Swaziland Pre-Service Teachers' Understanding and Enactment of Inquiry-Based-Science Teaching: A Case of a University in Swaziland

by

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ABSTRACT

The current study adopted a case study design to understand the knowledge and skills related to inquiry-based science teaching (IBST) held by pre-service teachers at the conclusion of their three years training in science courses in an educational institution in Swaziland. Placed in the pragmatism paradigm, the study used a multi-methods approach. The purposively selected study sample consisted of 34 pre-service teachers at the end of their 3-year teacher preparation programme. In the first phase of the study, the researcher assessed the 34 pre-service teachers' understanding of IBST using a teaching scenario based questionnaire in combination with individual interviews with eight of the participants. Six participants from the sample of eight also volunteered for the second phase of the study, where their lesson plans, classroom observation recordings, and lesson interviews were used to gather evidence pertaining to their enactment of IBST during teaching practice. Data were analysed using a conceptual framework of IBST that outlines two dimensions: the cognitive and guidance dimensions.

Findings from the first phase indicated that at the completion of the training programme pre-service teachers held inadequate but varying conceptions of IBST. They either regarded IBST as engagement of learners in constructing knowledge about phenomena themselves based on evidence; or associated the pedagogy with different forms of learner engagement during the teaching process. Participants only identified prominent characteristics of the cognitive dimension of IBST, particularly those of the procedural domain. Concerning the guidance dimension, they connected IBST more with teacher directed activities.

In their enactment of IBST, the six participants focused more on the conceptual domain while the epistemic domain was least represented. Concerning the guidance dimension of IBST, they mainly guided learners in formulating evidence-based conclusions. In the main, their enactment of IBST was shaped by their comprehension of the cognitive dimension of inquiry and their pedagogical content knowledge for facilitating inquiry-based learning. Extensive recommendations for teacher education and educational leadership are given. The effectiveness of the conceptual framework for identifying the pre-service teachers' conceptions is discussed.

PREFACE

The work described in this thesis was carried out in the School of Science, Mathematics and Technology Education, University of KwaZulu-Natal from February 2014 to April 2019 under the supervision of Professor Nadaraj Govender (Supervisor) and Doctor Doras Sibanda (Co-supervisor). This study represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any other tertiary institution. Where use has been made of the work of others, it is duly acknowledged in the text.

Signed……………………………………….Date... 5 June 2019…………………………

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Dedication

I dedicate this work primarily to God who is the source of all knowledge and wisdom. I also dedicate it to those who not only value science education, but also make efforts towards the development of this worthwhile endeavour.

CHAPTER 1

1.1 INTRODUCTION

Most science curricula in schools, including that of Swaziland, specify that besides promoting learners' understanding of natural phenomena, science education should also develop learners' skills and proficiencies in doing science and their understanding of scientific inquiry. However, frequently the teaching of science focuses on rote memorization of facts. In line with a number scholars in science education (Abd-El-Khalick, 2012; Harris & Rooks, 2010), the researcher holds the view that learners learn science best when they engage in activities that reflects science as a way of "generating and validating knowledge" (Abd-El-Khalick, 2012, para 1). A number of studies provide evidence that teaching science by using a scientific inquiry method can improve learners' performance in science (Minner, Levy, & Century, 2010; Schroeder, Scott, Tolson, Huang, & Lee, 2007). It is in this regard, a number of proposals for developments in the teaching of science such as those envisioned in American Science Education Standards (National Research Council [NRC], 2000, 2013) and the South African Curriculum and Assessment Policy Statement [CAPS] emphasize that learners should learn science by inquiry.

Inquiry-based science teaching (IBST), like problem-based teaching, is founded on the philosophy of John Dewey, which views learning as originating from the curiosity of the learner (Savery, 2006). There are, however, many different meanings associated with IBST in the science education reform literature; meanings vary in terms of the kind of activities and cognitive processes in which students are engaged (Furtak, Seidel, Iverson, & Briggs, 2012; Kock, Taconis, Bolhuis, & Gravemeiger, 2015). For instance, Savery (2006) defines IBST as a "learner centred, active teaching approach that is focused on engaging students on questioning, investigating solutions and creating new knowledge on the basis of collected information, discussing discoveries and experiences and reflecting on new found knowledge" (p. 16). In this meaning, teacher guidance is central to an inquiry-oriented lesson. Based on this characteristic, instruction through inquiry may vary from, on one end, strategies that are very teacher or material directed with the other end of the continuum being schemes that are entirely student directed.

Consistent with the Swazi science curriculum, which focuses on both science content and process skill development, in this study IBST is used to refer to a teaching approach whereby in the context of investigative learning activities that are similar to those carried out by scientists, students are guided in constructing meaning of science concepts and processes (Cobern et al., 2010; Eick & Reed, 2002). This understanding of inquiry is in line with that of Bertsch, Kapelari, and Unterbruner (2014), who assert that the aim of primary school science is not concerned with developing scientists, but is rather to develop students' understanding of science concepts and processes. Along these lines, research findings support the view that learners' inquiry activities have to be teacher directed in order to promote learners' conceptual understanding (Kock, Taconis, Bolhuis, & Gravemeiger, 2015).

Inquiry-based science teaching (IBST) is regarded as a learner-centred teaching strategy appropriate for promoting the much desired international goal of scientific literacy (Gormally, Brickman, Hallar, & Armstrong, 2009). Thus, it is important. Involving learners in inquiry activities provides an appropriate classroom context within which they can reflect upon the nature of the scientific process and how to use scientific knowledge in everyday life (Harris & Rooks, 2010). Studies also indicate that IBST can promote conceptual understanding (Kock et al., 2015; Njoroge, Changeiwe, & Ndirangu, 2014), knowledge of the procedures used to generate scientific knowledge (Bell, Blair, Crawford, & Lederman, 2003) as well as ideas about the nature of science (Khisfe, 2008). These three forms of knowledge, commonly referred to as content, procedural and epistemic knowledge, respectively, are considered critical elements of scientific literacy (Laugsch, 2000; Organization for Economic Co-operation and Development [OECD]). Developing knowledge and skills related to IBST should therefore be a priority in the training of pre-service teachers. In order to facilitate development of inquiry based science teacher education programmes, it follows that it is imperative to enquire into how and why such pre-service teachers engage with the desired instructional approach.

This study explores experiences of inquiry-based science teaching among a group of pre-service teachers at the end of their 3-year science content and methods course in one university in Swaziland, now referred to as Eswatini. Since the study was concluded prior to this name change, the former name is used in this report. There are few studies of science education in Swaziland in general, and, in particular, there appear to be none that concentrated on inquiry-based science teaching.

The study took place at a time when the country had approved, and was about to implement a new curriculum framework based on competency-based education (Ministry of Education and Training, 2018d). In line with this framework, aimed at equipping learners with knowledge and skills that could help them cope in a knowledge driven society, teachers' ability to teach using an inquiry-based approach would therefore be vital. The study also took place at a time when the university, where the study took place, had adopted its first strategic plan, wherein the first goal is that:

> "By 2020, the university would have transformed its educational programmes, methods and processes to ensure quality educational programmes, employability and relevance of graduates" (*Strategic Plan*, 2015, p. 5).

Accordingly, investigating the final year pre-service teachers' experiences of IBST was therefore in step with both the requirements of the newly introduced Swaziland National Curriculum Framework for General Education and the strategic goal of the university.

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1.2 BACKGROUND TO THE STUDY

Following a comprehensive study carried out by the Ministry of Education and Training in conjunction with the World Bank (Ministry of Education and Training, 2011), the government of Swaziland realized the need for curriculum reforms. The results of the study indicated the low quality of education accessible to most Swazis: Swazi students were generally lacking the skills necessary in a knowledge-based society. Moreover, the study revealed that most students' performance in science and mathematics was particularly low (Marope, 2010). This is worrying because literacy in these areas is generally regarded as being critical for the development of any society (Fatima, 2013; Ministry of Education, 1999). In order to address this state of affairs, the country decided on a new National Curriculum Framework based on competency-based education (MOET, 2011). Competency-based education (CBE) refers to an education system driven by defined competences or “skills, knowledge and attitudes learners must demonstrate through carrying out some task under specified conditions to attain success” (Ministry of Education and Training, 2018b, p. 3). The researcher is of the view that an inquiry-based science teaching (IBST) approach has the potential to not only improve students’ performances in science, but also their general competencies essential in a knowledge-driven society.

To clarify the context of the study, the next subsections describe the organisation of the general education system of the Kingdom of Swaziland, her teacher education programmes, the primary teachers’ diploma and the science teacher programme in which the study is more specifically located.

1.2.1 School Educational System in Swaziland

Both the formal and non-formal education sectors in Swaziland fall under the responsibility of the Ministry of Education and Training (MoET). It is currently made up of four segments: pre-primary, primary, secondary and tertiary education, as illustrated in Figure 1.1

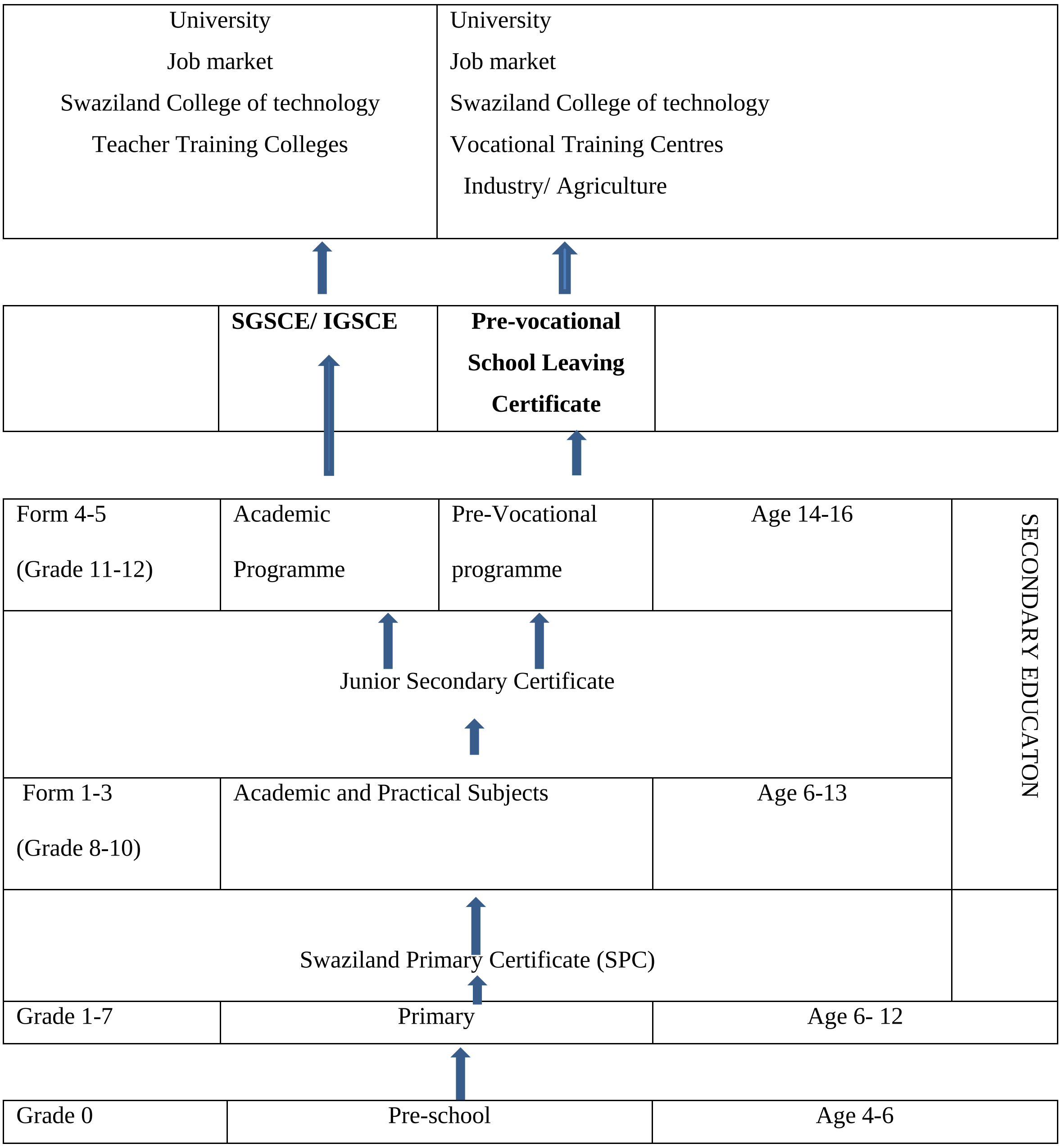

Figure 1.1 *The organization of the educational system in Swaziland* (Khumalo, 2010, p. 5)

Pre-primary schools are currently initiated and run by communities or the private sector; and most of them are found in urban and semi-urban areas (Ministry of Education, 1992). As a result, only a small proportion of Swazi children have access to pre-schooling (Ministry of Education and Training, 2018a). Primary education currently begins at 6 years of age; and consists of seven levels (Grades 1 to 7), at the end of which, learners sit for the Swaziland Primary Certificate (SPC) Examination, a locally based examination (Ministry of Education and Training, 2018). The primary curriculum consists, currently, of nine subjects: “English, Mathematics, Science, Religious Education, siSwati, French, Home Economics, Practical Art, and Physical Education" (MoET, 2018b, para 8).

The secondary programme consists of two levels: a 3-year junior secondary programme (Forms 1 to 3) and a 2-year senior programme (Forms 4 and 5) (Ministry of Education, 1992). The secondary programme offers a number of subjects categorized as either core or electives. Schools are expected to offer not less than six of these subjects (core and electives combined) at both the junior and senior levels. The 3-year junior secondary programme leads to the Junior Certificate (JC) examination, while the 2-year senior secondary school programme ends with the Swaziland General Certificate of Education (SGCE) or the International Certificate of Education (IGCE). The Cambridge International Examination authorizes these two exams (Ministry of Education and Training, 2018c). The tertiary level consists of courses at universities, colleges, and vocational training centres.

Figure 1.2 provides a summary of the education system in Swaziland under the new curriculum framework. It shows the relationship between different levels of education, vocational training institutions and the world of work.

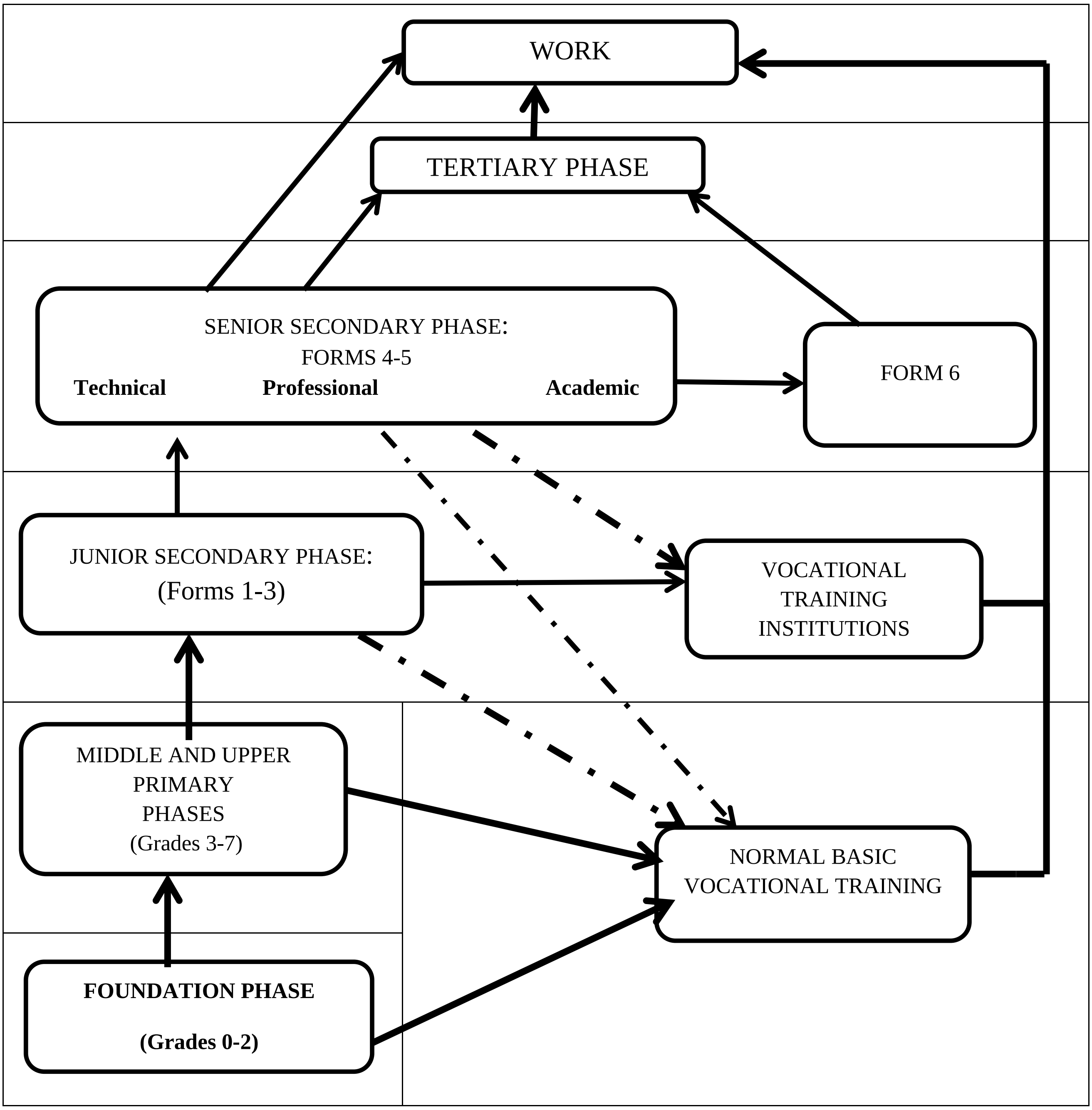

Figure 1.2 *Organization of the education system in Swaziland in the new curriculum framework (Ministry of Education and Training, 2018b, p. 22)*

The Swazi government's goal for primary or basic education is to not only provide a base for secondary education, but also to lay the foundation of knowledge and abilities that will eventually be needed to make a living, in the formal or informal economy (Ministry of Education, 1999). It is through adopting a competency-based approach that the Swazi government hopes that learners will be able to move directly into vocational schools after primary education as demonstrated in Figure 1.2. A new school education structure that caters for the implementation of such an approach is to be implemented for Grade 0 in January 2019 as the national curriculum framework for general education. The structure as specified in the National Curriculum Framework (Ministry of Education and Training, 2018d) consists of six phases. The foundation phase constitutes Grades 0-2; the middle primary phase of Grades 3 and 4; the upper primary phase of Grades 5-7; the junior secondary phase include Forms 1-3 while the senior phase constitutes Forms 4 and 5. Form 6, at the end of secondary education, acts as a bridge to tertiary institutions outside Swaziland, as it meets the regional requirements.

