed and assessment activities will be highlighted in each lesson plan. You have one hour to develop this lesson plan.



Day 2: Session Four

In this session, each group will make a presentation of the lesson developed. The members in the whole group will give commendation; make comments and recommendations as needed at the end of each presentation. The facilitator will guide the discussions so that the elements of alignment and subject matter knowledge are highlighted. This session should last for one hour.

Facilitator: Now that we have completed the designing and development of the lesson plan you will now present the developed lesson to the group. In sharing the lesson you will outline the topic that the group has chosen, the objectives to be achieved in the lesson, the skills to be developed, content knowledge that is relevant and critical to the topic, the assessment activity for the lesson. Other participants will listen and ask questions regarding elements of the lesson that may be omitted or may not be properly developed.

Evaluation Activity

Evaluation for Professional Development Session - Day 2

Date: ____

Select the number which best indicates your views on the session.

SA- Strongly Agree, A- Agree, U Undecided, D Disagree, SD Strongly Disagree

		SA	A	U	D	SD
1	The objectives outlined in the session responded to your training needs.	4	3	2	1	0
2	The information received was clearly outlined and coherent.	4	3	2	1	0
3	You are more confident in writing lesson plans which demonstrate correct sequential approach towards delivery of the curriculum.	4	3	2	1	0
4	The session was adjusted based on cues and questions from participants to assure understanding of topics and objectives.	4	3	2	1	0
5	The time allotted to the session was sufficient for a thorough critique of the lesson plans.	4	3	2	1	0
6	You are satisfied with the overall training experience	4	3	2	1	0

How has the professional development session enabled you in becoming better at developing more effective lesson plans?

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What about the training you would have wanted to be done differently?

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Day 3 of the ETSESF Professional development Program

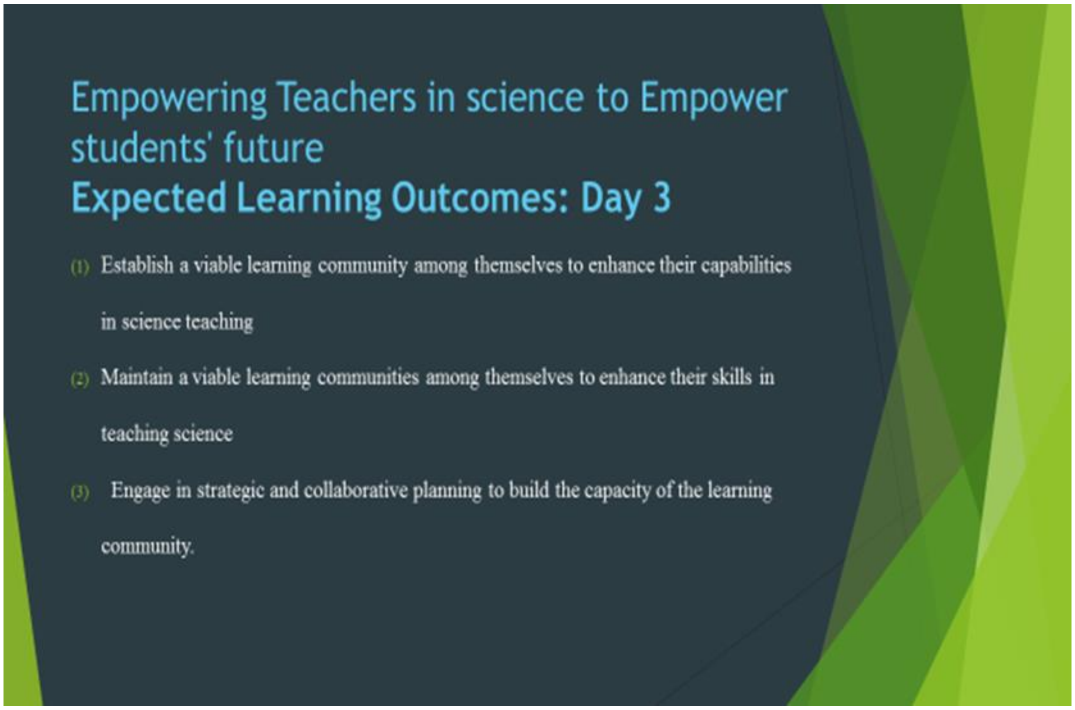
Day Three: Establishing and maintaining a viable learning communities for science