The framework specifies end of phase competencies, that is it is explicit in the competencies that learners should be able to demonstrate at the end of each particular phase (Ministry of Education and Training, 2018b). According to McCrarty and Gaertner (2015), "competencies can be a more precise indication of what graduates know and what they are able to do rather than time spent in a traditional classroom" (p. 1). The foundation phase includes Grade 0, in order to connect Early Childhood, Care and Development (ECCDE) provision with primary schooling. This should allow an easy transition from Grade 0 to Grade 1 and ensure that all children begin primary school from a comparable base. Another notable change in the curriculum is that the senior secondary phase now has three pathways from which learners can choose: the technical pathway, professional pathway and the academic pathway. These three pathways lay a foundation for technical, professional and academic careers, respectively.

Table 1.1 below shows the curriculum for the primary sub-sector in accordance with the new curriculum framework. The details are limited to the primary curriculum as this phase is the focus of the study. As indicated in the table, subjects have been organised into groups referred as learning areas. Table 1.1 shows that in earlier phases, learners encounter science under General Studies. Later in the upper primary phase (Grades 5-7) they begin to study science in conjunction with technology ((Ministry of Education and Training, 2018b).

Table 1.1 *Learning areas and subjects taught at the foundation and primary phases*

Learning areas	**Foundation phase (Grade 1-2)**	**Middle Primary Phase (Grade 3-4)**	**Upper primary Phase (Grade 5-7)**
Languages	siSwati Swazi Sign Language English	siSwati/Swazi Sign Language English Foreign Language (French) Basic Sign Language	siSwati/Swazi Sign Language Foreign Language (French)
Mathematics	Mathematics	Mathematics	Mathematics
Sciences, Humanities, Social Studies	General Studies Religious Education	General Studies Religious Education	**Science** and Technology Consumer Science Agriculture
ICT		ICT	ICT
Health and well being	Health and Physical Education Braille Orientation and Mobility Daily Living Skills	Health and Physical Education	Health and Physical Education

(Ministry of Education and Training, 2018d, p. 29)

The main goal of basic science education (Grade 0-12) is to promote scientific literacy. This goal is apparent in the National Education Sector Policy of 2011: “The Education and Training Sector’s goal is to empower people in Swaziland to understand the natural and physical world, and the processes by which scientists construct and modify such knowledge” (Ministry of Education and Training, 2018, p. 6).

This statement from the Science Education guidelines 1997 for Grade 1 to Grade 12 sciences also demonstrates this goal:

> The central objective of science education in Swaziland is that all learners should learn science that is suitable for their abilities for all the years of their education. Full attention must be on the development of scientific skills/competencies and science processes as well as knowledge, understanding and attitudes at all school levels. (Ministry of Education and Training, 2012, p. 4)

In line with both the National Education Sector Policy and the above cited science education guidelines, the primary curriculum aims at promoting learners’ understanding of science content and development of skills, which should be taught in a context-based approach so learners can appreciate the relevance of science to their daily lives. Moreover, the new curriculum framework specifies a number of core skills, which portray the goals of the whole education sector. Each subject curriculum defines how the individual skills should be addressed (Ministry of Education and Training, 2018b). Table 1.2 presents these core skills, with their components that are most relevant in the context of learning science.

Table 1.2 *Core skills needed to achieve the education sector's goals*

Core skill	**Key skill components**
Learning skills	• Ability to construct meaning from their experiences. • Applying new knowledge in new situations • Setting, evaluating and achieving learning goals • Working effectively individually and in groups • Ability to handle success and failure • Awareness of and responding appropriately to strengths and weakness • Ability to adjust in light of new ideas and situations
Personal skills	• Self-awareness and self-directedness and initiative • Responsibility, accountability and flexibility • Being confident and assertive • Leadership skills • Living healthy lifestyles • Ability to use tools and materials in a safe manner
Social skills (Interpersonal skills)	• Participating effectively in social activities, networking and collaborating with others • Taking care of others and the environment, • Acknowledging individual difference and respect of others, tolerance, managing conflict through appropriate dialogue and mediation
Thinking skills	• Analysing and solving a variety of problems • Ability to make reasonable inferences • Ability to synthesize a variety of information; critical, reasoning and reflective thinking; and ability to evaluate processes and solutions
Creativity and Innovative Skills	• Asking questions about phenomena and exploring ideas • Creating and applying ideas to explain phenomena • Connecting ideas from different contexts • Demonstrating imaginative and creative skills • Designing and making products
Numeracy skills	• Performing calculations accurately, making estimations and measurements using different instruments • Collecting, organizing, analyzing and interpreting different forms of mathematical data presentations
Literacy and communicative skills	• Good listening and critical reading skills • communicating effectively orally, in writing, and in various social and cultural contexts

Core skill	Key skill components
Information and Communication Technological skills	• Organizing, analyzing, synthesizing, and evaluating information by means of various technologies • Communicating well using ICTs and use technologies to retrieve and process information.

(Ministry of Education and Training, 2018d, pp. 12-15)

Assessment of the science in the old curriculum focused on knowledge and comprehension, and learners' ability to apply scientific information within the conceptual domain, as indicated in Table 1.3 below. The table also describes what learners had to demonstrate within each assessment objectives (Examination Council of Eswatini, 2017).

Table 1.3 *Assessment objectives for Science in the Swaziland Primary School Certificate curriculum*

Category	**Objectives:** Learners should demonstrate:	**Weighting (%)**
Knowledge and Comprehension	Knowledge and understanding of facts, concepts, phenomena, definitions, scientific vocabulary, instruments and conventions, symbols, quantities and units.	50
	An ability to apply science in the world around them	
Application of scientific information	An ability to locate, select, organize, present information from different sources.	30
	Identify patterns, trends, and draw conclusions from given information	
	Translate information from one form into another	
	Manipulate information and other data	
	Give explanations for phenomena, patterns and relationships	
Investigative skills	Incorporate scientific attitudes in their investigative skills	20
	Formulate hypothesis and predictions	
	Use techniques, apparatus and materials,	
	Make and record observations, measurements and estimates	
	Interpret and evaluate observations and data	
	Solve problems	

(Examination Council of Eswatini, 2017, p. 4)

Some past studies indicate that shortage of time and the need to cover content are some of the factors that have been found to limit the implementation of IBST (Mugabo, 2012; Ssempala, 2017). Thus by focusing on the conceptual than other domains of science, the assessment framework does not seem to promote an inquiry-based science teaching approach. The researcher therefore contends that in the context of this assessment framework, which is still in use as the new curriculum has just begun and currently only implemented in Grade 1, teachers are less likely teach science in a way that also promotes learners' procedural and epistemic knowledge.

The Examination Council of Swaziland has not yet published new assessment syllabuses in line with the new curriculum as the national curriculum framework has only been recently instituted. However, assessment of learning according to the new curriculum framework is to focus on generating evidence of the "knowledge, skills and attitudes that learners have acquired" (Ministry of Education and Training, 2018d, p. 37). For this reason, the new curriculum promotes a school-based assessment, which in line with the principles of competency-based education, relies on criterion-referenced grades. An emphasis on school-based assessment favours inquiry-based science teaching approaches as it allows teachers to concentrate on developing learners' inquiry abilities and mind-sets as learners perform scientific activities in the classroom than just on training learners to pass external examination. Moreover, by focusing on assessment for learning, the new curriculum framework allows teachers to elicit learners' ideas, prior knowledge and interests, which allows learners to take more responsibility of their own learning in line with the rationale for IBST.

In the advocated criterion-referenced assessment, each grade has descriptors specifying what the learner should display to obtain that grade. A grade in this framework therefore indicates the learners' level of mastery of a given competency based on data collected by various instruments such as observation schedules or rubrics (Ministry of Education and Training, 2018). Table 1.4 provides the weights that the new curriculum has assigned to on-going versus end of term assessment of learning at different phases of primary education.

Table 1.4 *Assessment framework of learning in the Primary education*

Subjects	Foundation phase		Middle primary phase		Upper primary phase	
	On-going	End of term	On-going	End of term	On-going	End of term
Academic subjects	100%	0	50%	50%	30%	70%
Practical subjects	100%	0	70%	30%	50%	50%

As evident from Table 1.4, while assessment at the foundation phase is only of the formative type, the middle and upper primary phases have both formative and summative aspects. The emphasis in academic subjects, such as science is more on the summative assessment at the upper primary phase. At the middle phase however, the on-going and end-of term assessments have equal weights. The reverse is true for practical subjects; more emphasis is placed on on-going assessment during the middle phase while at the upper phase the two forms of assessment have equal weighs.

1.2.2 The Primary Teachers' Diploma (PTD)

Swaziland offers pre-service teacher training programmes in both colleges and universities. Currently, there are two universities and four colleges that offer two or more of the following programmes: certificates in adult education, the Post Graduate Certificate in Education (PGCE), diplomas in primary, secondary or adult education, and degrees of Bachelor of Education (B.Ed.) and Master of Education (M.Ed.).

The study took place in the context of a 3-year full time primary teachers' diploma (PTD) programme offered in one of the universities in Swaziland. The new private university (referred to in this study as University Q) was constituted in 2010 after upgrading and unifying three colleges into one university. The three colleges had been career oriented. Now, in addition to diploma courses all three faculties in the university offer degree courses, which is the minimum requirement for a university.

The university's mission is in the direction of an "integrated education programme which combines critically informed professional instruction with practically applicable degree work" (Southern Africa Nazarene University, 2017). The framework, which aligns with the

Swaziland Qualification Framework, has 10 levels: Levels 1-4 are levels at General Education and up to Technical Vocational Education and Training (TVET). Level 5-6 includes Certificates and Diplomas. Higher education is levels 7 -10; level 7 corresponds to graduate diplomas and Bachelor Degrees. Currently, the university is limited to Levels 5-7, because, at present, it does not offer any degrees at Masters (Level 9) or Doctorate (Level 10) levels. (Southern Africa Nazarene, 2018)

The PTD programme, which is at Level 6, equips primary teachers for teaching all the subjects in the primary school curriculum. The aims of the programme are to develop knowledge, skills, and values necessary for effective and inclusive teaching and learning at the primary school level, along with the ability to conduct an educational-based research.

The entrance requirement for the PTD programme is six passes in the Swaziland General Certificate of Education (SGCE) (or a comparable school-leaving certificate), of which one must be English Language and four must be credit passes in the subjects taught at the primary school level. The credited subjects must therefore fit into one of the following combinations for specialization in the final year:

- Mathematics & Science **or** Agriculture or Consumer Sciences
- Consumer Sciences & Science
- Social Studies & Religious Education
- English & SiSwati
- English & French

All participants studied science, some of them had maths as a second major while the remainder had consumer science as a second major.

1.2.3 The Science Education Programme

The study was carried out during a science teacher methods module. As given in the science education programme units' specifications, the four major goals of the programme are that by the completion of the module pre-service teachers should demonstrate:

(a) Knowledge of the characteristics, aims and general limitations of science as a way of investigating the natural world;

(b) Abilities to employ the methods of science;
(c) A comprehension level of scientific concepts that is greater than that specified in the science primary syllabus;
(d) An understanding of the theory behind teaching science;
(e) Science pedagogical skills that facilitate learners' scientific process and critical thinking proficiencies, interest in learning science, and their conceptual and epistemic understanding of science;
(f) Positive outlooks about science and the teaching of science

(Nhlengethwa, 2013).

The programme has two components. One component deals with the science content area including biology, chemistry, and physics, while the other component focuses on science teaching methods. The module also exposes pre-service teachers to discussions about the character of science integrated within the science methods and science content sessions. During the first year of the science, programme participants learn basic science concepts, the character of science, alongside basic and intergraded science processes skills. During their second year, they study theories relevant to teaching science and methods of teaching science. In both the first and second year of study, two science contact sessions of one hour are scheduled each week over twelve weeks per semester. In their final year, pre-service teachers specializing in science education register for four modules: general life science, chemistry, physics, and a science methods course (Nhlengethwa, 2013). Each of the four modules has a 2-hour contact session per week for the 12 weeks.

The three content-based modules (general life science, chemistry and physics) are intended to enrich the pre-service teachers' understanding of science concepts and their proficiency in employing the methods of science to a level that is higher than what they have to teach. To achieve this goal, the three science content modules engage pre-service teachers in lectures, demonstrations and practical work. It is noteworthy though that the practical work that pre-service teachers are more teacher directed. However, even though the curriculum they are to teach does not prescribe approaches to use, it recommends the use of more learner-centred pedagogical approaches. Moreover, development of desired competencies demands the employment of more learner-directed inquiry-based approaches.

Two of the main goals of the final year science methods module are to promote pre-service teachers' understanding and confidence in enacting inquiry-based science teaching. In this module, IBST refers to instruction that is in line with an "investigative approach and reliance on evidence that scientists employ in constructing knowledge" (Cobern et al., 2010, p. 1). Subsequently, pre-service teachers are introduced to the 5E learning cycle (Bybee et al., 2006). The 5E instructional model, to be explained later in Section 2.2.2.5 engages learners in constructing scientific principles and conceptions based on their exploration. The approach is thus a suitable context for promoting inquiry-based learning and conceptual change. Pre-service teachers were firstly introduced to the five essential elements of IBST (NRC, 2000) and the 5E instructional model. The instructor then presented and a model lesson that has all the essential elements of IBST and an explicit reflective discussion of the nature of science. After a classroom discusson of this lesson, in groups, pre-service teachers were involved in preparing, enacting and discussing lessons guided by 5E instructional model. After revising their lesson plans, they implemented them during their microteaching sessions and subsequently, and they reflected and discussed the success or failure of their lessons.

1.3 MOTIVATION AND RATIONALE FOR THE STUDY

My personal interest in science education arises from my many years of working as a science teacher educator training primary teachers. I have observed the teaching of science in different primary schools for quite some time. I have noted that pre-service teachers generally use direct rather than inquiry-based approaches to teaching science during their teaching practice in schools. Even when they engage learners in hands-on activities, these are usually, either for promoting conceptual understanding or the learning of skills such as learners' ability to classify objects or to make accurate measurements. This approach to teaching science is detrimental to both the country's science education goal of promoting a scientifically literate society and that of developing a populace that has the learning, thinking, creative and innovative skills desirable in a knowledge driven society (Ministry of Education and Training, 2014).

As earlier pointed out, in addition to promoting learners' conceptual understanding and science process skills, IBST presents an appropriate context for promoting learners' general cognitive skills and their understanding of the epistemology of science. Several scholars are in agreement with this outlook (Alake-Tuenter et al., 2012; Cobern et al., 2010; Crawford, 2007; Harris & Rooks, 2010; Kock et al., 2015). Harris and Rooks (2010), for example, argue that an inquiry-based science teaching approach integrates scientific knowledge and processes in a manner that brings to light their interrelationship. Moreover, research (Abdi, 2014; Aktamis, Hiğde, & Özden, 2016) provide evidence that indicates that IBST promotes learners' academic achievement in science and facilitates the development of general thinking skills among learners (Bybee, 2009; Hu, Kuh, & Li, 2008). All these likely benefits of IBST are consistent with the country's goal of developing a populace that has the learning, thinking, creative and innovative skills desirable in a knowledge driven society (Ministry of Education and Training, 2014).

Engaging learners in classroom inquiry-based learning nevertheless, does not ensure the achievement of the above mentioned goals, but teachers must possess an ability to structure inquiry activities and organize them in a way that facilitate learners' understanding of the desired content (Harris & Rooks, 2010; Kock et al., 2015). The question that then arises is whether the current teacher education programmes in Swaziland do equip primary teachers with an adequate understanding and skills necessary to implement inquiry based science teaching. Part of my research question was therefore to seek final year pre-service teachers' experiences in the courses we offer as they engage with inquiry and finally, I wanted to understand the factors that shape the way they engage in inquiry-based science teaching. Answers to these questions were of particular importance considering that the teacher education institution was about to revise its programmes to ensure that they were in step with the demands of the newly introduced competency-based curriculum. Such a study was therefore valuable as it was going to provide some information necessary to undertake this exercise. While there are a number of studies on inquiry-based science teaching, most of them have focused on in-service secondary teachers; knowledge about pre-service primary teachers' understanding and enactment of IBST is still very scanty, especially in developing countries like Swaziland. Moreover, teachers need an understanding of various knowledge domains related to the inquiry process and of how to enable learners acquire these competencies in order to enact IBST effectively. However, there is lack of reserch that uses a framework that incoportaes all these domains (Abd-El-Khalick, 2012; Harris & Rooks, 2010; van Uum, Verhoeff, & Peeters, 2016). This explorative case study can also inform larger scale studies aimed at understanding the kind of knowledge and skills pre-service and in-service teachers hold at the end of their teacher training education programme.

1.4 RESEARCH QUESTIONS

A research question is an essential element of any form of scientific research, according to Jansen (2007), who says that it "becomes the beacon that guides the whole research process" (p. 3). The aim of the study was to explore the pre-service teachers' understanding and practices of inquiry-based science teaching in the context of a specific pre-service science tutoring programmes. Accordingly, the study aimed at addressing the following research questions:

Q1. What do pre-service primary school teachers understand by inquiry-based science teaching (IBST)?

Q2.1 How do pre-service primary school teachers enact inquiry-based science teaching (IBST)?

Q2.2. What factors influence pre-service teachers' enactment of inquiry-based science teaching?

The study, which was based on the pragmatism paradigm, made use of a case study design to collect both numerical and textual data necessary to address the research question. A case study aims at exploring how people in a particular context "make meaning of a phenomenon of interest" (Nieuwenhuis, 2007c, p. 75). It also enhances an understanding of people's behaviours in a particular context (Baxter & Jack, 2008). Nieuwenhuis (2007c) asserts that the case study design has been used successfully in a variety of situations to "answer 'how' and 'why' questions. In line with the requirements of a case study method, the current study employed a variety of data collecting strategies in order to get a deeper understanding of the research problem (Baxter & Jack, 2008; Nieuwenhuis, 2007c). These comprise a questionnaire, semi-structured interviews, analysis of documents, and classroom observations.

1.5 SIGNIFICANCE OF THE STUDY

While there are a number of studies on teachers' experiences with inquiry-based science teaching, the few from developing countries are limited to countries like Uganda, South Africa and Rwanda (Chabalengala & Mumba, 2012; Mugabo, 2012; Ramnarain & Hlatshwayo, 2018; Ssempala, 2017). Furthermore, these have focused on secondary in-service teachers. Knowledge relating pre-service primary school teachers and inquiry-based science teaching is not available. This is therefore the first study to investigate pre-service teachers' understanding and enactment of inquiry-based science teaching and factors that influence their enactment of this pedagogical approach.