ETSESF Day 3 will be held Tuesday May15, 2018 at the Clarke Primary School

Day 3 Agenda

Time	Session	Activities
8:30 – 8: 45	Registration and Devotion	N/A
8:45- 9:00	Welcome and Opening Remarks	N/A
9:00 – 10: 30	Science Teachers Learning Club: The Benefits	Participants will complete a KWL activity in the session.
10:30 – 10:45	BREAK	
10: 45- 12:15	Establishment of the Science Teachers Learning Club	Participants will design a module to depict their concept of the Science Teachers Learning Club
12: 15- 1:15	LUNCH	
1:15 -3:15	Strategies for Maintenance of the Science Teachers Learning Club	Participants will develop a maintenance plan to be presented to the whole group.
3:15- 3:30	EVALUATION AND DISMISSAL	

Day 3: Session One



Facilitator: Our expected learning outcomes for today are: to establish a viable learning community among yourselves to enhance your capabilities in science teaching, maintain a viable learning community among yourselves to enhance your skills in teaching science, engage in strategic and collaborative planning to build the capacity of the learning community.

Science Teachers Learning Club (STLC): The Benefits

In this session, the facilitator will engage participants in a discussion to highlight the importance and the benefits of designing a science teachers learning club. Participants will discuss with group their conception of what the science learning club could offer. Facilitator will highlight the sharing of best practices in science. The benefits will be listed and incorporated into a framework document that will be developed to guide the operations of the STLC.

Facilitator: What are some of the benefits that can be derived from the establishment and the maintenance of a science teacher's learning club (STLC)?

Expected responses: Teachers are provided with technical support by other specialists in the discipline, teachers will enhance their own skill set when they discuss with others, teachers may feel comfortable learning from peers instead of someone outside the community, teachers develop confidence in teaching as a result of increased knowledge in the subject area, students may benefit ultimately from the learning experiences of teachers.

- **Facilitator**: Now that we have outlined the benefits let us list some challenges that can be encountered in the establishment and the maintenance of the STLC. Let us examine the following areas
- Resources required (financial, human and material)
- Frequency of face to face meeting
- Refreshment

Expected responses: availability of meeting time, availability of individuals to lead the meeting sessions and commitment or lack of commitment of the members of the STLC

Participants will then make proposals as to how to hurdle the challenges which may occur. These include:

- Resources required
- Frequency of face to face meeting
- Refreshment

This session will last for 90 Mins.

Expected Responses: Develop a proposal to present to school leaders regarding the necessity of the STLC, write to school leaders to negotiate release time to participate in meetings, establish virtual meeting sessions outside of students contact time, or write to stakeholders and ask foe sponsorship in order to satisfy some of the financial and material needs.

Day 3: Session Two

Establishment of the Science Teachers Learning Club (STLC)

Facilitator will guide groups into discussions regarding the components of the Science Teachers Learning Club. The following chart will be used to guide the discussion

.

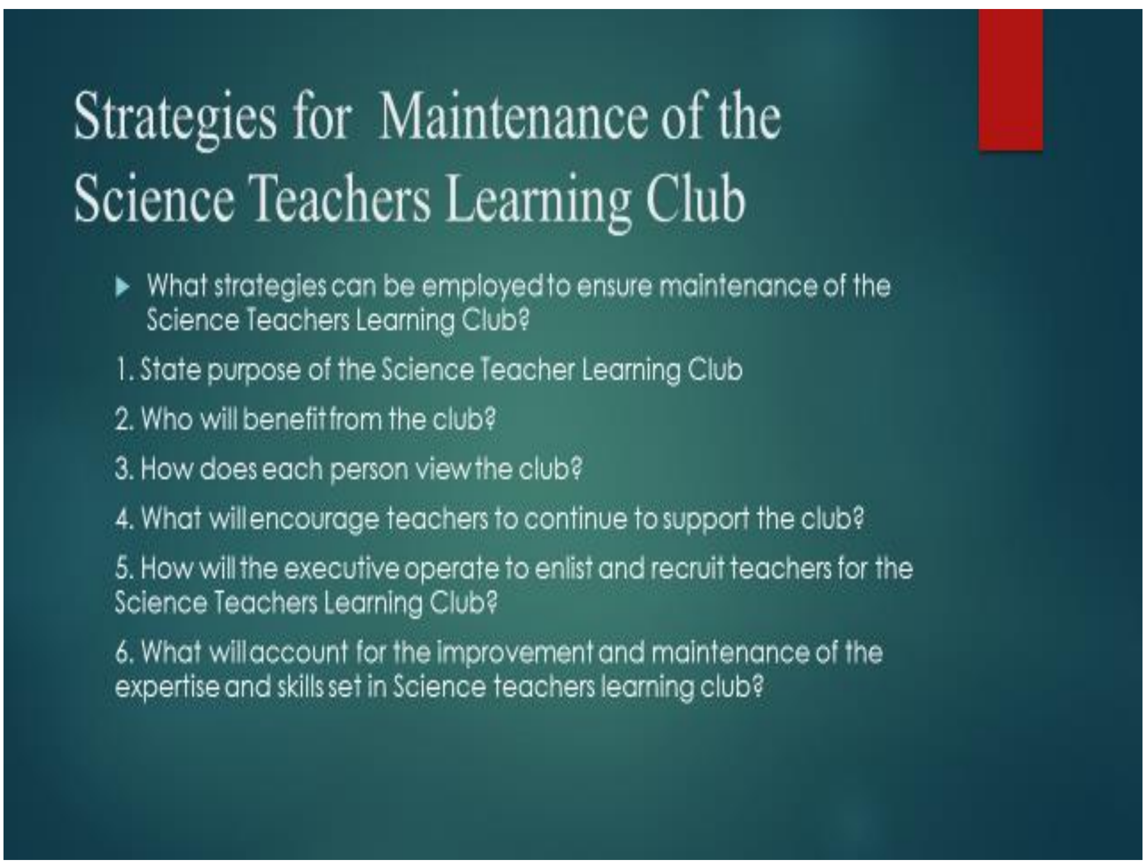
The facilitator will outline the major areas that should be highlighted in the framework that will guide the establishment of the Science teacher learning club. This session will last for 90 minutes.

Day 3: Session Three

Strategies for Maintenance of the Science Teachers Learning Club

In this session the facilitator will have participants work in group to develop a proposal as to how the Science teachers club can be maintained. This activity should last for 35 minutes.

Facilitator: Participants we will now develop a proposal regarding the establishment and maintenance of STLC. The proposal writing will be guided by ate of the elements outline on the chart displayed.



Each group will present their proposal as to how the science teacher learning club can be maintained. Each proposal will be critiqued and discussed by the participants. Appropriate elements from the different proposals will be infused into the framework and the proposal for maintenance of the Science Teachers Learning Club. This activity should last for 45 mins.

Summative Evaluation

Evaluation Activity

Evaluation of the ETSESF Professional Development Program

(1) To what extent did the professional development sessions meet the expectations you had?

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(2) How has the professional development experience enriched your science teaching practice?

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(3) What are your views on the timing and pace of the workshop?

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____

(4) Based on your experience with the professional development program, what things (if any) would you have done differently?

____
____

(5) How have you been using the new strategies explored in your science lessons?

____
____

(6) What recommendations do you have for the professional development program?

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____

(7) Is there anything else you would love to communicate regarding the professional development design?

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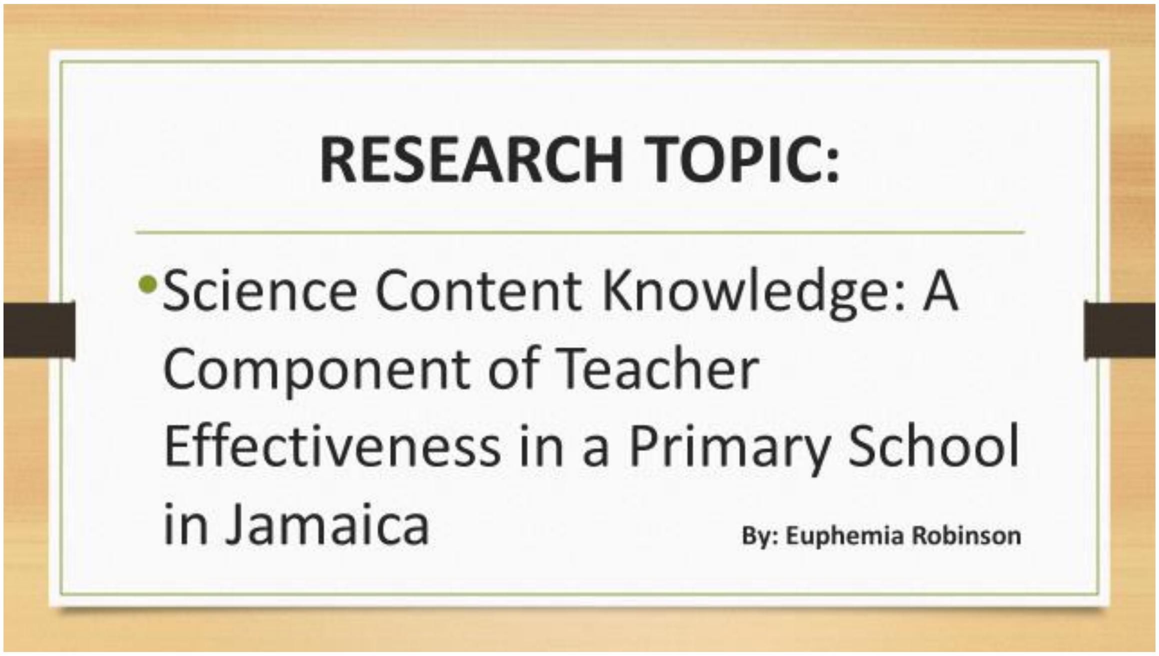
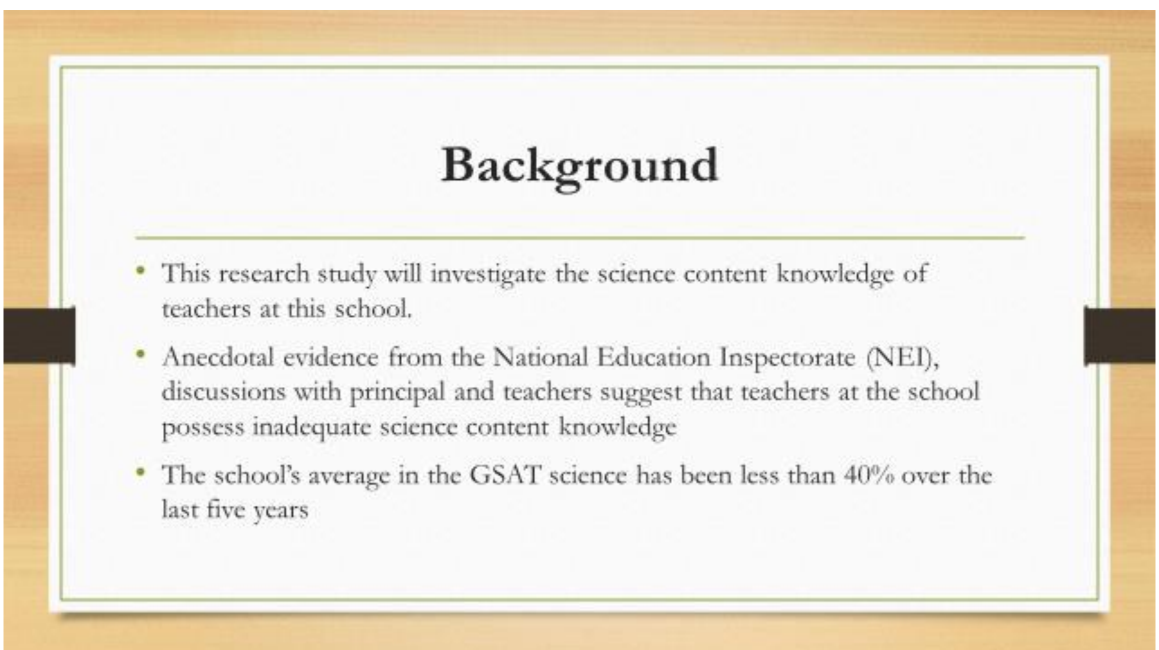
Appendix B: PowerPoint Presentation Used in Teacher Sensitization Session