Moreover, among the few education studies conducted in Swaziland centred on science education none of them, to the best of my knowledge, involved inquiry-based science teaching. This is despite the country's science education main goal being to develop a scientifically literate society and the intention of the science being to build up investigative skills and scientific attitudes among learners (Education, 2012). In the context of the existing challenges such as overcrowding of classes, lack of infrastructure and teaching materials, which have escalated since the implementation of the Free Primary Education Act of 2010 (Ministry of Education and Training, 2015), this study is even more imperative if Swaziland is to successfully implement the new competency-based curriculum. The exploratory study will not only shed light on, how pre-service teachers attempt to put into action their understanding under these challenging conditions, but also provide insights on issues that may facilitate or limit the implementation of the competency-based curriculum reform.

The significance of the study has therefore three facets. Firstly, the pre-service teachers stood to gain personally from their participation in the study. The study provided them with opportunities to reflect on inquiry-based science teaching, thereby possibly enhancing their understanding, confidence and implementation of this pedagogical approach in their future teaching. Secondly, the study findings are significant to the researcher and other science teacher educators. Knowledge of how pre-service teachers enact IBST and the factors that shape the manner in which they do, can inform the design and implementation of programmes for developing pre-service teachers' knowledge and enactment of IBST. Thirdly, continuous development of teachers in learner-centred approaches is necessary for the effective implementation of a competency-based education (Ministry of Education and Training, 2018b). The outcomes of this study could indicate some relevant strengths and weaknesses of teachers who enter the profession, and thus inform the planning of appropriate in-service workshops. Moreover, contextual factors affecting the enactment of the inquiry-based approach will be useful input for both education managers and educators on issues that are likely to constrain the implementation of the competency-based education. This knowledge may be valuable in overcoming such constraints (Mugabo, 2012).

In addition to the above, the current study is novel because it concerned primary school pre-service teachers' enactment of IBST in the Swaziland context: a context that has not been previously explored. As such, it extends current knowledge on pre-service teachers' IBST practices by providing information on the extent to which pre-service teachers' engagement with IBST is generalizable or context specific. The application in this study of the inquiry-based science-teaching framework put forth by Furtak et al. (2012), with its detailed categories is novel because the framework has not been used before in exploring teachers' experiences of IBST. The study therefore provides information regarding the usefulness of the framework for this purpose.

1.6 STRUCTURE OF THESIS

The research report in this thesis is presented in eight chapters. The current chapter introduces the study. It presents the background of the study, the motivation and rationale of the study, the questions guiding the study, and its importance.

Chapter 2 describes the theoretical framework of the study and gives an analysis of literature connected to the research. The literature review section includes a description of the meaning of inquiry-based science teaching, its historical background, and a discussion of studies related to teachers' understanding and enactment of this pedagogical method. Chapter 3 presents the conceptual framework of IBST employed in the analysis and interpretation of the pre-service teachers' understanding and enactment of IBST.

Chapter 4 gives details of the methodology of the study. It details the research approach and design, the study participants and the context of the study; and the data collection and analysis methods and processes. The chapter also presents a discussion of methodological standards and ethical considerations.

The research findings are presented in three chapters, corresponding with the research questions. Chapter 5 presents the findings regarding the pre-service teachers' understanding of IBST. Chapter 6 focuses on the pre-service teachers' enactment of IBST, and Chapter 7 addresses the question of factors that influenced the way pre-service teachers enacted IBST. Each of the three chapters presents the analysis of data, the research findings and their discussions. Lastly, Chapter 8 presents the conclusions and recommendations of the study. It also discusses the limitations of the study and suggests future research.

CHAPTER 2

THEORETICAL FRAMEWORK AND THE LITERATURE REVIEW

This chapter examines the literature connected to the study and links it to the theoretical framework supporting the study. The researcher situates the study in the constructivism learning theory, in that it is the theoretical foundation for inquiry-based science teaching and learning. The study also uses this theoretical tool to make sense of the way pre-service teachers develop an understanding of inquiry-based science teaching. In other words, the researcher adopts the theoretical perspective that pre-service teachers "actively construct their own knowledge" about inquiry-based science teaching (Kanselaar, 2002, p. 1). Pre-service teachers construct this knowledge based on their prior beliefs and understanding, and through interaction with the learning environment and the wider society (Amineh & Asl, 2015; Kanselaar, 2002; Key & Bryan, 2001). To tackle the research questions, the study adopts the view of inquiry-based science teaching and learning as presented by Furtak et al. (2012). The researcher describes this conceptual framework in Chapter 3.

2.1 CONSTRUCTIVISM

As already stated, this study seeks to understand pre-service teachers' enactment of inquiry-based science teaching. For this study, the researcher regards inquiry-based science teaching as a pedagogical approach that involves learners in the process of constructing scientific knowledge themselves as they ask and offer answers to scientific questions. Moreover, she holds the view that pre-service teachers construct personal knowledge about inquiry-based science teaching, on the grounds of their prior knowledge, attitudes and experiences, which they later apply when they enact this teaching methodology. Constructivism as a learning theory is a general frame of reference that usefully connects concepts and categories essential in understanding issues related to the construction of knowledge (Karameta, 2013).

2.1.1 Constructivist learning theory

A variety of definitions of knowing and learning arise in constructivist theories. However, there is consensus that learning does not occur passively; instead, learners generate personal knowledge while they actively participate in understanding their experiences. (Serafín, Dostál, & Havelka, 2015; Ültanır, 2012). They all therefore view learners as constructors of their own knowledge than recipients. For instance Ültanır (2012) highlights that learners construct knowledge as they tackle problems. Different forms of constructivism place emphasis on different aspects of the construction of knowledge. Some of these are described next.

Piaget, a cognitive psychologist, puts emphasis on the individual learners as they try to comprehend their experiences. Learning, according to Piaget's perspective, is an adaptive process that involves assimilation and accommodation (Amineh & Asl, 2015; Cakir, 2008; Kanselaar, 2002). Piaget, later supported by Ausubel, proposed that learners generate new understanding on the grounds of knowledge, experiences and beliefs they already have; that is they attempt to assimilate the new experience into an already existing framework (Cakir, 2008; Ültanır, 2012). If, however, the new experience is in conflict with their existing framework, it leads to a cognitive conflict (Cakir, 2008). In order to resolve this conflict, accommodation or conceptual change must occur. Accommodation is a process by which a learner creates new cognitive structures or reorganises existing ones in order to fit in with the new experience (Amineh & Asl, 2015; Cakir, 2008). As Cakir (2008) therefore argues, learning is easier when new concepts relate well to existing knowledge structures. Some scholars (Keys & Bryan, 2001; Van Dusen, Ross, & Otero, 2012; Wilson & Peterson, 2006) believe it is of limited value so other constructivist theories need to be examined as well.

Social-cultural constructivism, as framed by Vygotsky in 1978, offers another valuable theoretical lens for understanding learning. Vygotsky highlights the role of language and culture in one's cognitive development and meaning making and, thus, contends that "knowledge is constructed first in a social context" before being assimilated and implemented by individuals (Amineh & Asl, 2015, p. 14). Proponents of social-cultural constructivism therefore view learning as a social process and argue that individuals form knowledge as they interact with each other and their environment (Amineh & Asl, 2015; Keys & Bryan, 2001; Kim, 2001; Ültanır, 2012). Consequently Keys and Bryan (2001) highlight that the understanding of the social and cultural context is crucial in understanding the meaning people make of a phenomenon.

Another aspect of Vygotsky's theory is that it regards learning as a continuous progression to higher levels of understanding, according to a learner's potential. This progression occurs within what Vygotsky termed the "zone of proximal development (ZPD)" (Amineh & Asl, 2015, p. 15). The zone of proximal development is, according to Vygotsky, the gap between a learner's actual intellectual level judged by means of his or her independent problem solving ability, and the potential intellectual level judged on what that he or she can achieve only under the guidance of an adult or in collaboration with others (Amineh & Asl, 2015). Accordingly, social constructivists regard guided social conversations, discussions, collaborations, and debates as crucial for learning (Kim, 2001; Tam, 2000; Wilson & Peterson, 2006). Kim (2001) argues that "young children advance their intellectual abilities as they intermingle with more knowledgeable others and" emphasizes that without this guidance, "it is impossible to acquire social meaning of important symbol systems and how to use them" (para.15).

2.1.2 Constructivist learning theory and development of teacher competencies related to IBST

A number of scholars (Keys & Bryan, 2001; Mugabo, 2015; Ssempala, 2017; Wallace & Kang, 2004) regard both the cognitive and socio-cultural lenses as necessary for understanding teachers' construction of knowledge and abilities related to inquiry-based science teaching. Based on both these perspectives about learning, the researcher holds the view that pre-service teachers form personal interpretations of inquiry-based science teaching according to their prior knowledge, experiences and beliefs (Amineh & Asl, 2015; Keys & Bryan, 2001). However, in line with Vygotsky's, social-cultural theory, the study also regards individual pre-service teachers' learning about IBST as being mediated by not only their social interactions, with both their tutors and colleagues within the teaching and learning space but also by the broader socio-cultural environment in which they learn (Amineh & Asl, 2015).

Beliefs are the main factor influencing the construction of meaning according to Wallace and Kang (2004). Beliefs are "psychologically held understanding, premises or propositions about the world that are thought to be true" (Philip, 2007, p. 259). Wallace and Kang (2004) assert that beliefs and values "fall into patterns that involve assumptions and choices about meaning based on simple models of the world" (p. 938). Based on this assertion, the researcher contends that participant pre-service teachers can form different meanings of inquiry-based science teaching as influenced by varying social and cultural beliefs and values. They may, however, also exhibit mutual understanding stemming from some shared beliefs and experiences within their socio-cultural settings and from interactions with teacher educators and colleagues within the classroom setting.

In line with the socio-cultural theory, the researcher is, moreover, of the view that external socio-cultural factors in the different schools where pre-service teachers carry out their teaching practice also influences their constructs about and execution of inquiry-based science education. "Just like in the development of species in evolution only those species that are best adapted to the environment survive, knowledge constructions are viable if they prove useful to the constructor" in their different contexts" (Duit, 1996, p. 42). Similarly, Dudley-Marling (2012) assert that learning to practice in a social context demands coordinated practice among members of the social community and it is thus the coordinated activity that is learnt. They equate the teaching and learning interaction to a dance in which both pupils and learners participate, and which is mediated by various background aspects, for instance, the curriculum, school policies, the culture of the school and the classroom. They point out that in the classroom, different moves, by either the learner or the teacher always influence the form of the dance and consequently shape the identities of the participants. What the teacher or the learner subsequently learn are particular moves or practices that count as learning in the classroom. From this perspective, learning how to teach by IBST cannot be regarded as only a personal construction that depends on the pre-service teachers' cognitive activity; rather, it is a "coordinated activity in, with, and emerging from a socially and culturally constructed world" (Dudley-Marling, 2012).

2.2 INQUIRY-BASED SCIENCE TEACHING

The current study explores the understanding and enactment of inquiry-based science education among a group of pre-service teachers in one university in Swaziland. The study also seeks to understand factors that influenced the way pre-service teachers enacted this pedagogical approach during their final year teaching practice in schools. Inquiry-based science teaching is the major concept of the study. This section therefore attempts to elucidate the meaning of this concepts and its development.

2.2.1 The meaning and goals of inquiry-based science teaching (IBST)

The term ‘inquiry’ in science education has two main meanings. One meaning is synonymous with scientific inquiry, which denotes what “scientists do to learn about the natural world”. According to the National Research Council (NRC) (1996), the process of scientific inquiry involves a number of features, which includes:

> Making observations, posing questions, examining books and other sources of information, to see what is already known; planning investigations; reviewing what is already known in the light of available empirical evidence; using tools to gather and analyse evidence; and interpret data; proposing answers, explanations; and communicating the results. (p. 23)

Another meaning for ‘inquiry’ refers to an approach in science education whereby learners are engaged in activities that resemble the investigative nature of science (Anderson, 2002; National Research Council (NRC), 1996). The following statement illustrates this dual meaning of inquiry:

> Scientific inquiry refers to the diverse ways by which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world (National Research Council (NRC), 2000, p. 23).

While acknowledging the concept of inquiry-based science teaching, Kyle (1980), however, contends that only individuals who have gained “a broad critical knowledge of the subject matter as a result of formal learning processes” (p. 123) can engage in scientific inquiry and since learners are still in the process of developing this knowledge, they cannot do science. Similarly, some scholars use the human cognitive architecture models to argue against the idea that learners can learn science by engaging in scientific inquiry (Clark, Kirschner, & Sweller, 2012; Kirschner, Sweller, & Clark, 2006). These scholars argue that abilities to understand the features of a situation and to quickly ascertain what to do and how to do it are linked to how much relevant information one has in his or her long term memory; and they point out that learners do not yet possess such knowledge.

These arguments about IBST indicate that for successful enactment of IBST, an explanation of this pedagogical approach is of utmost importance. Currently, however, there is no agreement among science education scholars regarding the meaning of inquiry-based science teaching (Furtak et al., 2012; McCOnney, Oliver, Woods-McConney, & Schibec, 2014; Mokiwa & Nkopodi, 2014; Mugabo, 2015). As a result, McCOnney et al. (2014) observe that enactment of IBST indicates an association between this pedagogy and various forms of learner-directed or active learning instructional strategies, which include “practical work, discovery learning and collaborative group activities” (p. 5). Uno (1999), for example, asserts that IBST is a combination of “hands on and minds-on activities with student-centred discussions and discovery of concepts” (p. 47). Cobern et al. (2010), however, emphasize the portrayal of the discovery nature of science and point out that, it is this aspect that sets IBST apart from other active learning instructional strategies.

In addition to the various interpretations of inquiry-based science teaching, Lederman, Lederman, and Antink (2013) assert that the purposes of teaching science in this manner have also been unclear in many previous science curriculum documents. The review of literature, however, generally reveals three main goal of teaching science by inquiry. Firstly, IBST can target developing learners’ ability to carry out scientific inquiry or their inquiry skills (Anderson, 2002; Harris & Rooks, 2010; Lederman et al., 2013), their understanding of scientific inquiry (Abd-El-Khalick et al., 2004; Anderson, 2002; Bianchini & Colburn, 2000; Harris & Rooks, 2010) or their understanding of science concepts (Harris & Rooks, 2010; Lederman et al., 2013; Marshal & Dorward, 2000). In addition to developing these aforementioned competencies, it is believed that, unlike rote learning, inquiry based pedagogical approaches have the potential of enhancing learners’ abilities to think analytically and resolve problems (Anderson, 2002; Bodzin & Mitchell, 2003); these are the skills desirable for daily life and work in the 21st century (NRC, 2000).

Variations in terms of learning goals and learners’ cognitive level have led to forms of inquiry that differ in terms of the amount of direction a teacher provides or what the teacher leaves to learners to define (Furtak et al., 2012). For example, by building on the work of other scholars Bell, Smetana, and Binns (2005) present a model of IBST consisting of four levels of experiences *open, guided, structured* or *confirmatory inquiry*. On this spectrum of levels, *open or independent inquiry* refers to the most learner-centred approach of science instruction because learners are involved in first selecting a problem, and then designing and conducting their own research to address the problem. In *guided inquiry,* which represents the second level of inquiry learning activities, the teacher selects the research question, but then learners decide on the data they need to address it. The third level of inquiry based instruction, according to this model, is *structured or directed inquiries,* in which the teacher decides on a research question and how to answer it, but the learners do not know the answer beforehand. *Confirmatory experiences* are the lowest level of IBST, in which learners follow prescribed procedures to confirm principles that are already known. In all the different activities, including open inquiry, the teacher acts a guide, directing learners as they carry out their different roles.

A comprehensive range of inquiry-based science pedagogies or teaching activities based on varying levels of teacher direction and learner mental engagement has been developed by Wenning (2005), based on previous work, such as Colburn (2000) and Herron (1971), as illustrated in Table 2.1.

Table 2.1 A basic hierarchy of inquiry-based science teaching

Discovery Learning	**Interactive Demonstration**	**Inquiry Lesson**	**Inquiry Lab**	**Hypothetical Inquiry**
Low	⟵	Intellectual sophistication	⟶	High
Teacher	⟵	Locus of control	⟶	Learner

(Wenning, 2005)

With the view that goals of science instruction often determine the chosen level of inquiry-based science teaching, Wenning (2011) provides a description of the purpose of each of the five levels of inquiry, he defined. In *discovery learning,* teaching aim to allow learners to find out knowledge themselves, based on teacher-directed experiences. In *interactive demonstrations,* teachers engage learners in generating predictions and explanations, which may reveal learners’ non-scientific ideas about a phenomenon, after which, teachers present experiences to facilitate conceptual change. *Inquiry lessons and labs* aim at providing opportunities for an active role as learners work in collaboration with others in constructing scientific principles or relationships based on their own hands-on investigations. In hypothetical science, learners work more independently, but collaboratively in proposing explanations for natural phenomena.

In this section, the researcher has shown the meaning of inquiry-based teaching in the science classroom according to the science education literature. It has indicated that different writers highlight different goals of teaching science, which leads to variations in the meaning attached to inquiry-based science teaching. In line with the Swazi science schooling programme which emphasizes both science content and process skill development, in this study, IBST refers to a teaching approach whereby, in the context of investigative learning activities, students are guided in answering questions or constructing meaning for scientific concepts and processes. (Beere & Bodzin, 2004; Bell et al., 2005; Cobern et al., 2014; Eick & Reed, 2002; Prince & Felder, 2006; Sproken-Smith, 2012). These activities vary are not necessarily identical to long-term investigations carried out by scientists (Eick & Reed, 2002). However, activities that engage learners in proving what has been prior presented to them by direct instruction are no, in this study regarded as a form of IBST (Cobern et al., 2010; Prince & Felder, 2006). Therefore, the basic feature of IBST is that learners should construct knowledge themselves by means of their exploration. Rather than regarding science processes and knowledge as separate domains, IBST provides learners with an opportunity to reflect on and apply scientific knowledge in a way that promotes both their conceptual understanding, science process skills and how scientists employ scientific processes to develop knowledge about the natural world (Harris & Rooks, 2010).

2.2.2 The historical background of inquiry-based science teaching

2.2.2.1 Introduction

This section depicts the origin and the growth of IBST. It shows that the concept of IBST has evolved over a period of many years since its origin in ancient times to today’s conceptualization of IBST as engagement of learners in scientific inquiry practices. The presentation is thus in four sub-sections: the origin of IBST, the work of John Dewey, the learning cycles, and finally learning about scientific practices.

2.2.2.2 Ancient origin of inquiry-based science teaching approaches

Inquiry as a way of understanding the natural world and learning is considered to have originated in around 450 BC with the questioning method used by Socrates, the Greek philosopher. He would engage other orators in well-organized questioning with the aim of unearthing basic truths about the natural world and some moral questions (Friesen & Scot, 2013). Socratic inquiry, commonly known as the Socratic Method, unlike traditional teaching methods where the more knowledgeable person transmits information to a less knowledgeable individual, “uses questions to engage students in a dialogue that helps to examine the values, principles and beliefs of students” (Reich, 2003, p. 2). Thus both teacher and students are involved in asking and answering probing questions focused on clarifying basic assumptions regarding what is viewed as truth (Friesen & Scot, 2013). Therefore Reich (2003) highlights that “the Socratic teacher is neither the sage on the stage nor the guide on the side”, but both the teacher and student are interactively engaged in the inquiry” (p. 1).

2.2.2.3 The work of John Dewey: empirical methods as an instructional approach

While the spirit of inquiry started in ancient Greece, the term inquiry itself originated in the middle of the 13th century through the Latin word “inquirere” which in the literal sense, means to seek for (Friesen & Scot, 2013). Nevertheless, traditional beliefs or superstitions about natural phenomena were common until empirically based answers became more popular in the Europe in the 16th century. This was prompted by not only the availability of suitable technologies, such as the sealed containers for Antoine Lavoisier, but principally a change in the worldview. Such modern thinking became more prominent during the European Enlightenment, beginning in the 18th Century (Friesen & Scot, 2013).

The use of empirical methods or scientific discovery as a primary teaching strategy in the science classroom was first proposed by the educational philosopher John Dewey at the beginning of the 20th century (Barrow, 2006; Friesen & Scot, 2013; Won, 2009). Dewey observed that frequently teaching of science was mainly focused on transmitting facts to learners with little or no emphasis on promoting scientific thinking skills and attitudes (Barrow, 2006; Duran & Duran, 2004). Persuaded by his conception of “science as a way of thinking and an attitude of mind rather than a body of knowledge” (NRC, 2000), Dewey moved science educators to embrace an inquiry-based method to teaching science (Barrow, 2006; Friesen & Scot, 2013). As a rationale for the promoting inquiry-based science teaching, Won (2009) quotes Dewey's direct words:

> The future of our civilization depends upon the widening spread and deepening hold of the scientific habit of mind; and that the problem of problems in our education is therefore to discover how to mature and make effective this scientific habit. (p. 78)

In 1916, Dewey, similarly to Socrates, pointed out that the teaching of science should not be the end in itself but should be a means of developing students' personal knowledge, which they could use to address everyday life challenges and he therefore suggested that learners' inquiries should address questions that are of interest to them (Barrow, 2006; Friesen & Scot, 2013). Nevertheless, Friesen and Scot (2013), caution that inquiry based teaching, according to Dewey, does not imply a completely unguided scenario. Instead, the teacher should guide learners in their empirical investigations in order that they construct new knowledge. Dewey further emphasized the importance of ensuring that students are engaged with problems that are within their mental capabilities, so that they would be actively involved in their investigations (Barrow, 2006). Dewey's model of inquiry-based science teaching consists of six steps: "sensing perplexing situations, clarifying the problem, formulating tentative hypotheses, testing the hypotheses, revising them with vigorous tests and finally acting on the solutions" (p. 266). This model, according to Bybee et al. (2006) later formed the basis for reforms proposed by the 1938 report: *Science i*n *General Education* (p. 5)

In 1944, Dewey revised his model to a one that was more in line with his philosophy about thinking, and this model consisted of only four phases: "*presentation of a problem, formation of a hypothesis, collecting data* and *formulating a conclusion"* (Barrow, 2006). According to Bybee et al. (2006), the revised model's emphasis on reflective thinking implies that even though sometimes Dewey's work is frequently associated with the promotion of learners' hands-on and empirical experiences, he regarded such experiences, by themselves, as not being enough to promote learning. Dewey regarded a teacher as a guide who direct learners while they make meaning of the natural world through reflecting on their experiences by interaction with others (Sikandar, 2015).

2.2.2.4 John Schwab and the establishment of inquiry in the science classroom

Though the idea to bring inquiry into the classroom was raised by Dewey, the actual establishment of inquiry as a suitable pedagogy in science education was a result of the influential voice of John Schwab in 1960 and 1961 (Garritz, Labastida-Pina, Espinosa-Bueno, & Padilla, 2010). Schwab proposed that students should view science as a succession of human interpretations of natural phenomena that are subject to change in light of new evidence. He therefore proposed an inquiry-based approach to teaching science (Barrow, 2006). For inquiry-based learning (IBL), teachers should use laboratory activities to help students construct and revise their understanding of science concepts on the basis of evidence, instead of merely using laboratory activities to verify previously taught science content (Garritz et al., 2010). Schwab also emphasised that students should not just learn science content, but should in addition learn about scientific inquiry itself (Barrow, 2006). Schwab was interested in school science that portrayed real science, or as (Chabalengula & Mumba, 2012, p. 307) put it: "*engaging learners in posing questions, designing and executing scientific procedures, analysing and interpreting data, and forming conclusions*" Schwab therefore seemingly regarded classroom inquiry "as both a means as well as an end" (Abd-El-Khalick et al., 2004). Consequently, the work of Schwab and Dewey, along with others such as Piaget, greatly influenced the nature of curriculum materials that were developed from the 1950s up to the early1970s (Barrow, 2006).

Launching of the Sputnik by the Russians in 1957 further promoted new science education developments in the west, for example those by the National Science Foundation (NSF) (National Research Council (NRC), 2000). Inquiry was also one of the areas promoted by Project Synthesis, an amalgam of three NSF sponsored projects. In line with Schwab's views, Project Synthesis viewed inquiry as both content that teachers and students should learn as well as a teaching approach that teachers should use in the classroom to help students learn science concepts. The Project Synthesis report showed three categories for students' learning outcome with regard to inquiry "science process skills, nature of scientific inquiry, and general inquiry process" (Barrow, 2006).

2.2.2.5 The inquiry learning cycles

In the 1950s, a scientific approach to curriculum development followed the launching of Sputnik. Robert Karplus and his co-workers began to prepare teaching theories based on Piaget's cognitive theory. Following this work, they identified the need for an instructional tool that would allow them to translate their idea into classroom tradition. Karplus and his co-worker, Myron Atkins first named the learning strategy guided discovery. Then in 1967 Karplus and Herbert Thier first coined the term learning cycle (Ssempala, 2017).This learning strategy, called the Science Curriculum Improvement Study (SCIS) learning cycle, consisted of three phases: "*preliminary exploration, invention and discovery*" (Bybee et al., 2006, p. 7). According to Fuller (2003), this learning cycle was very effective in converting the pedagogy in science classrooms from textbook-based teaching to hands-on experiences. In this cycle, the exploratory phase provides learners with unstructured experience for the purpose of collecting information about some phenomenon, followed by invention, where learners learn the definitions and terms of new concepts related to the particular phenomenon, and finally during discovery, learners apply the concept to new but related contexts (Bybee et al., 2006; Ssempala, 2017).

In the 1980s, Lawson and others slightly modified the phases to exploration, term introduction and concept application, as being more representative of what takes place in each phase, according to (Bybee et al., 2006). Around the same period, Bybee et al. added two new phases on Karplus' instructional model and developed the BSCS 5E instructional model consisting five phases: *engagement, exploration, explanation, and elaboration* and *Evaluation.* Table 2.2 below compares and contrasts the SCIS and BCSC 5E instructional models. This comparison shows that the three middle phases of the BCSC are in fact equivalent to aspects of the SCIS learning cycle.

Table 2.2 *The SCIS and the BCSC 5E instructional models*

SCIS model	**BCSC model**
	Engagement (New phase)
Exploration	Exploration (Modified from SCIS)
Invention (Term definition)	Explanation (Modified from SCIS)
Discovery (Concept application)	Elaboration (Modified from SCIS)
	Evaluation (New phase)

(Bybee et al., 2006, p. 8)

The two new phases are engagement and evaluation. Engagement is about eliciting learners' ideas and drawing from learners' prior knowledge, while evaluation involves assessment of learners' understanding and providing them with feedback, which takes place during all of the phases as shown in Figure 2.1. The diagram also shows that teaching within the 5E model does not always move from one phase to the next in one direction but can also move backward whenever there is need (Duran & Duran, 2004). The three middle phases are, as mentioned, equivalent to those of the SCIS model. While engagement allows for cognitive dissonance or uncertainty, the exploration phase then initiates the process of equilibration. During exploration, learners get an opportunity to investigate the ideas revealed during the engagement phase. The purpose of the explanation phase is to help learners make sense of the engagement and exploratory phases. The first stage of this phase involves learners providing their own explanations, following which the teacher presents them with explicit scientific or technological definitions and clarifications. The 5E-model has provided a foundation for many science-teaching resources such as the Full Option Science System (FOSS) and the Science Teaching Centre (STC), (McHenry & Borger, 2013).

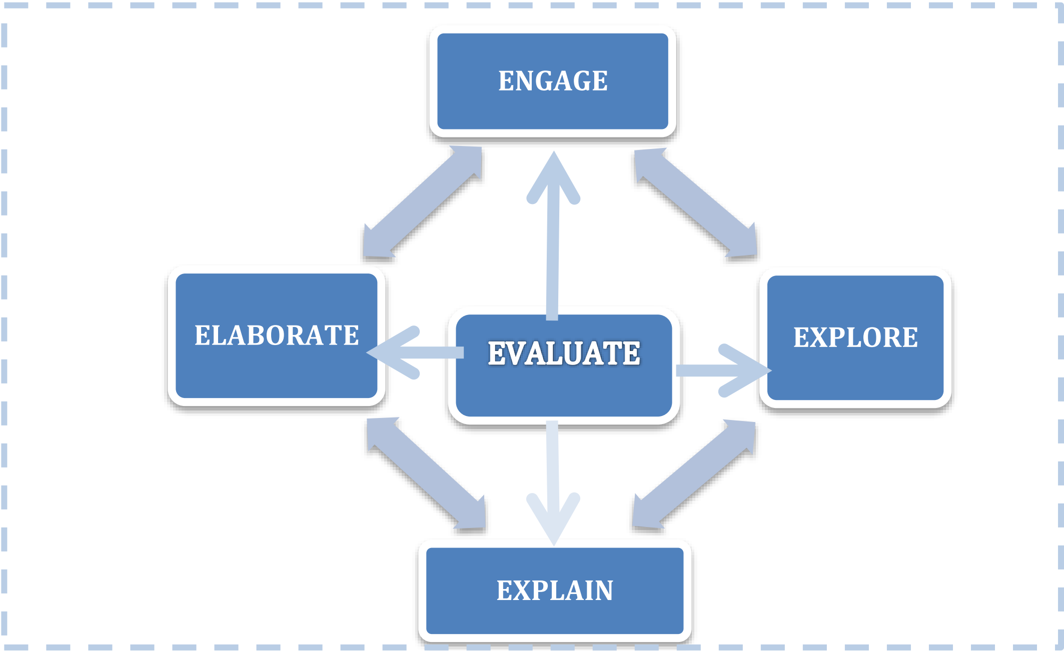

Figure 2.1 *The 5E instructional model with its 5 phases* (Duran & Duran, 2004, p. 52)

2.2.2.6 Defining IBST in terms of scientific practices

Current scholars in the 21st century, such as (Hattie, 2009; Keselman, 2003) emphasize that the central goal of teaching science using inquiry as being engagement of learners in scientific activities. Keselman (2003) for example, defines inquiry-based learning as engagement of learners in "activities and methods similar to those carried out by scientists" (p. 892). Hattie (2009), in defining this pedagogy, provides a list of the scientific practices that learners must participate in when they learn science by inquiry, as follows:

> An approach to teaching science that engages learners in observing and questioning phenomena; posing explanations of what they observe; devising and conducting investigations in which data are collected to support or contradict their theories; analysing data; drawing conclusions from experimental data; designing and building models; or any combination of these (p. 208).

Similarly, several recent standard documents have called for science classrooms to move from emphasizing the facts of a discipline and called for inquiry that stresses scientific processes and how the scientific way of knowing operates. The National Research Council

(2012), in describing its vision for science education, points out that during their school years K-12 learners should actively engage in scientific practices in order to learn these practices. As noted below in Table 2.3, while earlier standards (National Research Council, 1996; 2000), referred to abilities to perform inquiry, the K-12 framework (National Research Council, 2012) presents a list scientific practices in which learners must engage.

Table 2.3 *A comparison of abilities to do inquiry (NRC, 1996, 2000) and scientific practice (NRC, 2012)*

Scientific inquiry abilities IBST (NRC, 1996; 2000)	**Science practices (NRC, 2012)**
Define investigation-based questions	Posing questions
Design and conducting investigations	Planning and conducting investigations
Use relevant tools and methods to analyse and interpret data	Analysing and interpreting data
Give evidence-based descriptions and explanations, predictions and models	Developing and employing models
Involve critical and logical thinking to connect evidence to explanations	Engaging in evidence-based arguments
Recognize alternative explanations and predictions	Creating explanations
Communicate scientific procedures and explanations	Obtaining, evaluating, and communicating information
Employ mathematics in all aspects of scientific inquiry	Using mathematics and computational thinking

(Ssempala, 2017, p. 29)

Looking at Table 2.3, it may appear that there is little difference between the scientific practices as described by the National Research Council (2012) and inquiry skills. However, the National Research Council (2012) clearly points out the difference: “We use the term practices instead of a term such as ‘skills’ to emphasize that engaging in scientific investigations requires not only skills, but also knowledge that is specific to each practice” (p.30). Therefore, from this perspective, the goal of inquiry-based science teaching is not only for learners to experience science and gain scientific inquiry skills, but also to promote their understanding of the practices that scientists do to when carrying out their work, and the character of the scientific knowledge generated (National Research Council, 2012). It is based on the curriculum framework (NRC, 2012) that the latest science standards, known as *The Next Generation Science Standards: For States by States (NGSS)* were developed (National Research Council, 2013). These standards articulate more clearly the performances: the knowledge and skills learners are expected to demonstrate when learning science (NRC, 2013). In addition, the new standards also lay more emphasis on modelling and argumentation, which are two aspects that were understated in previous standards (National Research Council, 2013). These two aspects are essential in developing learners' inquiry abilities, and their appreciation of science concepts and the epistemology of science (National Research Council, 2012).

This section therefore has served to highlight the origin and development of inquiry in science education. It has clarified the rationale for inquiry-based science teaching and the key historical figures associated with this pedagogical approach. Moreover, it has shown that the meaning of IBST has developed over the years from viewing IBST as performance of scientific inquiry to learning of science concepts and currently to teaching the practices of science, which incorporates the inquiry skills, the epistemological and conceptual understanding of science. In the next subsection, the researcher attempts to describe teachers' understanding of inquiry-based science teaching.

2.3 RESEARCH ON TEACHERS' UNDERSTANDING OF IBST

Teachers' understanding of the IBST pedagogical approach would appear to be critical for their enactment of inquiry-based science teaching (Abd-EL-Khalick, 2012; Capps, Shemwell, & Young, 2016; Kang, Orgill, & Crippen, 2008). In this study, teachers' understanding of IBST refers to their constructed knowledge of IBST, consistent with the constructivist perspective about learning (Mokiwa & Nkopodi, 2014; Wallace & Kang, 2004). Unlike beliefs, knowledge is "rational, well-defined and based on evidence" (Crawford, 2007, p. 616). Ozel and Luft (2013) assert that teachers' knowledge of inquiry-based instruction includes their "understanding of scientific inquiry, and how to enact it in the classroom" (p. 308).

This section describes current research findings regarding teachers' understanding of inquiry-based science teaching. Section 2.3.1 describes pre-service and beginning teachers' understanding, while 2.3.2 focuses on experienced teachers' understanding of IBST. The last section 2.3.3 provides a summary on teachers' understanding of IBST.

2.3.1 Pre-service and beginning teachers' understanding of IBST

Pre-service and beginning teachers, unlike experienced teaches, are still developing their knowledge for teaching, which includes their content knowledge, pedagogical knowledge about learners' capabilities, and how learners construct knowledge (Schwarz, 2009). This section seeks to provide insights from previous studies regarding this group of teachers' understanding of IBST.

The study of literature shows that several studies have explored the subject of pre-service or beginning teachers' understanding of IBST employing varying research approaches. Crawford (2007) used a qualitative approach to explore five American high school pre-service teachers' understanding of IBST over a period of one year of teaching, in which they had been guided by trained in-service teachers. The findings indicate that the pre-service teachers had a range of understanding, ranging from naive to more informed. The study also found that pre-service teachers' construction of inquiry-based science teaching shaped their enactment of this pedagogy.

Ozel and Luft (2013) assessed American beginning teachers' understanding of IBST at the commencement and towards the completion of their first year of teaching. The 44 teachers had been exposed to at least one science methods course and most (41) possessed a bachelor degree. The authors however, do not provide any information regarding the group's past experiences with inquiry-based science teaching or any factor that could have affected their understanding of this pedagogical approach. Examination of the interview data showed that, like the pre-service teachers in the study by Crawford (2007), the group's understanding of IBST had not improved during the first year of their teaching. They focused on only two of the essential features of IBST documented in the National Science Education Standards when describing IBST. Both before and after one year of teaching, they described it mainly in terms of posing "scientific questions and giving priority to evidence" (Ozel & Luft, 2013, p. 308). In both their pre-and post-teaching interviews, they also demonstrated a more teacher-directed view of this pedagogy, as shown by no mention of involvement of learners in designing investigations. Ozel and Luft (2013) concluded that beginning teachers need to be inducted into required competencies, including an appropriate understanding of IBST.

A similar study by Binns and Popp (2013) explored how a group of seven American secondary pre-service teachers defined inquiry-based science teaching. The participants were engaged in one-year Master of Arts teaching programme. At the beginning of the teaching practice exercise, in their definitions of IBST they referred mainly to only two essential features: posing science questions and giving priority to evidence. They varied in their understanding of learners' responsibility in IBST. With regard to the question feature, three characterized IBST with learners addressing their own questions, two with learners answering teacher-given questions, and the rest of the participants regarded every learning activity that gives precedence to evidence in addressing a question as inquiry-based, regardless of the source of the question. Others also associated learners' responsibility in IBST with either one or both of these inquiry activities: learners collecting data themselves and learners creating their own answers to questions.

These descriptions of IBST remained the most popular features in their discussion about IBST even after the teaching placement and the methods course. So these teachers had a similarly limited understanding of the IBST pedagogy as had the participants in Ozel and Luft (2013). The Binns and Popp (2013) paticipants, however, also mentioned some new features after placement: they associated IBST with discovery learning and with learners' participation in the activities of scientist. These findings indicate that the methods course did not have sufficient impact on what the pre-service teachers regarded as essential features of IBST. However, similarly to Ozel and Luft (2013), the authors did not give details about the content of the science methods course other than that pre-service teachers learnt IBST as one of the strategies for teaching science. The lack of focus on IBST during the course, as implied in the author's statement that enactment of IBST was not one of the requirements for passing it, could be the reason for the lack of improvement in the pre-service teachers' understanding of IBST.