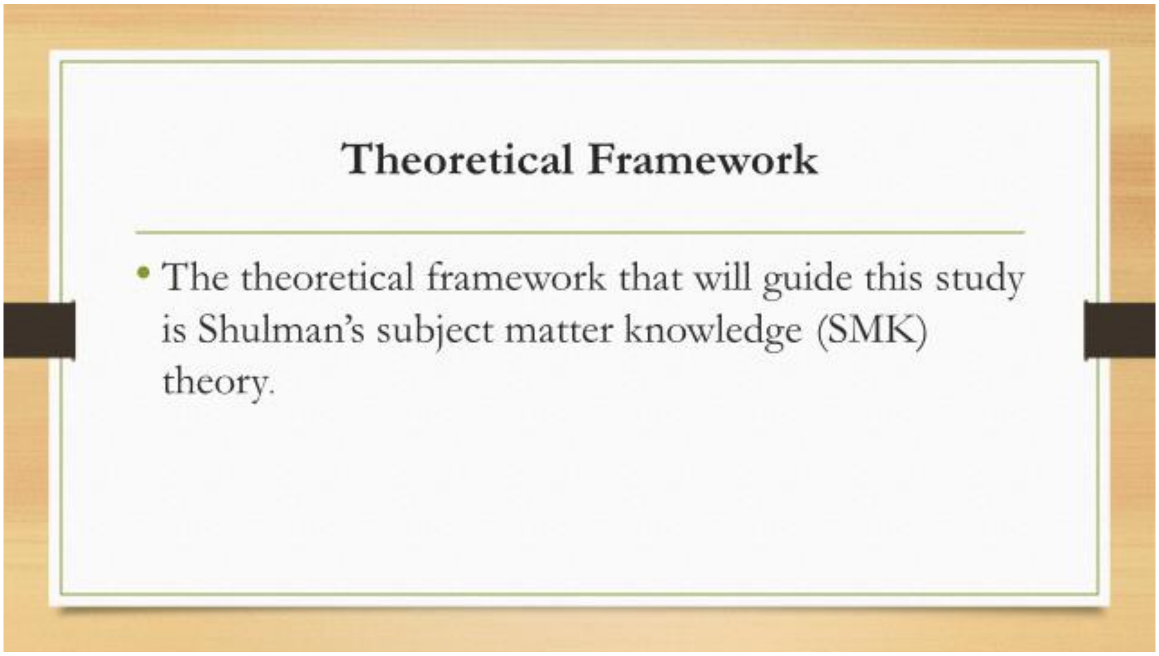


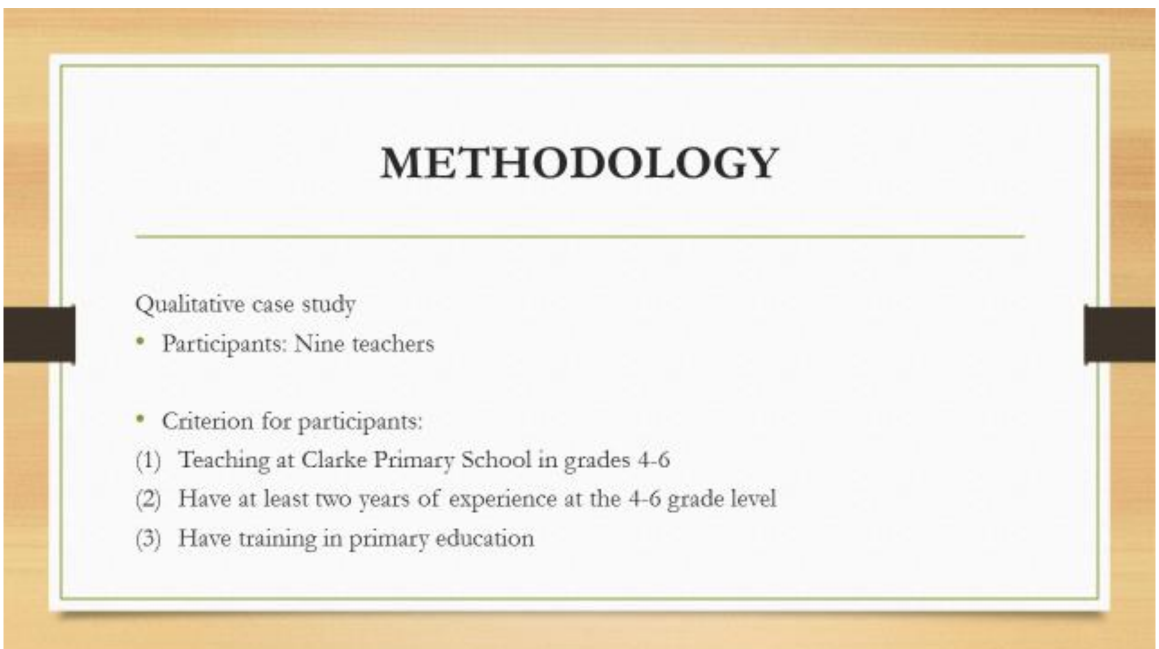
Purpose of study

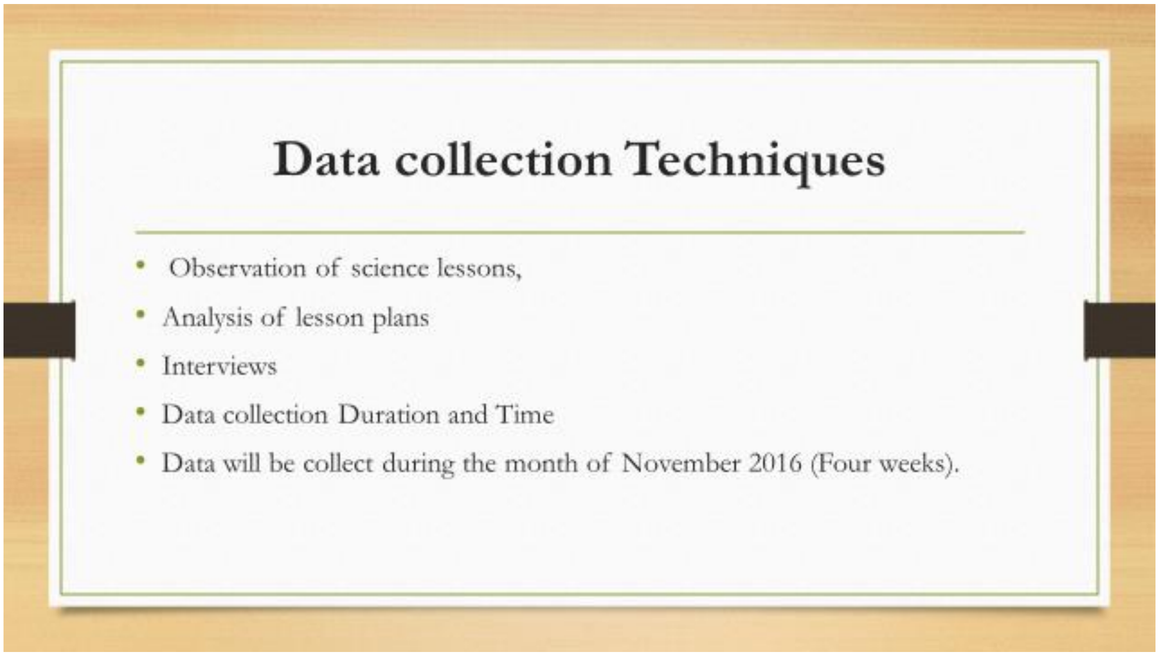
- The purpose of this project study is to provide a deeper understanding of Clarke Primary School teachers' science content knowledge as a component of science teacher effectiveness.

Research Questions