In contrast with the three studies described above, other research (Lee & Shea, 2016; Plevyak, 2007; Schwarz, 2009) indicates the potential of a science methods course focused on enhancing pre-service elementary teachers' understanding of the inquiry-based pedagogical approach. To elaborate, in a more recent study by Lee and Shea (2016), 54 American pre-service primary teachers were able to display adequate understanding of IBST after their engagement in different levels of inquiry activities, within their science methods course. In their pre-test questionnaire the pre-service participant teachers, in the same way as participants in the study by Ozel and Luft (2013), had described IBST only in terms of asking questions and carrying out hands-on activities. However, after their engagement with different levels of inquiry activities, they provided detailed descriptions of the pedagogical approach. For example, they characterized the questions posed in IBST as "investigative or explorative" (Lee & Shea, 2016, p. 229). Plevyak (2007) found that 52 American early childhood education pre-service teachers' understanding of IBST improved after implementing inquiry-based science teaching within their 10 weeks-long science methods course. They moved from initially associating IBST with only hands-on experiences to later regarding it as questioning and development of learners' thinking about why things happen. Moreover, at the end of the intervention, they also associated IBST with teachers motivating learners to pose their own questions, while in the pre-test; they only referred to questions posed by the teacher. Schwarz (2009) used a modelling centred inquiry-based programme to enhance American pre-service elementary teachers understanding of model-based inquiry-based science teaching. The modelling framework was adapted from the BCSC 5E instructional model by Bybee (1997) and incorporated scientific practices as outlined in the framework for K-12 Science Education (NRC, 2012). Their findings showed that at the completion of the programme participants were more aware that IBST involves conducting investigations and creating evidence-based explanations.

In line with the constructivist learning theory, the six studies reviewed above (Binns & Popp, 2013; Crawford, 2007; Lee & Shea, 2016; Ozel & Luft, 2013) indicate that pre-service and beginning teachers have an understanding of IBST which is, at best, only partially or, at worst, is completely incompatible with the representations of the construct in reform documents. However, three of the reviewed studies indicate that participation in an inquiry-based curriculum can augment their understanding. Lee and Shea (2016) also highlight that explicit discussions of features of this pedagogical approach after exposing teachers in inquiry activities can greatly improve participant teachers' understanding of IBST.

The review of literature also indicates that a significant number of the studies on pre-service teachers' understanding of IBST took place in the United States. This review therefore indicates that there has been little research on pre-service teachers' understanding of IBST in other countries. Moreover, most of the reviewed studies do not provide details of the background of study, most importantly, the content of the teacher education programme that teachers and the science curriculum they had been exposed to. Such knowledge would be useful in making sense of teachers' construction of inquiry-based science teaching.

2.3.2 Experienced teachers' understanding of IBST

For the purpose forming a better meaning of pre-service teachers' understanding of IBST, the researcher thought it would be worthwhile to also find out how these constructions of IBST relate to those of more experienced counterparts. Furthermore, the review includes studies conducted in both developed countries and developing countries in order to compare the two groups' conceptualization of IBST.

A phenomenological study among Australian elementary teachers' was carried out by Ireland, Watters, Brownlee, and Lupton (2012), where they asked teachers to describe a lesson they had taught, which in their view, was representative of their best inquiry-based lesson. The analysis of the interview data focused more on what appeared central in their description of their inquiry-based lessons. It was found that participants' conceptualization of inquiry-based science teaching could fit into three main categories of understanding: "experience-centred, problem-centred, and question-centred understanding" (p. 159).

An experience-centred understanding, which represents the most naive of the three categories of understanding, is an association of IBST with learners' direct experiences with the phenomenon under study. They regarded these direct experiences as necessary to stimulate learners' curiosity and to engage them in their own learning. Teachers falling within the experience-centred understanding of IBST do not regard questions as important in driving inquiry-based lessons. Instead, they are likely to regard confirmatory hands-on activities as inquiry-based. Teachers' experience-centred construction of inquiry-based science teaching could be the reason why Asay and Orgill (2010) found that only a small proportion of inquiry-based lessons focused on a driving question.

Teachers holding a problem-centred understanding of inquiry-based science teaching are those that view inquiry as activities that involve students in addressing teacher-initiated questions. Inquiry-based lessons designed with this understanding of inquiry in mind focus on a question that the teacher wants learners to answer. The teachers categorized as holding a question-centred understanding as defined by Ireland et al. (2012) however regarded inquiry-based science teaching as learning activities that address learner-initiated questions. This group of participant teachers argued that such learning activities are useful in motivating and engaging students with science content and materials.

A problem-centred perspective was also held by most of the participant in-service teachers in the study by Lotter, Harwood, and Bonner (2006). The study revealed that most teachers prior to participating in a professional developmental programme viewed inquiry-based teaching as involving learners in activities where they seek solutions to problems, with the teacher neither providing them with answers nor with a method of solving the problem. Participants viewed the teacher as the facilitator; presenting students with the problem or question to engage with. However, in conflict with this seemingly more learner-directed view of IBST, most of the participants in Lotter et al. (2006), also believed that providing learners with background information was an essential element of such IBST. The participant teachers believed that teacher should furnish this information by means of lectures or questioning sessions, before learners engage in inquiry activities.

Moreover, more in line with direct instruction, the participants in the study by Lotter et al. (2006) associated inquiry-based learning with the employment of traditional knowledge resources: they regarded textbooks and the internet as sources of answers to problems or questions. Only one of the teachers regarded learners' minds with their prior experiences as important resources in inquiry-based learning. Moreover, similarly to Ireland et al. (2012), participants in Lotter et al. (2006) did not say anything regarding teachers' acknowledgment of the need to give priority to evidence in solving problems or answering questions. Participant teachers were however able to provide comprehensive definitions of IBST after participating in a professional development programme aimed at enhancing their ability to implement this teaching approach. In their post-development definitions of IBST, the teachers included the use of more open-ended and student-centred approaches than they had prior to the programme. In line with the problem-centred understanding of inquiry-based science teaching held by some teachers in the study by Ireland et al. (2012), these teachers pointed out that inquiry could effectively cover prescribed content as long as students address teacher questions that connect to the school curriculum. Their study therefore highlights the utility of programmes focused on developing teachers' understanding of IBST as one of the crucial strategies for promoting the execution of this pedagogical approach.

A number of other studies on in-service teachers' understanding of inquiry-based science teaching (Capps et al., 2006; Chabalengula & Mumba, 2012; Kang et al., 2008) used the essential characteristics of IBST (National Research Council (NRC), 2000) as a framework for judging participant teachers' understanding of IBST. To be specific, Kang et al. (2008) used a teaching scenario-based questionnaire to assess in-service teachers' understanding of characteristics of IBST. They found that teachers mainly associated IBST with only three of the characteristics of IBST (NRC, 2000). They talked about learners' "engaging with scientifically oriented questions, giving priority to evidence and developing explanations based on evidence" (Kang et al. 2008, pp. 344-345). With regard to learners' responsibility in IBST, they mainly associated IBST with learners creating answers or conclusions themselves.

Most of the studies described above pertaining teachers' understanding of characteristics of IBST took place in developed countries. However, a review of similar studies in developing countries (Chabalengula & Mumba, 2012; Mokiwa & Nkopodi, 2014, Mugabo, 2015; Ssempala, 2017) indicates similar results. Teachers from developing countries, generally, harbour varied and insufficient understanding of IBST. To illustrate, Mugabo (2015) in his mixed method study, revealed that 150 Rwandan lower secondary school tended to describe the IBST pedagogical approach in terms of only two of the five essential features of inquiry (National Research Council (NRC), 2000). Qualitative studies by Chabalengula and Mumba (2012), Mokiwa and Nkopodi (2014), and Ssempala (2017) yielded similar results. Mokiwa and Nkopodi (2014) found that some experienced South African teachers associated inquiry-based science teaching only with experimentation. Similar to participants in developed countries, the characteristic of connecting explanation to scientific knowledge was either not cited at all, or only mentioned by very few participants in each study. Thus the studies indicate that teachers do not associate IBST with learning of science concepts (Kang et al., 2008).

2.3.3 Summary of teachers' understanding of IBST

The result of the review of literature indicates that teachers hold varying and often naïve or inadequate understanding about inquiry-based science teaching. The review also indicates little difference between pre-service teachers and experienced teachers and between developing and developed countries. However, several of the reviewed studies indicate that engaging in-service teachers in an inquiry-centred professional training course or science methods courses has the capacity to improve their comprehension of IBST.

It is also noteworthy that in all of the reviewed studies from developing countries concerning teachers' knowledge of IBST involved only in-service secondary teachers and none involved pre-service teachers or primary school teachers. This indicates a knowledge gap pertaining to how pre-service teachers and primary teachers in developing countries like Swaziland construct an understanding of IBST. Moreover, the few studies that compared teachers' understanding with their enactment of IBST yielded contradictory findings. Three of the studies reported in this review (Mokiwa & Nkopodi, 2014; Ozel & Luft, 2013; Ssempala, 2017) indicate that teachers' poor enactment of this pedagogy matched well with their limited conceptions of this pedagogy. However, the study by Crawford (2007) indicates that pre-service teachers' enactment of IBST may contradict their description of this pedagogy. Munck (2007) concluded, based on the results of his study, that pre-service teachers may have knowledge of some inquiry-based practices, such as engaging learners with a science-oriented question, but lack knowledge of how to effectively enact the strategies in the classroom.

Boakes and Moorer (2009), similarly, found that that while two of the pre-service teachers they investigated used structured inquiry; the approaches used differed. They then concluded that pre-service teacher have different conceptions of how content topics can be translated into inquiry lessons. These studies point out that teachers' being able to give an informed description of IBST may not be an indication of an ability to enact this pedagogical approach. This highlights that a study on pre-service teachers' understanding of IBST must go hand in hand with an endeavour to find out how they attempt to put their knowledge into practice in the actual context of the classroom. Such enactment of IBST is the topic on the next section.

2.4 RESEARCH ON TEACHERS' ENACTMENT OF IBST

The second goal of this study was to explore how the participant pre-service teachers attempt to enact IBST during teaching practice in schools. Research on actual enactments of this pedagogical approach provides more reliable insights of the extent to which reform efforts can influence classroom practice than does teacher self-reporting on their practice or describing this pedagogy. Based on an assumption that teachers' classroom practices influence students' learning, knowledge of teachers' classroom practices can provide insights regarding factors that facilitate or hinder the achievement of societal educational goals. The following sub-sections describe firstly teachers' enactment of IBST, and later on, present a discussion of factors that have been found to influence the manner in which teachers enact this pedagogical approach in the classroom.

2.4.1 Pre-service and beginning teachers' enactment of IBST

In spite of the many international calls for inquiry based science teaching, many researchers point out that it is not yet practiced extensively by either experienced teachers or pre-service teachers (Abd-El-Khalick et al., 2004; Asay & Orgill, 2010; Ramnarain & Hlatshwayo, 2018). In particular, pre-service and beginning teachers, find it very difficult to enact IBST (Binns & Popp, 2013; Crawford, 2007; Eick & Reed, 2002; Lehane, Reilly, & Simmie, 2014).

Crawford (2007) explored five secondary pre-service teachers' enactment of IBST in the setting of a one year science professional training seminary. All the pre-service teachers were doing their teaching practice in a single school, but each one was partnered with a different mentor teacher, who provided the teacher feedback after conducting classroom observations. Mentor teachers attended professional development workshops on objective supervision aimed at developing their supervision skills. Analysis of different forms of data indicated that the pre-service teachers displayed a number of different forms of science pedagogy, ranging from traditional to open inquiry. Other than pointing out the different science backgrounds of the pre-service teachers, Crawford does not however provide specifics of the pre-service teachers' science method courses. Although he mentions that one of the goals of the seminary was to develop the pre-service teachers in using innovative teaching methods, there is no specific information regarding how they attempted to meet this goal, in particular with regard to IBST.

Ozel and Luft (2013) used classroom observations to examine the beginning teachers' enactment of IBST during their first year of in-service teaching. They found out that beginning teachers focused on just two of the five essential characteristics of IBST. They talked about engaging learners with a question, and in analysing data. They also rarely engaged learners on the features of communicating and making connections to scientific knowledge. They rarely engaged learners in posing personal questions or in gathering their own data. It was concluded that pre-service teachers generally enacted more teacher-directed or traditional instruction in line with their understanding of this pedagogical approach.

Boakes and Moorer (2009) used the Science Teacher Inquiry Rubric (STIR) as an observation instrument (Bodzin & Mitchell, 2003) to study eight elementary and early childhood pre-service teachers' enactment of IBST. Half of the pre-service teachers engaged learners in learning the science content by inquiry, while the other half used direct instruction. Pre-service teachers' STIR scores indicated that their instruction style ranged from slightly better than direct instruction to slightly beyond moderate use of inquiry-based attempts. The data also indicate that the group that did engage learners in inquiry learning used structured inquiry and was therefore most effective in engaging learners in formulating proper evidence based conclusions and explanations. They were however; least proficient in engaging learners in science-oriented questions through open or guided inquiry. On the basis of analysed lessons from two of the participant pre-service teachers, these researchers found that even though both teachers used structured inquiry, they approached IBST differently and thus concluded that individual conceptions of scientific inquiry influence pre-service teachers' enactment of IBST. They therefore proposed the use of model lessons to demonstrate explicitly to prospective teachers how to plan and execute inquiry-based lesson.

Lehane et al. (2014) carried out a study on the effects of a pedagogical content knowledge (PCK) centred approach on developing pre-service teachers' tendency to use inquiry in teaching science content. The pre-service teachers had first participated in a workshop where they were engaged in-group discussions on how they could present different scientific ideas to students through the inquiry approach. Participants were also involved in teaching practice and in reflecting on their classroom experiences. The study found that the pre-service teachers who had taken part in the workshop were able to develop inquiry orientations in their teaching much more readily than non-participant pre-service teachers and were better even than in-service teachers who had not been part of the programme. Other qualitative data collected from the pre-service teachers also revealed inquiry thinking in their approaches and reflections. When interviewed, the pre-service teachers who had taken part in the programme pointed out that their involvement in the programme steered their thinking towards inquiry, and ultimately led to the enactment of inquiry in the classroom.

2.4.2 Experienced teachers' enactment of IBST

In an attempt to understand better pre-service teachers' enactment of IBST, the researcher also reviewed empirical studies on in-service teachers in order to find out if they are notable disparities in the way the two factions of teachers enact the pedagogy. Some studies (Binns & Popp, 2013; Crawford, 2007) have, however, indicated that pre-service teachers often do not get support for or an opportunity to observe inquiry-based science teaching from their mentors (experienced teachers). This is an anecdotal indication that in-service teachers do not use inquiry-based teaching approaches.

Asay and Orgill (2010) analysed a number of articles that represent how teachers employ classroom-based inquiry in United States schools in terms of its essential features (NRC, 2000). Their results indicate that in-service teachers' enactment of IBST does not encompass all the essential features of inquiry-based science teaching. They found that teachers focused mostly on engaging learners in collecting and analysing data. Asay and Orgill (2010) inferred that US teachers apparently viewed "inquiry more as a process than as a means of teaching science content" (p. 57). Studies in Africa (Mokiwa & Nkopodi, 2014; Mugabo, 2012; Ssempala, 2017) similarly found that participant teachers focused on only a few of the features of inquiry. Mokiwa and Nkopodi (2014) investigated four experienced South African teachers and found that their portrayal of IBST was limited to experimentation as a means of verifying science concepts. In-service teachers appear to have an understanding of IBST that is little more developed than their pre-service counterparts. There is therefore little surprise that pre-service teachers gain little experience in IBST when mentored by these teachers.

2.4.3 Summary of teachers’ enactment of IBST

The review of literature on classroom enactment of IBST indicates a gap in the knowledge about pre-service teachers’ enactment of inquiry-based science teaching in developing countries. Furthermore, the majority of the studies concerning pre-service teachers were conducted in developed countries; the few conducted in developing countries focused on mainly on in-service teaching at secondary schools. Primary school pre-service teachers face many challenges that may include inadequate content knowledge, scientific inquiry process skills, and deficiency of appropriate pedagogical strategies and skills for creating an effective inquiry-based learning environment. It would thus be worthwhile to understand how pre-service teachers in a developing country like Swaziland develop knowledge about IBST.

Inquiry-based science teaching denotes an instructional approach that reflects the different processes scientist use when developing knowledge, and promotes learners’ self-directedness in the learning process. An experienced teacher should have developed more knowledge and skills related to teaching than has an inexperienced teacher, and is thus expected to be in a better position to “support students’ reasoning in seeking solutions themselves” (Harris & Rooks, 2010, p. 230). The review of the empirical studies has however also shown few differences between the manner in which pre-service teachers and in-service teachers enact inquiry-based science teaching. Neither of the groups includes all the essential features of IBST in their conception of the pedagogy, and they both tend towards using teacher-directed approaches. The next section focuses on factors that have a bearing on the manner in which pre-service teachers enact inquiry-based science teaching.

2.5 FACTORS INFLUENCING TEACHERS’ ENACTMENT OF IBST

The preceding section has highlighted that teachers’ enactment of inquiry-based science teaching can be either consistent or run contrary to their espoused understanding. A study of literature, in accordance with the theoretical framework of constructivism guiding the study, indicates a number of internal and external factors that shape teachers’ enactment of inquiry-based science teaching. The next two sections discuss factors that previous studies have shown to affect the manner in which teachers enact inquiry-based science teaching. These are categorized as intrinsic and extrinsic factors (Ramnarain, 2016).

2.5.1 Intrinsic factors shaping teachers' enactment of IBST

Intrinsic factors that may have an effect on teachers' intentions and use of inquiry-based teaching strategies have been identified in the literature. The main factors identified that shape teachers' enactment of inquiry-based teaching are teacher knowledge and beliefs (Crawford, 2007; Lebak, 2015; Ozel & Luft, 2013; Wallace & Kang, 2004). A number of scholars note that knowledge and beliefs, though different constructs, influence each other, and sometimes it becomes difficult to distinguish one from the other. Crawford (2007) tries to distinguish knowledge from beliefs in pointing out that knowledge is "based on empirical evidence, is not emotional, it develops gradually and has an appropriate structure" (p. 616). Similarly, Monsour (2004) points out that knowledge is "based on objective fact" (p. 27). Current research findings indicate that teacher knowledge and beliefs that are likely to have an impact on the way teachers' attempts to use inquiry in their teaching of science include teachers':

- knowledge of inquiry-based science teaching and related pedagogical strategies,
- subject matter knowledge,
- knowledge of the character of science,
- technical factors,
- beliefs about learning, learners and teaching.

Next is a discussion of each of these identified factors:

2.5.1.1 Teachers' knowledge of IBST and related pedagogical strategies

Teachers' knowledge of IBST and related pedagogical strategies seems to be one of the factors necessary for teachers' enactment of IBST. Some studies, such as (Crawford, 2007; Mokiwa & Nkopodi, 2014; Ozel & Luft, 2013; Ssempala, 2017) have found that teachers' poor enactment of inquiry-based science teaching matched their espoused understanding of this pedagogical approach being inadequate. These studies therefore substantiate the claim that teachers' understanding of inquiry-based science teaching is a prerequisite for teachers' enactment of this pedagogy. However, other factors may be necessary to enable teachers to translate informed understanding of IBST into classroom practice.