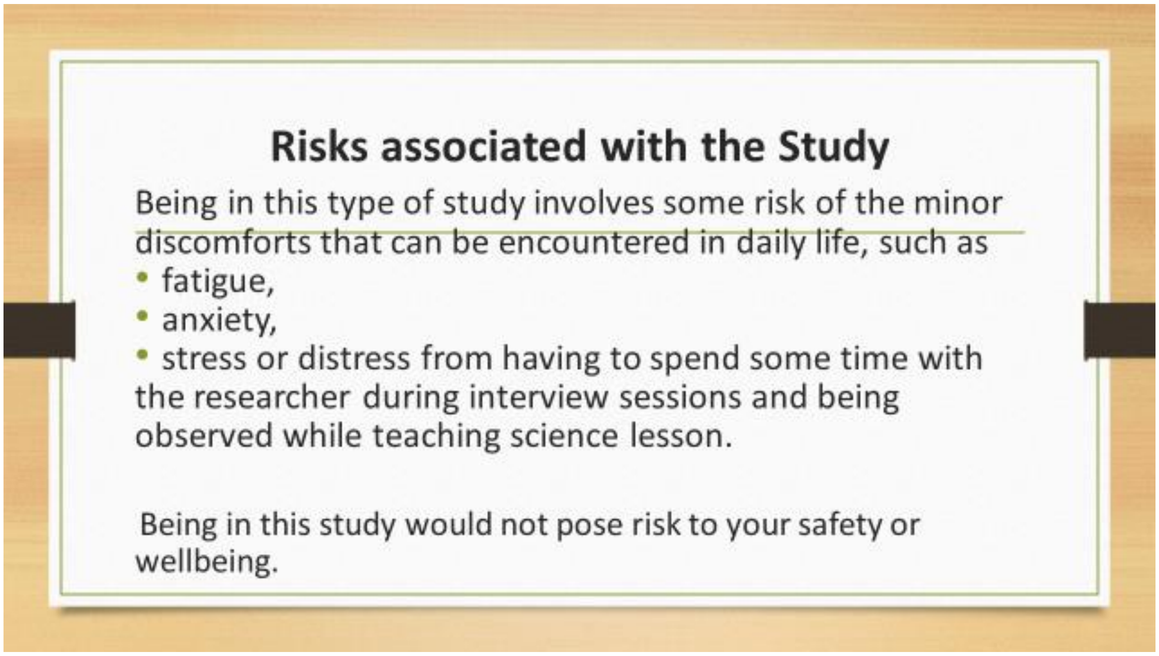
- RQ 1: What are the strengths and weaknesses of teachers' science content knowledge at Clarke Primary School?
- RQ 2: How do teachers at Clarke Primary School demonstrate depth of knowledge while teaching science concepts?
- RQ 3: What are the possible solutions to the problem of teachers' science content knowledge at Clarke Primary School?

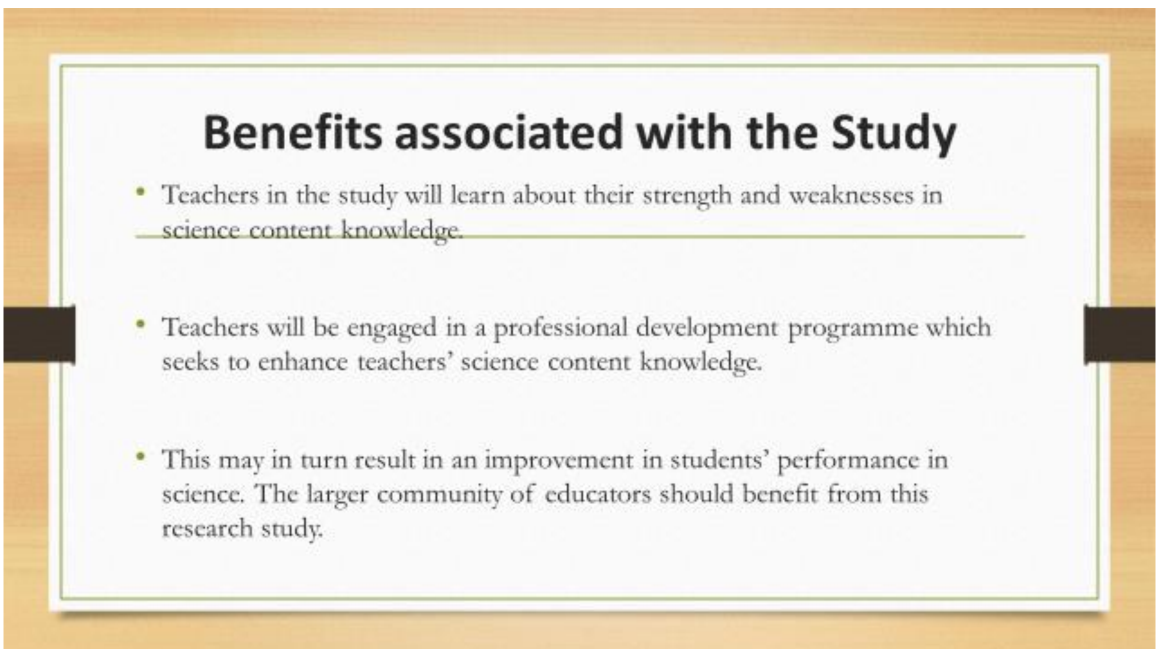

Theoretical Framework
• The theoretical framework that will guide this study is Shulman's subject matter knowledge (SMK) theory.