Pre-service teachers' experiences with and understanding of scientific investigations developed before their teacher training programmes seem to be critical in developing their knowledge of IBST, and their inclination and ability to use this approach in the classroom (Boakes & Moorer, 2009; Crawford, 2007; Eick & Reed, 2002; Windschitl, 2001, 2002, 2004). Teachers' lack of experience in doing scientific inquiry may limit their technical ability to engage learners in inquiry exercises, for instance creating science oriented questions, planning procedures for investigations, and formulating evidence based explanations (Harris & Rooks, 2010; Wallace & Kang, 2004). Crawford (2007) observed that a number of research participants were not confident in teaching by means of inquiry because they lacked knowledge about the scientific inquiry process. Several studies have also found that inquiry experiences in teacher education courses served to develop understanding and inquiry pedagogical skills of only those who already held informed views of scientific inquiry (Windschitl, 2001, 2002, 2004).

2.5.1.2 Teachers' subject matter knowledge

Some studies have indicated that teachers' subject matter knowledge influences how they use reform-based teaching in the classroom. Two earlier studies (Carlsen, 1996; Hashweh, 1987) indicate that teachers' subject matter knowledge can influence how they enact IBST. Carlsen (1996) established that teachers are less likely to engage learners with higher order reasoning questions when they lack subject matter knowledge. Similarly, Hashweh (1987) found that teachers with more subject matter knowledge were more able to draw and make sense of learners' ideas, and were more able to ask questions demanding higher order thinking than those who lacked such knowledge. Recent studies on the influence of teachers' subject matter knowledge on classroom strategies include Capps and Crawford (2013), who used interviews and Usak, Ozder, and Erlks (2011), who included subject matter assessments. Both studies found that teachers who demonstrated a higher level of subject matter were less likely to stick to a fixed lesson plan, and more often attended to learners' ideas during class discussions than did those with less subject matter knowledge. However, Leonard et al. (2009) found that pre-service teachers' content knowledge did not match with their ability to enact more learner-directed forms of IBST. Thus other factors seem necessary to enable teachers’ enactment of more learner-directed teaching approaches.

2.5.1.3 Understanding of Nature of science

An earlier study by Crawford (2007) and a later one by Ssempala (2017) both indicate that there is a connection between the way teachers understand the nature of science and the manner in which they teach science by inquiry. Crawford (2007) discovered that pre-service teachers’ understanding of scientific inquiry was the greatest significant factor influencing their adoption and successful implementation of inquiry-based lessons. This supports a claim made by some scholars such as Windschitl (2004) and Abd-El-Khalick (2012) that an understanding of the character of science: for example, informed views regarding the relationship between data and scientific claims, as well the role of theories in guiding a scientific study seems necessary in facilitating teachers’ enactment of inquiry instruction that is more in line with real science. There are, nevertheless other contrasting findings in this regard, such as those of Bartos and Lederman (2014) and Yoon and Kim (2015). Bartos and Lederman (2014) found that teachers’ knowledge about the nature of science did not match their representation of this knowledge dimension in the classroom. Similarly, Yoon and Kim (2015) found that the way pre-service teachers understood the nature of science did not correlate well with their beliefs about teaching. For example, one participant pre-service teacher demonstrated an understanding that scientists can make different valid interpretations of the same evidence, but at the same time believed teachers could tell learners that their alternative conceptions are wrong. Knowledge alone may not to be the only factor necessary to enable a teacher to implement inquiry-based classroom practice.

2.5.1.4 Technical Factors

Technical factors have also been found to be useful in explaining teachers’ poor implementation of IBST. To initiate and foster the culture of inquiry learning in the classroom, the teacher must help learners develop the necessary skills and perspective to learn in this manner (Harris & Rooks, 2010; Kock et al., 2015). This change in approach for science teaching demands the teacher to change from being a dispenser of knowledge to being a facilitator, whose primary role is to create suitable conditions for learning as learners participate in scientific inquiry (Harris & Rooks, 2010). Frequently, it is difficult for novice teachers to enact inquiry in the classroom in a way that balances allowing students some degree of independence with offering enough guidance to ensure meaningful construction of concepts (Crawford, 2007; Harris & Rooks, 2010). This could explain why Leonard et al. (2009) did not find a relationship between the level of subject matter knowledge pre-service teachers held and the level of learner-autonomy that they exhibited in their IBST.

Even if teachers have adequate content knowledge, their lack of pedagogical skills and confidence associated with inadequate training may hamper their attempts to enact learner-centred pedagogical approaches, as was found in Rwanda and Swaziland (Mthethwa, 2007; Mugabo, 2012). In this regard, this suggests that the poor relationship between the content knowledge held by participant teachers and their use of learner-directed inquiry-based pedagogy noted by Leonard et al. (2009) could be a result of teachers' lack of pedagogical content knowledge to teach science in this manner. A number of pre-service secondary school teachers in a study by Reaume (2011) pointed out their lack of knowledge on how certain chemistry topics could be taught using the inquiry-based pedagogy. Although, this factor links to teachers' subject matter knowledge, it points to the idea that subject matter knowledge alone is not sufficient to teach science appropriately by inquiry; it also demands necessary technical expertise.

2.5.1.5 Teacher beliefs

There is plenty of empirical evidence that beliefs have a great influence on teachers' enactment of science teaching, including inquiry-based science teaching. Wallace and Kang (2004) assert that beliefs refer to "remembered events, feelings, subjective evaluations, and presumptions". They further point out that: "beliefs are an important aspect of practical knowledge and serve as a filter through which practical knowledge is developed" (Wallace & Kang, 2004, p. 938). Teacher beliefs that have been found to have a bearing on the manner in which teachers enact inquiry-based science teaching include beliefs about learners and learning, about teaching and the responsibility of the teacher, about the character of the scientific inquiry and the knowledge it generates, and epistemological beliefs (Crawford, 2000, 2007; Lotter et al., 2006; Wallace & Kang, 2004).

Crawford (2007) found that beliefs about teaching, students, and school held by participant pre-service teachers were the major factors shaping their planning and execution of IBST, in addition to their naive beliefs about scientific inquiry. Likewise, participant teachers in a previous study by study by Lotter et al. (2006) believed it was obligatory to use teacher-centred approaches to provide students with background knowledge related to their investigations. Moreover, a significant number of the teachers in that study held beliefs about learners that conflicted with inquiry-based science teaching. Participants believed that their students' knowledge oriented view of science would interfere with the use of more open-ended investigations. Likewise, in Wallace and Kang's (2004) study, three teachers' enactment of inquiry was constrained by their belief that their learners were too lazy to carry out inquiry activities.

Teachers' choices of instructional strategies in Lotter et al. (2006) were not only influenced by their viewpoints about students, but also by their beliefs about effective strategies of teaching. On the one hand, some teachers held beliefs akin to those of scholars such as Kirschner et al. (2006) and supposed that non-inquiry strategies such as lecturing would be more effective than inquiry strategies in addressing students' learning difficulties. On the other hand, some teachers seem to regard guidance as unnecessary for learning in the context of inquiry activities; this idea seems to be based on an assumption that learners can, on their own, construct scientific concepts meaningfully from their investigations alone. For example, Abrahams and Reiss (2012) point out that, teachers may believe that target ideas would simply crop up from the learners' observations. A similar perspective was adopted by last century science educators who employed an implicit methods to teaching about the epistemology of science (Abd-El-Khalick & Lederman, 2000; Lederman, 2007). Studies however, indicate that guidance is necessary to help learners connect the activities they are engaged in with target concepts (Furtak et al., 2012; Kock et al., 2015).

The discussion in this section has shown that teachers' enactment of IBST is influenced by different knowledge and beliefs. However, knowledge and beliefs alone may not to be the only factors necessary to enable a teacher to implement inquiry-based classroom.

2.5.2 Extrinsic factors

Some research shows that, especially with inexperienced teachers, actual classroom practice does not always align with their understanding and beliefs about IBST (Lederman, 1999; Ramnarain & Hlatshwayo, 2018; Shah, 2009). For example, Ramnarain and Hlatshwayo

(2018) investigated beliefs and attitudes held by some South African teachers, and the way they enacted inquiry-based science teaching. Their study revealed that even though the teachers held positive attitudes towards inquiry-based science teaching, they often did not enact this pedagogy in the classroom.

Teachers report various external cultural factors such as parental resistance, shortage of teaching equipment and space, and constraints of externally prescribed content hinder their translation of subject matter knowledge and inquiry oriented beliefs into classroom practice (Anderson, 2002; Binns & Popp, 2013; Mkimbili, Tiplic, & Ødegaard, 2017; Mugabo, 2012; Panjwani, 2015; Ramnarain & Hlatshwayo, 2018; Ssempala, 2017; Wallace & Kang, 2004; Wallace & Kang, 2004). To illustrate, Wallace and Kang (2004) found that a concern about covering the prescribed curriculum in preparing students for an examination seems to be the major external factor inhibiting secondary teachers' intentions to enact inquiry-based science teaching. One teacher, for example, who espoused strong personal goals of promoting the culture of scientific thinking among her students, nevertheless, felt coerced to adapt her teaching to the school culture of high stake examinations by adopting a more teacher-guided approach where she prescribed the inquiry problem for her students. In a more content-oriented curriculum, teachers often complain about their inability to cover all the prescribed content when using a true inquiry approach (Lotter et al., 2006; Mthethwa, 2007). Inadequate teaching resources and large classroom sizes were reported by Mthethwa (2007) as contextual factors impeding teachers' use of learner-centred pedagogical strategies. The same two factors were also found to limit secondary teachers' implementation of IBST in Rwanda (Mugabo, 2012) and Tanzania (MKimbili, Tiplic, & Ødegaard, 2017).

It is worth noting that all the reported studies mentioned above were primarily focused on in-service teachers. For pre-service teachers, other external factors can shape their implementation of IBST. For example, Crawford (2007) found that a pre-service teacher's inclination towards or against IBST may be influenced by his or her mentor's orientation to teaching science. However, although this factor affected some of the pre-service teachers' enactment of IBST, Crawford observed that others were able to implement inquiry lessons that were in line with their conceptions of IBST regardless of their mentor's science teaching orientations. Crawford (2007) therefore argues that pre-service teachers need to be more well-versed about inquiry and related beliefs in order to overcome any constraints due to the culture of the school in which they are practicing.

2.6 SUMMARY

An analysis of studies on teachers’ knowledge and execution of IBST has indicated that teachers construct many different meanings of inquiry-based science teaching, which is in line with the cognitive constructivist view that participants construct personal understanding of phenomena based on what they already know and their beliefs (Keys & Bryan, 2001; Staver, 1998). Generally, all the studies indicate that teachers’ enactment of IBST is not consistent with principles recommended in curriculum reforms. Furthermore, their enactment of this pedagogy may match or contradict their espoused understanding.

In line with a number of scholars (Keys & Bryan, 2001; Lebak, 2015; Wallace & Kang, 2004), the review of literature also supports the view that both cognitive and socio-cultural perspectives are necessary to understand teachers’ construction and enactment of inquiry-based science teaching. Several studies indicate a variety of internal and external factors that may shape teachers’ enactment of IBST. These factors include their personal understanding of IBST and subject matter knowledge, cultural beliefs learners developed from their experiences in schools, and some contextual factors. Figure 2.2 below shows that teachers’ enactment of inquiry-based science teaching is mediated, both cognitively and culturally, by internal and external factors.

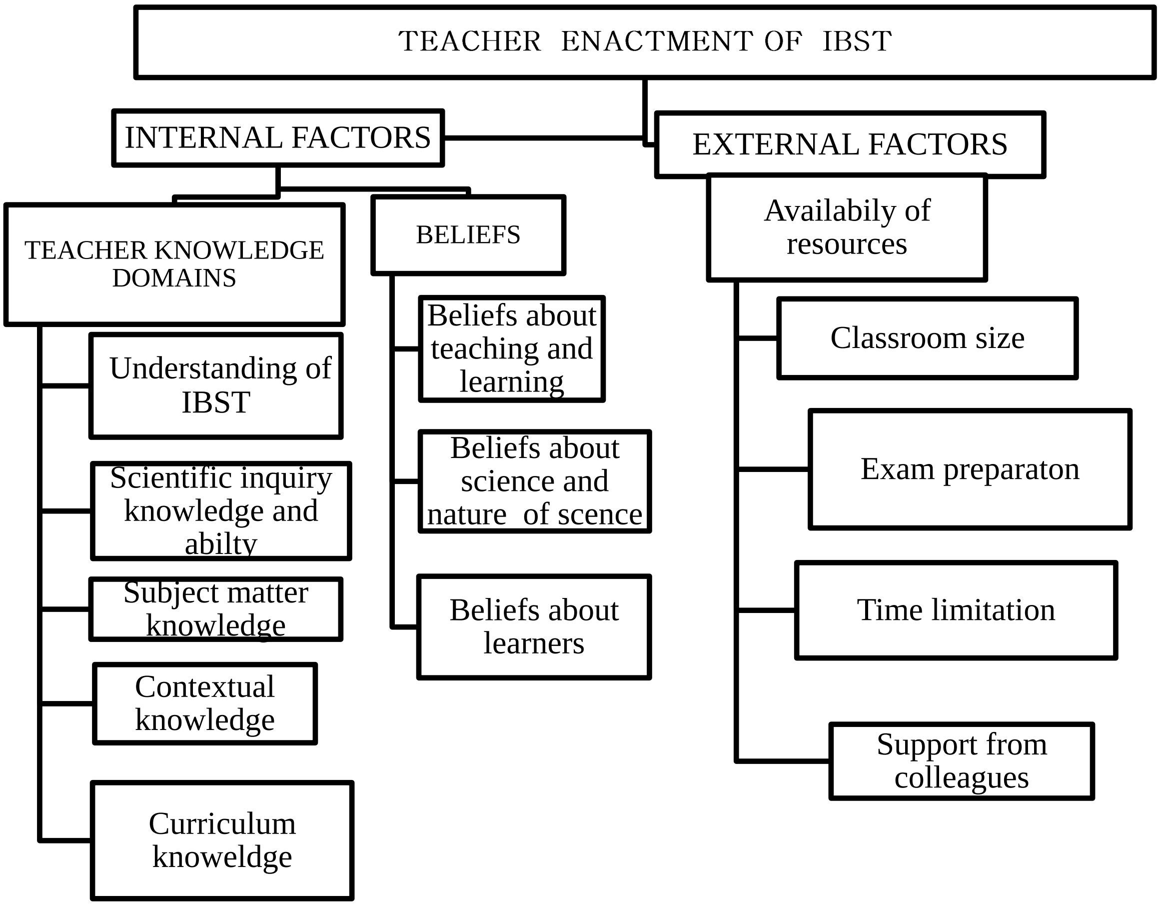

Figure 2.2 *External and Internal factors influencing teachers' enactment of IBST*

CHAPTER 3

CONCEPTUAL FRAMEWORK FOR THE STUDY

Chapter 2 outlined the theory behind the study, in terms of the history, meaning and descriptions of IBST distilled from the review of literature. It also highlighted teachers' understanding and enactment of IBST as revealed in previous studies. This chapter presents the conceptual framework of inquiry-based science teaching employed in this research. In line with Dickson, Kamil, and Agyem (2018), a conceptual framework in this particular study refers to the specific perspective of IBST that the study employed to "analyse and interpret the data" in order to make evidence-based conclusions regarding the pre-service teachers' understanding and enactment of IBST.

First, Section 3.1 presents the conceptual framework of IBST adopted in this study and Section 3.2 links this conceptual framework of IBST with the constructivism learning theory, which is the theoretical perspective about learning and teaching adopted in this study.

3.1 CONCEPTUALIZATION OF IBST

This study made use of the conceptualization of inquiry-based science teaching adopted by Furtak et al. (2012) to explore the participants' understanding and enactment of IBST,. Accordingly, for this study inquiry-based science teaching is regarded as a pedagogical method that involves learners in constructing answers to science questions themselves under the guidance of the teacher, as opposed to being merely recipients of knowledge. This is more in line with how real science operates than is conventional teacher-centred instruction. In that sense, the study does not regard instructional approaches that engage learners in conducting investigations for confirming concepts previously presented by means of direct instruction as inquiry. Furtak et al. (2012) recognize two dimensions of IBST: the cognitive dimension and the guidance dimension. Section 3.1.1 and 3.1.2 describe these dimensions, respectively.

3.1.1 The cognitive dimension of IBST

Furtak et al. (2012) regard inquiry-based science teaching as activities that provide learners an opportunity to experience certain essential features of the process by which scientists discover and construct knowledge. This definition aligns with those given by several other scholars (Beere & Bodzin, 2004; Cobern et al., 2010; Kock et al., 2015). Furtak et al. (2012) present a comprehensive list of features that constitute what they collectively refer to as, the cognitive dimension of inquiry-based science teaching. The cognitive dimension, according to Furtak et al. (2012) encompasses the cognitive and social activities carried out by the learners. Furtak et al. (2012) categorized such scientific inquiry activities into four domains: the *conceptual, procedural, epistemic and social.*

3.1.1.1 The conceptual domain

Scientific inquiry is a way of knowing that generates a body of knowledge (facts, knowledge and theories) representing current understanding about different aspects of the natural world. In addition, scientists use the existing knowledge concerning the phenomenon under investigation to form a theoretical framework that guides all their work, including the questions they ask, how they collect and analyse data and the way they interpret evidence (Halai, 2010). Likewise, based on the constructivist' view about learning, learners construct meaning of the natural world using their prior knowledge as well as their experiences. It therefore follows that IBST should include a conceptual domain which includes both the scientific knowledge learners are to develop by means of inquiry and the prior knowledge they draw from when addressing problems about the natural world: asking questions, planning investigations and constructing evidence-based conclusions (Furtak et al., 2012; Harris & Rooks, 2010). In line with this description of the conceptual domain, the Academy of Science of South Africa (2011) regards IBST to be both a means for learning scientific knowledge and for developing learners' inquiry skills.

Inquiry- based science activities should therefore include eliciting learners' ideas, prior experiences and knowledge, thereby allowing them to develop the necessary background knowledge upon which to draw when carrying out the different scientific knowledge construction activities (Furtak et al., 2012; Harris & Rooks, 2010). Other supporters for IBST highlight the value of a conceptual framework to draw from. Notably, Abd-El-Khalick

(2012) links teachers' understanding of the conceptual domain of IBST to their construction of the character of science; he points out that educators who are aware of the theory driven nature of scientific activities, are less likely to ignore learners' prior knowledge and ideas. Kock et al. (2015) found that providing learners with a theoretical background was necessary to enable them to form explanations for phenomena they observed.