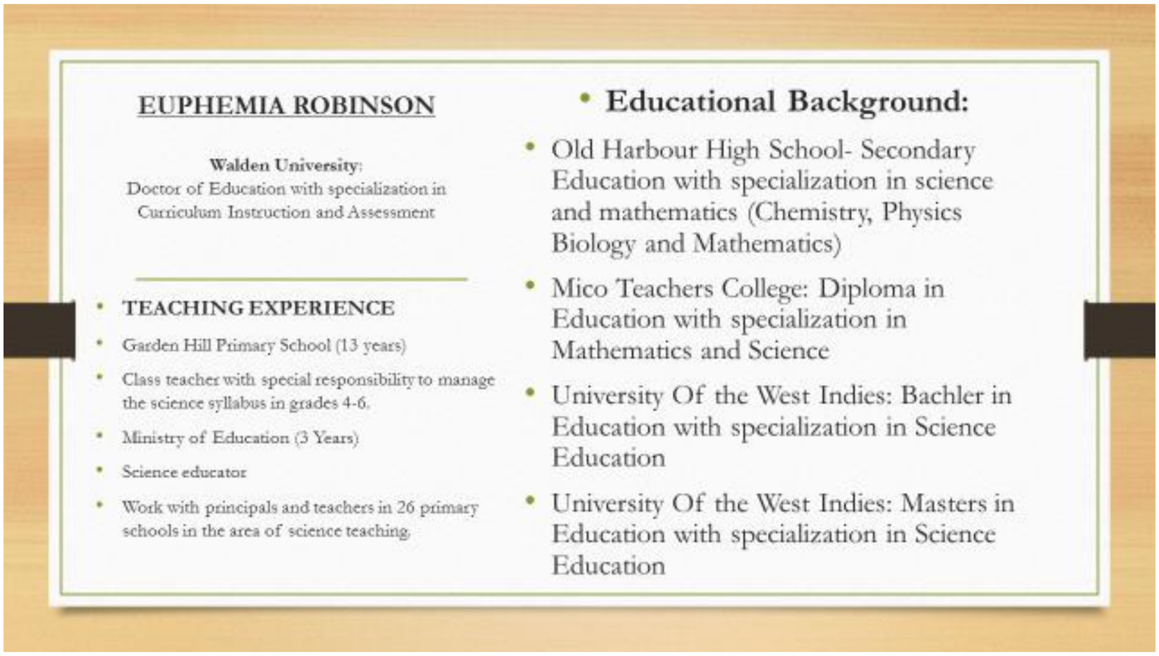

METHODOLOGY
Qualitative case study
• Participants: Nine teachers
• Criterion for participants:
(1) Teaching at Clarke Primary School in grades 4-6
(2) Have at least two years of experience at the 4-6 grade level
(3) Have training in primary education


Data collection Techniques
Observation of science lessons,
Analysis of lesson plans
Interviews
Data collection Duration and Time
Data will be collect during the month of November 2016 (Four weeks).


Protection of Participants
Agreement and signing of consent form.
Use of pseudonyms
Engaging participants in member checking
Securing of data generated from participants
Approval acquired from IRB to engage in data collection
Engendering a relation with participants based on honesty and trust.


Risks associated with the Study
Being in this type of study involves some risk of the minor discomforts that can be encountered in daily life, such as
• fatigue,
• anxiety,
• stress or distress from having to spend some time with the researcher during interview sessions and being observed while teaching science lesson.
Being in this study would not pose risk to your safety or wellbeing.


Benefits associated with the Study
• Teachers in the study will learn about their strength and weaknesses in science content knowledge.
• Teachers will be engaged in a professional development programme which seeks to enhance teachers' science content knowledge.
• This may in turn result in an improvement in students' performance in science. The larger community of educators should benefit from this research study.


EUPHEMIA ROBINSON
Walden University:
Doctor of Education with specialization in Curriculum Instruction and Assessment
TEACHING EXPERIENCE
Garden Hill Primary School (13 years)
Class teacher with special responsibility to manage the science syllabus in grades 4-6.
Ministry of Education (3 Years)
Science educator
Work with principals and teachers in 26 primary schools in the area of science teaching.
Educational Background:
Old Harbour High School- Secondary Education with specialization in science and mathematics (Chemistry, Physics Biology and Mathematics)
Mico Teachers College: Diploma in Education with specialization in Mathematics and Science
University Of the West Indies: Bachler in Education with specialization in Science Education
University Of the West Indies: Masters in Education with specialization in Science Education

Appendix D: Science Lesson Observation Matrix

Science Lesson observation matrix

Teacher: ____________________ Grade: Topic: Date:

		Observed: Evident	Inferred: Incident	Comment
(1)	Knowledge of subject matter			
(2)	Knowledge of the skills embedded in the subject			
(3)	Knowledge of educational context, history and philosophy of the subject.			
(4)	Knowledge of education context of the subject.			
(5)	Knowledge of the broad content base of the subject relating to pedagogical aspects of the subject.			
(6)	Knowledge of the learner			
(7)	Knowledge of educational goals and purposes of the subject.			

Comments:____

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Appendix E: Science Content Writing Analysis Matrix for Lesson Plan Review

Science Content Area Writing Analysis Matrix

Teacher: ___________________ Grade: ________ Topic: Date: ____________

	Shulman (1986) SMK Tenet 1	Shulman (1986) SMK Tenet 2	Shulman (1986) SMK Tenet 3	Shulman (1986) SMK Tenet 4	Shulman (1986) SMK Tenet 5	Shulman (1986) SMK Tenet 6	Shulman (1986) SMK Tenet 7
Type I conceptual gaps							
Type II conceptual gaps							
Type III conceptual gaps							
Type IV conceptual gaps							

Comments:

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