3.1.1.2. The epistemic domain

The epistemic domain refers to learners' development of an understanding of "how knowledge is produced in science" (Furtak et al., 2012, p. 305), commonly denoted as the "nature of science" (Abd-El-Khalick, 2012, p. 1). Although constructing new scientific knowledge based on evidence encompasses many scientific processes, in this study the epistemic domain is taken as comprising "learners' engagement in analysing data, examining the quality of the evidence, and interpreting the evidence to create explanations for phenomena" (Furtak et al., p. 305). In line with several other scholars (Abd-El-Khalick, 2012; Halai, 2010; Harris & Rooks, 2010) this study regards merely engaging learners in inquiry activities as being insufficient to promote their understanding of the character of science. Consequently, learners' reflection of how their activities relate to authentic science is an essential feature of the epistemic domain of inquiry-based science teaching (Furtak et al., 2012; van Uum, Verhoeff, & Peeters, 2016). Moreover, some writers, such as Chinn and Malhotra (2002) and Kyle (1980), assert that most classroom inquiry-based learning activities do not mirror the epistemology of real science. It is necessary to engage learners in explicit deliberations on how their activities are similar or different from real science in order to promote more informed views of how science really operates as a way of knowing.

3.1.1.3 The procedural domain

Furtak et al. (2012) regard the *procedural domain* as constituting the procedures learners carry out when they generate data, excluding the aspects of making sense of, or constructing, knowledge based on of the data. These include learners' involvement in asking scientifically oriented questions, designing and conducting hands-on investigations. Duschl (2008) considers these processes to form part of the epistemic domain. However, some research indicates that teachers may tend to associate inquiry-based science teaching merely with hands-on data collecting activities, such as observing and classifying objects. According to (Abd-El-Khalick, 2012), this may stem from a teacher' lack of awareness of the need to interpret data when addressing answers to science questions. The researcher, therefore like Furtak et al. (2012), believes that separating the features that deal with making sense of data from the remainder of the scientific procedures is necessary to gain deeper insights of teachers' understanding and enactment of IBST.

3.1.1.4 The social domain

The social domain describes the collaborative and communicative aspects of inquiry-based science learning. It emphasizes that consistent with the social nature of science, inquiry-based teaching activities should involve learners in communicating, discussing and arguing ideas, and making joint decisions (Abd-El-Khalick, 2012; Harris & Rooks, 2010). This is necessary to enable learners to evaluate their developing understanding of science in line with the view of knowledge as a social construction. Ültanır (2012) points out that: "we construct our own reality with those in our own circles" (p. 198).

Table 3.1 provides a description of each of the domains within the cognitive dimension of inquiry-based science teaching, as conceptualized by Furtak et al. (2012).

Table 3.1 *Domains of Inquiry-based science teaching and categories of description*

Doman of IBST	**Description**
Procedural	Asking scientifically oriented questions
	Designing investigations
	Carrying out investigations
	Documenting data
	Representing data
Epistemic	Nature of science
	Drawing evidence-based conclusions
	Generating and revising scientific theories
Conceptual	Eliciting learners' ideas
	Drawing on learners' prior knowledge
	Providing conceptually oriented feedback
Social	Participating in class discussions
	Debating ideas
	Presentations
	Working collaboratively

Furtak et al. (2012, p. 309).

3.1.2 The guidance dimension of IBST

In as much as learners in inquiry-based science teaching construct answers to questions themselves, Furtak et al. (2012) do not equate this approach with student-led or discovery learning. They recognize guidance as an important dimension of inquiry-based science teaching and assert that in this teaching approach, "learners receive guidance from their teacher or the curriculum" as they actively participate in constructing their own understanding" (p. 306). A number of other scholars (Bybee, 2009; Gil-pérez et al., 2002; Hmelo-Silver & Barrows, 2006; Hmelo-Silver, Duncan, & Chinn, 2007; Ramnarain & Hobden, 2015) hold a similar view, while also emphasizing the guidance dimension to inquiry-based education. In particular, Hmelo-Silver et al. (2007) strongly refute the claim made by Kirschner et al. (2006) that in inquiry-based education, learners receive very little support from the teacher. This study also adopts the teacher-guided understanding of inquiry-based science, which Furtak et al. (2012) define as an approach that falls between two extremes; one where a teacher provides answers to learners, commonly referred to as a traditional instructional approach, and the other where learners conduct a completely unguided independent inquiry.

Some scholars (Furtak et al., 2012; Ramnarain & Hobden, 2015) characterize guidance in inquiry-based science teaching in terms of the amount of direction that a teacher gives, or the extent of learner directedness in inquiry-based teaching or learning. Furtak et al. (2012) assert that in any reform-based teaching, there are "transitions of responsibility from teacher to learner, and then back to the teacher" (p. 306). In defining the guidance dimension IBST, Furtak et al. (2012) refer to the "essential features of classroom inquiry" presented in the *Inquiry and the National Science Education Standards* (NRC, 2000, p. 29). Table 3.2 provides the different levels of teacher direction or learner self-direction pertaining to each essential feature of an inquiry based instruction, as indicated in the standards. For example, teacher direction in inquiry-based science teaching may vary according to whether the teacher defines the subject of investigations or leaves it to learners to decide (Dobber, Zwart, Tanis, & Oers, 2017). From this perspective, Furtak et al. (2012) recognize inquiry in the science classroom as being either teacher-directed or learner-directed.

Table 3.2 *Essential Features of inquiry-based science teaching and their variation.*

Essential features	**Less ← Teacher-directed More →** **More ← Learner self-directed Less →**			
1. Learners engage in scientifically oriented question	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided.	Learner engages in question provided.
2. Learner gives priority to evidence in responding to question.	Learner determines what data to collect as evidence	Learner is directed to collect certain data	Learner given data and asked to analyse it	Learner given data and told how to analyse it
3. Learner formulates explanations from evidence.	Learner formulates explanation from evidence	Learner guided in the process of formulating explanations from evidence	Learner given possible ways to use evidence to create explanations	Learner provided with evidence.
4. Learner connects explanations to scientific knowledge	Learner, on their own, study other sources and forms links to explanations	Learners directed towards areas and sources of scientific knowledge	Learners given possible connections	Learner given all connections
5. Learner communicates and justifies explanations or conclusions,	Learner forms reasonable and logical argument to communicate explanations.	Learners coached in development of communication.	Learners provided with broad guidelines to use to sharpen communication.	Learners given steps and procedures for communication.

(National Research Council (NRC), 2000, p. 29)

3.2 INQUIRY-BASED SCIENCE TEACHING AND CONSTRUCTIVISM

As already mentioned this study is located within the constructivist theoretical framework about learning and teaching and interprets inquiry-based science teaching from Furtak et al.'s (2012) perspective of reform-based inquiry-based science. This section seeks to show how inquiry-based science teaching links to the constructivist view about learning and how the framework of IBST by Furtak et al. (2012), in particular, meets the demands the of constructivist learning and teaching.

3.2.1 Constructivism and science teaching approaches

This study adopts the view that teaching based on inquiry is consistent with constructivist perspectives about teaching. While scholars who contest inductive teaching and learning approaches argue that learners construct knowledge themselves whatever the mode of teaching, the researcher in this study, in line with a number of other scholars (Amineh & Asl, 2015; Serafín et al., 2015) holds the view that that constructivism does suggest particular teaching strategies. Prince and Felder (2006) assert that "inductive teaching and learning includes various teaching approaches such as inquiry-based learning, case- based learning, and problem based learning" (p. 2). These teaching approaches often described as learner-centred: instead of beginning by explaining general principles and theories to learners, they allow learners to construct knowledge themselves from particular instances such as "interpreting a set of observations or data, analysing a case study, or solving a real world problem" (Prince & Felder, 2006, p. 1). The researcher regards teaching that is grounded on scientific inquiry, in particular, as providing a suitable learning environment for learners' active engagement in their creation of knowledge, which occurs as they design and execute scientific procedures, analyse and interpret data, converse, argue and think about their own ideas and experiences.

Rather than viewing learners as having no knowledge, constructivism acknowledges that learners enter the science classroom already with some knowledge, and the responsibility of teacher through the curriculum is to present them with an environment that will foster their reflection on their prior knowledge, deepen and refine this knowledge within collaborative groups. This view suggests the use of instructional approaches that cater for learners' individual needs and ideas and those that promote their intrinsic motivation to learn, to think critically, and to learn independently and in collaboration with others (Amineh & Asl, 2015; Aydin, 2013; Čestmír, Jiří, & Martin, 2015; Richardson, 2003; Serafín et al., 2015). Furthermore, to promote learners' reconstruction of their knowledge and conceptions, constructivist teaching must include finding out learners' ideas and knowledge, provide them experiences to judge the suitability of their conceptions, and to reflect on what they now know in relation to what they previously knew or believed. (Amineh & Asl, 2015; Richardson, 2003; Serafín et al., 2015).

On top of employing the pedagogical methods outlined above, which promote learners' active construction of knowledge, Serafín et al. (2015) add other aspects; they assert that in accordance with constructivism, such pedagogy must include the "individualization and differentiation of teaching" (p. 594). By using this description of constructivist pedagogy, the next section seeks to show the strength of IBST in general, and as postulated by Furtak et al. (2012), in meeting the demands of constructivist-oriented approach to teaching science.

3.2.2 Constructivism and Furtak et al.'s (2012) framework of IBST

By emphasizing the need to draw from learners' prior knowledge and seeking learners' ideas, the conceptual framework of IBST highlights the role of learners' prior ideas and beliefs in constructing knowledge in line with constructivist' perspective (Amineh & Asl, 2015; Serafín et al., 2015). These conceptual features of IBST seem to be lacking from the five essential features of inquiry provided in the *Inquiry and Science Education Standards* (National Research Council, 2000). Though Pedaste et al. (2015) refer to conceptualization in their description of phases of IBST, they do not highlight the need to draw from learners' prior knowledge, except where learners engage in testing their own hypothesis. The feature of drawing from learners' prior knowledge is critical from the constructivist perspective of learning: all meaning is constructed based on a personal theoretical framework shaped by one's prior knowledge, ideas and beliefs and experiences.

Engaging learners in posing science questions, designing investigations, and their engagement in the epistemic aspects of formulating evidence-based conclusions and models, as advocated by (Furtak et al., 2012), is in line with the constructivist call for teaching approaches that promote active learner participation in creating knowledge, critical thinking, problem solving skills and self-directedness (Amineh & Asl, 2015). The teacher in IBST becomes a facilitator, who as Serafín et al. (2015) assert, guides learners in choosing the most effective approaches for learning, rather than presenting learners with knowledge~~.~~

The inquiry-based teaching and learning features of drawing on learners' ideas and their engagement with hands-on investigations can, moreover, generate results that cause a cognitive conflict: a condition that persuades them to modify or reconstruct their existing knowledge schemes, thereby allowing them to incorporate new experience into their knowledge of the world (Cakir, 2008; Serafín et al., 2015). Cognitive conflict is defined in simple terms by Cakir (2008) as “ a surprise produced when an expected outcome does not occur” (p. 201), and its absence may lie the reason why some lessons fail to achieve conceptual change. Moreover, engaging learners in pursuing questions that are of interest to them or at the least, involving them in constructing the questions, makes the learning more authentic and thus encourages their active engagement in the learning process. Accordingly, in line with cognitive constructivism, IBST is a pedagogical strategy that motivates learners to modify or extend their existing knowledge (Serafín et al., 2015).

From the social constructivist view that learning occurs as learners interact with their environment and other people (Amineh & Asl, 2015; Serafín et al., 2015), another task of the facilitator, is to encourage learners to question each other and themselves about ideas. This is line with the social domain of IBST, which includes encouraging learners to communicate their ideas through constructing models to explain phenomena, classroom discussions, argumentation and group activities (Furtak et al., 2012). Furtak et al. (2012) contend that these interactive and cooperative engagements give learners an opportunity to “examine and evaluate their developing ideas about the natural world” (p. 305). Moreover, engaging learners in modelling and debating their models in IBST can help learners understand models as inferences, rather than truths about the natural world in line with constructivists’ views about such models. Learners also get an opportunity to reflect on their understanding of the character of science in the context of their inquiry activities (Nhlengethwa, 2013) as advocated by Furtak et al. (2012, p. 305), and this connects well with the view of knowledge as being actively constructed by learners themselves in a “stimulating environment and in interaction with others” (Serafín et al., 2015, p. 594).

Although, Furtak et al. (2012) do not explicitly refer to differentiation and individualization as promoted by constructivism (Serafín et al., 2015), these features are implied in their model. Both differentiation and individualization are about adapting teaching to the needs and preferences of learners; however, while in differentiation the teacher ensures that the teaching methods and resources are suitable for different groups of learners in a class, in individualization the teachers caters for the needs of individual learners. In addition to the general objectives set for the whole class, in individualization the teacher sets specific objectives for each learner who is also provided one-to one support (Bray & McClaskey, 2010).

The researcher in this study is of the view that by emphasizing the features of, firstly, eliciting learners' ideas and drawing from their prior knowledge and secondly engagement of learners in posing science questions, Furtak et al. (2012) have provided for issues of learner motivation. By emphasizing the guidance dimension of IBST, Furtak et al. (2012) in some way also address the issue of differentiation and individualization because the inquiry approach can vary by adjusting the amount of support the teacher gives the group of learners or the individual in accordance with their capability, prior knowledge and ideas. However, by defining this dimension of IBST in terms of the amount of, rather than the type of support, the framework does not fully allow for differentiation and individualization. Grangeat (2016) presents a model that is based on six dimensions of IBST and he thus provides different modes by which differentiation and individualization can be addressed in the context of IBST. For example, he talks about the adaptation of objectives, learning materials, achievement levels and time as some ways by which a teacher can address specific needs in an inquiry-based classroom.

The comparison of inquiry-based science teaching, based on Furtak et al.'s conceptualization, with the characteristic of constructivist pedagogy as characterized by Serafín et al. (2015) indicate that the framework does cover the basic requirements of a constructivists based pedagogy. However, the framework is not comprehensive with regard to the type of guidance or support a teacher needs to provide in IBST, and thus does not adequately cover issues of individualization and motivation promoted by constructivist pedagogy. Since the participants in this study were pre-service teachers, without much experience in teaching, and the study being the first of this nature in the country, the researcher regarded the framework by Furtak et al. (2012) as detailed enough to allow the researcher to form some general conclusions about the groups' competencies with regard to IBST. Other studies aimed at establishing specific competencies, such as teachers' level of understanding or ability with regard to managing inquiry-based teaching and learning could employ more elaborate models, such as that of Grangeat (2016).

Table 3.3 provides a summary of this discussion, which has attempted to highlight the relationship between inquiry-based science teaching and constructivism and to show how the conceptual framework of Furtak et al. (2012) brings to light these relationships, and where it seems indistinct.

Table 3.3 *IBST in relation to the Constructivist' pedagogy*

Basic principles of constructivism	**Related IBST feature**	**Furtak et al.'s domains of IBST emphasizing this aspect**
Learners are actively engaged in constructing knowledge themselves based on their prior knowledge	Posing science questions Engaged in hands on investigations Formulating evidence-based conclusion Creating or revising theories/ models	Procedural Epistemic Conceptual
Learning occurs in a social context. One's understanding is achieved with the support from others.	Discussing ideas Debating ideas Working collaboratively	Social
Learning is self-regulatory depending on contextual factors.	Learners assume responsibility for solving the problem with teacher acting as the facilitator.	Guidance or self-directed dimension
	Taking into considerations learners' individual needs and interest	Implied within the conceptual domain and the guidance dimension of IBST
Learners' motivation for the constructivists is the learner's need to understand the world and his or her own cognition.	Stimulating learners' curiosity and generating interest in the research problem or question by presenting a stimulating environment. This is necessary to encourage learners to propose their own questions.	Implied within the conceptual domain: drawing from learners' prior knowledge, ideas and experiences.
Learning is a process that demands cognitive conflict, which can lead to cognitive stability.	Eliciting learners' ideas Drawing form learners' knowledge Revising theories in light of evidence	Conceptual Epistemic
Learners are provided with opportunities to make sense of their own experiences	Drawing from their prior experiences Direct hands-on experiences Form evidence-based conclusions Create theories or models to account for their experiences	Conceptual Procedural Epistemic
Theories and models represents their interpretations of their experiences rather than reality.	Learners creating theories Learners discussing the nature of science	Epistemic
Language is an important aspect of cognition. it acts as an instrument that enables the creation of links between new knowledge and prior knowledge	Collaboration Teacher eliciting learners' ideas Class discussions Arguing ideas	Conceptual Social

3.3 SUMMARY

In this chapter, the researcher has presented the conceptual framework of IBST that the researcher will use to make sense of the pre-service teachers' conceptualization of IBST. The researcher has also attempted to synthesise a relationship between inquiry-based science teaching as defined by Furtak et al. (2012) and constructivism learning theory, thereby forming the theoretical basis for the study; this is also represented in Figure 3.1. This review reveals that the cognitive and guidance dimensions of IBST coined by Furtak et al. (2012) are rooted in constructivism. It has however indicated that the framework is not explicit with regard to personalizing of instruction and internal motivation, whereas these are critical in describing and explaining learning from the constructive perspective.

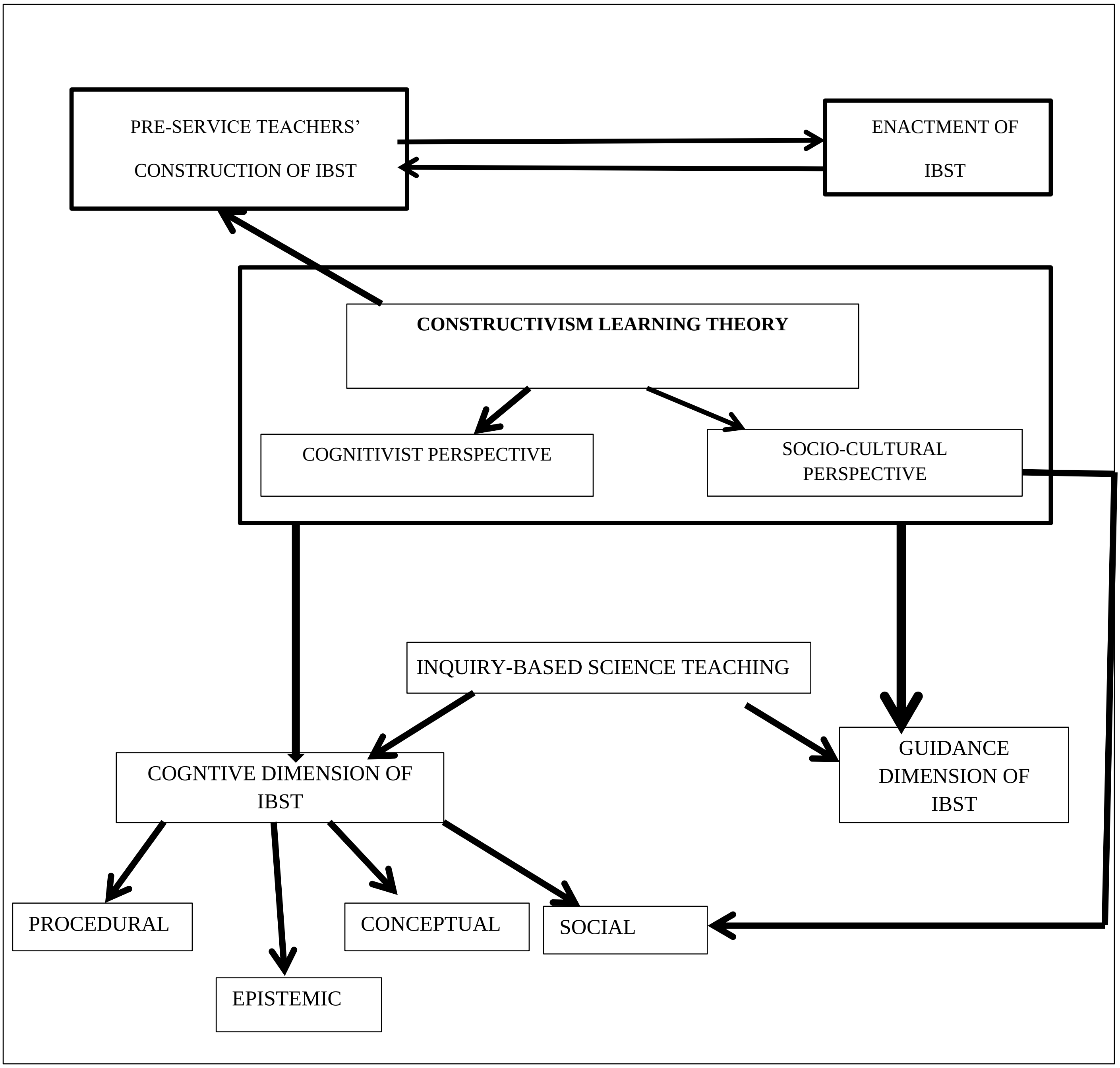

Figure 3.1 *Chart showing the theoretical and conceptual framework of the study*

Author's illustration

CHAPTER 4

METHODOLOGY

The previous chapter presented the conceptual framework of the study and attempted to link it to constructivism learning theory, which is the theoretical framework of the study. This chapter presents the methodology of the study. A research methodology in this context refers to a description of how the researcher attempted to address the research problem in a systematic manner. The chapter is presented in five sections: (a) the research approach; (b) the population, participants, and sample of the study; (c) data collecting strategies; (d) data analysis; (e) methodological; and (e) ethical deliberations.

As stated in Chapter 1, the study aimed at understanding enactment of inquiry-based science teaching (IBST) by pre-service teachers' at one teacher education institution in Swaziland. More precisely, the study was guided by the following research questions:

> Q1. What do pre-service primary school teachers understand by inquiry-based science teaching (IBST)?
> Q2.1 How do pre-service primary school teachers enact inquiry based science teaching (IBST)?
> Q2.2 What factors influence pre-service teachers' enactment of inquiry-based science teaching?

4.1 PARADIGMATIC PERSPECTIVES

A social research methodological approach is guided by certain philosophical assumptions regarding the nature of social reality investigated and how such reality can be uncovered; commonly referred to, respectively, as ontological and epistemological assumptions (Cohen, Manion, & Morrison, 2011; Nieuwenhuis, 2007b).

This study is based on pragmatism ontologies and epistemologies: a paradigm that originates from the ideas of John Dewey, Richard Rorty and Donald Davidson among others (Cohen, Manion, & Morrison, 2011; Ivankova, Creswell, & Plano Clark, 2007). Pragmatism is practice-oriented rather than idealistic (Cohen et al., 2011; Ivankova et al., 2007). It has more regard for actions that bring about desired outcomes than the pursuit of the most accurate representation of reality (Cohen et al., 2011; Goldkuhl, 2012). The truth in this philosophical perspective is therefore "what works best in addressing a particular problem" (Ivankova et al., 2007, p. 263). This reality is viewed as both singular and having multiple forms: sometimes subjective and sometimes objective" (Cohen et al., 2011, p. 23). Goldkuhl (2012) points out that pragmatism views the correspondence to reality claim about knowledge as varying with the complexity of the knowledge; it is applicable for simple statements, but complex claims such as theories are created and assessed based on their utility than as actual representations of reality.

The key goal of inquiry from this perspective is to develop an understanding of a particular situation in order to inform efforts aimed at bringing about some improvements in that situation (Goldkuhl, 2012). The focus of any research endeavour is on what works best in addressing the research questions (Cohen et al., 2011; Ivankova et al., 2007). Goldkuhl (2012) also argues that research in pragmatism does not only aim at creating explanations, which is the main idea of positivism; or understanding: a key element of interpretivism, but at creating different forms of knowledge, which include both descriptive and explanatory knowledge. Pragmatism therefore employs a variety of methods, drawing from both positivism and interpretivism based on "fitness for purpose and applicability, and the regard of reality as both objective and socially constructed" (Cohen et al., 2011, p. 23). Ivankova et al. (2007) also assert that in the pragmatism paradigm, the research method is determined by the research questions; and thus the research questions are regarded as more important than the methods employed to address them. Cohen et al. (2011) emphasizes that a researcher cannot evade using different methods and different forms of data if he seeks to provide a complete account.

4.2 RESEARCH DESIGN

The study made use of a case study research design. Yin (2003) defines a case study as research that seeks to understand a "contemporary phenomenon in its real life context when the phenomenon and the context cannot be easily separated as one influences the other, and when the researcher has generally no control over events. A case study design utilizes several sources of evidence and is the best option when one seeks to tackle 'how' and 'why' research questions (Baxter & Jack, 2008; Cohen et al., 2011; Nieuwenhuis, 2007b; Yin, 2003). Baxter and Jack (2008) further highlight that using several data collecting methods also allows the understanding of a phenomenon from different perspectives.

The case study research was therefore suitable for this current study as it allowed a detailed understanding of how *the case of pre-service teachers experience and enact IBST as well as factors that influences their enactment of this pedagogical approach within their specific context.* The case is circumscribed in the next section (Section 4.2) in terms of location, time and participants.

Drawing from the pragmatism paradigm, the case study adopted a multi-methods approach to explore the group of final year pre-service teachers' understanding and enactment of inquiry-based science teaching. The use of various methods therefore facilitated not only the understanding and appraisal of the group's construction and enactment of IBST; but it also helped to validate and extend conceptually, the existing framework for IBST (Hsieh & Shannon, 2005). The knowledge constructed about the groups' understanding and enactment of IBST is useful in informing action: the design of tailor-made programmes aimed at improving this group of teachers' understanding and enactment of IBST in line with the pragmatic view of knowledge although such knowledge could also be applicable in other similar contexts (Goldkuhl, 2012).

The case is circumscribed in the next section (Section 4.3) in terms of location, time and participants

Figure 4.1 provides a summary of the multi-method approach adopted in the qualitative case study.

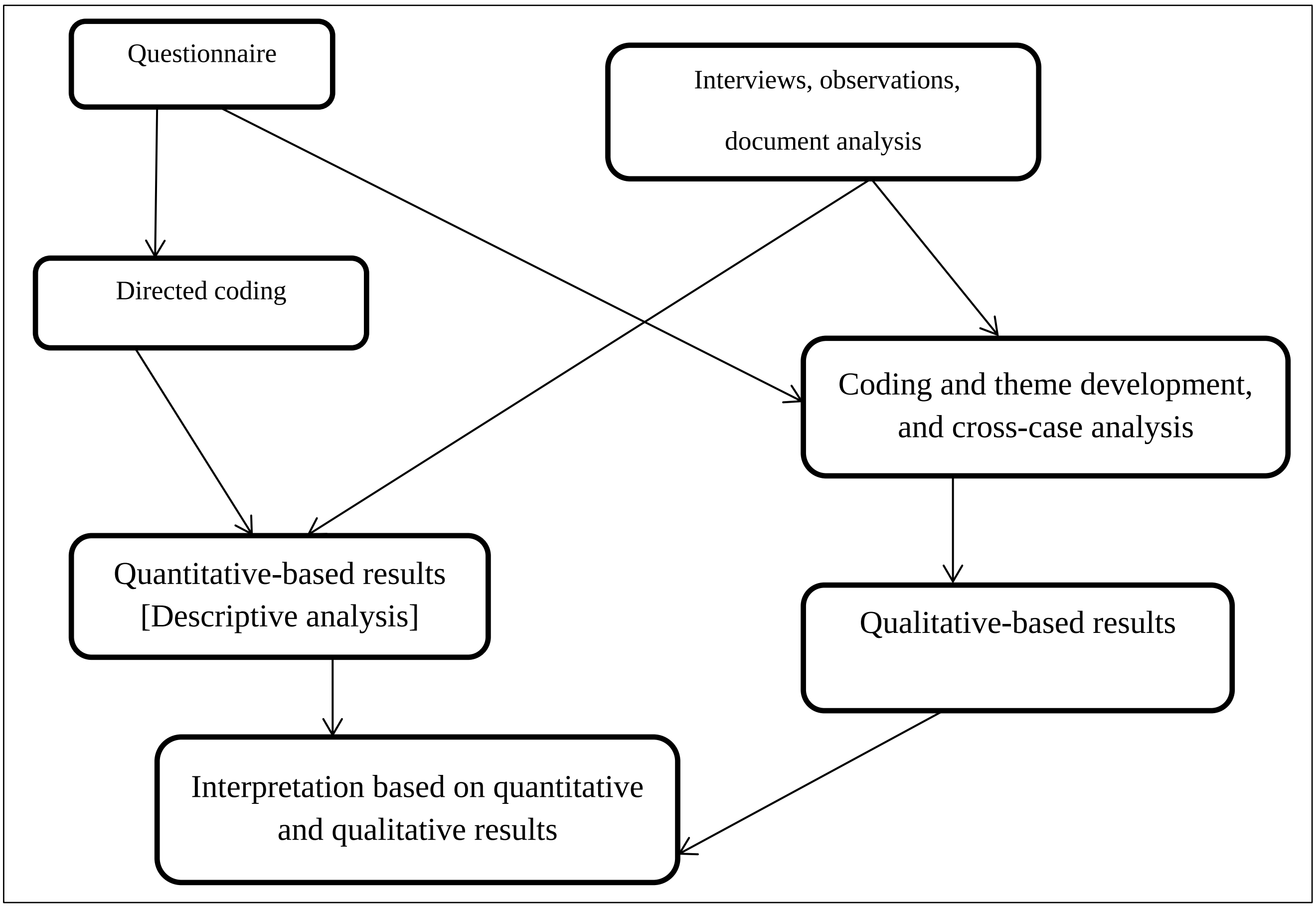

Figure 4.1 A diagram summarizing the multi-methods approach adopted in the study

4.3 THE STUDY SAMPLE AND PARTICIPANTS

The study was made of 41 purposively selected pre-service teachers who were enrolled for a primary teachers' diploma in one university in Swaziland. The participants were specializing in science. The science programme comprised three science content modules: general biology, chemistry and a physics module, and one science methods module. Participants had enrolled for their final year of the teacher education programme, and had already passed four of five science content modules designed to prepare them to teach science. Moreover, when the study took place, they were engaged in a science methods module, which had afforded them an opportunity to learn about IBST through being engaged in constructing and teaching inquiry lessons as well as reflecting on their teaching practice. The group was therefore an appropriate sample for investigating the effects of the academic programme on participants' understanding and enactment of inquiry-based science teaching.

The researcher invited all the 41 pre-service teachers to participate in the study, but only 34 of them agreed to participate. Three data collection strategies were employed: questionnaire, interviews, and classroom observations. In the first phase of the study, thirty-four (34) participants responded to the questionnaire. Furthermore, eight of the pre-service teachers signed informed consent forms and participated in the post-questionnaire interviews aimed at getting deeper insights into the groups' understanding of IBST. In the second phase aimed at exploring the pre-service teachers' enactment of IBST, only six of the eight participants consented to be observed during teaching practice in schools. One ethical aspect of a social or educational study is that study participants should not be coerced; rather they should participate voluntarily (Cohen et al., 2011).

Table 4.1 *Summary of the sampling procedure*

Phase	Research question	Participants invited (Purposive sample)	Number of participants who finally formed the (Voluntary sample)
1	Pre-service teachers' understanding of IBST	41 science specialists	34
		34 questionnaire participants	8
2	Pre-service teachers' enactment of IBST	34 questionnaire participants	6

As shown in Table 4.1, the criteria for participation in the study were specialization in science and participants' informed consent to participate in the study. .

4.4 DATA COLLECTION PROCEDURES

In a case study design, multiple data sources and methods are used in order to provide a deeper understanding of the phenomenon under consideration (Cohen et al., 2011; Nieuwenhuis, 2007c). Relevant data collecting methods include "questionnaires, interviews, document analysis and observations and sometimes the collection of physical artefacts" (Nieuwenhuis, 2007c, p. 76). In this study, the researcher used a teaching scenario-based questionnaire, individual semi-structured interviews, lesson plans, and classroom observations in addressing the research questions. The review of the literature influenced the data collection procedures, because it indicated the kind of data collecting strategies previous researchers had found useful in understanding the phenomenon under study. The data in this study was collected through a teaching scenario-based questionnaire, an after- questionnaire semi-structured interview, an observation schedule, and pre- and post-lesson interviews.

4.4.1 The teaching scenario-based questionnaire

As part of its objectives, the study sought to describe how the pre-service teachers conceive IBST at the conclusion of their 3-year teacher education programme. A questionnaire was viewed as suitable for this purpose because it permits the collection of relevant data from a larger group of participants and which can be done more quickly than other relevant methods (Maree & Pietersen, 2007); the researcher believed that it would yield a more representative account of the pre-service teachers' understanding.

Two main types of questions are found in questionnaires: open ended, closed questions or a combination of these types of questions. A number of scholars using qualitative data, point out the need for using data collection methods that allows participants to provide detailed responses, which then generate rich data sets; (Cohen et al., 2011; Maree & Pietersen, 2007). Nevertheless, a study by Mugabo (2012) found that open-ended questions may not elicit desired detailed responses regarding what participants know about IBST. Accordingly, this study made use of a semi-structured questionnaire format. Cohen et al. (2011) describe a semi-structured questionnaire as a "powerful tool consisting of a line of questions, statements or items, and the respondent needs to address or comment on them based on their knowledge or opinions" (p. 382).

Some studies indicate that scenario-based questionnaires can be useful in eliciting teachers' understanding of the different dimensions of IBST, in both developing and developed countries (Chabalengula & Mumba, 2012; Kang et al., 2008). The findings based on the teaching activity-based questionnaire in Kang et al. (2008) also matched closely those emanating from other data sources, such as group discussions and teacher narratives. Consequently, the researcher opted for a teaching scenario-based semi-structured questionnaire.

For the questionnaire in this study, Section A was straightforward; it mainly solicited participants' biographic data, which was necessary for making sense of participants' understanding. Part B of the questionnaire consisted of 10 teaching scenarios: participants had to explain in their own words whether each teaching scenario represented an inquiry-based lesson or not (Appendix A). The purpose of using the semi-structured scenario-based questionnaire was to understand, not only the kind of teaching scenarios participants associated with inquiry-based science teaching, but also what they regarded to be characteristics of inquiry-based science teaching.

4.4.1.1 Development of the teaching scenario-based questions

For Section B of the questionnaire the 10 chosen teaching scenario-based items were developed mainly from the 'Pedagogy of Science Teaching Tests' (POSTT) (Cobern et al., 2014; Cobern, Schuster, Adams, & Skyjod, 2013). The objective items that comprise the POSTT are based on actual teaching of specific topics in the classroom, rather than general statements about inquiry or science teaching. The POSTT had been extensively validated for the intended purpose: They were piloted among various groups of pre-service teachers; and were assessed by a number of science education professors from different universities (Cobern et al., 2014; Cobern et al., 2013).

For this study, a drawback of the POSTT was that it had been designed for assessing teachers' knowledge of pedagogical approaches for teaching science (Cobern et al., 2013, p. 3) rather than evaluating teachers' understanding of inquiry-based science teaching. To suit the purpose of the current study, the researcher adapted the questions. Firstly, instead of requiring participants to select a response from among a given list of options, they were asked to explain in their own words, whether each teaching scenario represented an inquiry-based lesson or not. Secondly, additional items were included and some existing ones were changed so that they would reflect particular essential categories (features) of the different dimensions of IBST as portrayed by Furtak et al. (2012). The items that were adaptations of the POSTT questionnaire were items 3, 5, 7 and 9.

Other questions had a different disposition, in that they focused on generating data on the different kinds of science instruction that the pre-service teachers mainly associated with IBST. These questions were adapted from other examples provided by (Schuster et al., 2006), Bertsch et al. (2014), and the National Research Council (NRC) (2000) and the Association for Middle Level Education (2011). The following example shows an original POSST question followed by the adaptation made for this study:

> *Ms Harvey's class has been learning about matter. She now wants her 4th grade students to learn that gases (like those of air) are also a form of matter. She plans to introduce the lesson by raising some questions with her students about whether air is matter and how they could find out. Ms Harvey is still considering what to do next. Thinking about how you would teach this lesson, of the following, which one is most similar to what you would you do.*
>
> A. *I would ask students to think out ways to test if air is matter using whatever equipment we have in the classroom. I would then allow them to go ahead and try their ideas.*
> B. *I would help students develop ways to test the question of whether air is matter, allow them to investigate with fans, and use fans at their desk to find evidence that proves that indeed air is matter.*
> C. *I would tell students that air is indeed matter, and that though it is not very dense, there is something there that can be felt. I would ask them to use fans at their desks to see if they could find evidence that air was indeed matter.*
> D. *I would tell the students that air is indeed matter, and that although it is not very dense, there is something there that can be felt. I would then demonstrate this property to the class by having them feel the air from a fan (POSTT 1#5)*

For the questionnaire, the researcher selected item C and asked learners to say, with reasons, whether they regarded the description as being inquiry or non-inquiry. She however added the introductory part that involved asking learners whether air is matter and how they could find out. This was meant to ensure the item had some conceptual and social features of IBST, *eliciting learners' ideas and class discussion* in addition *to the procedural features in the item C*.

> *Miss Sihlongonyane's class has been learning about matter. She now wants her 4th grade learners to learn that gases (like those in air) are also a form of matter. She*

> *starts by introducing her lesson by raising some questions with her students about whether air is matter, and how they could find out. She then tells the students that air is indeed matter, and that although air is not very dense, there is something there that can be felt. She then asks them to use fans at their desks to see if they could find evidence that air is indeed matter.* (Scenario-based questionnaire, item 5)

Similarly, item 7 of the questionnaire was an adaptation of POSTT2#4. The researcher selected option B. In addition to engaging learners in a discussion about soil types based on their hands-on investigation, she added aspect of learners discussing how the work they did was similar or different from what scientist do. This was meant to include an epistemic aspect: an explicit reflective discussion about the nature of science.

4.4.1.2 Validation of the teaching scenario-based questionnaire

In order to ensure its content validity, three groups checked the scenario-based questionnaire: two pre-service teachers, two teacher educators in the faculty where the study was conducted, and experienced researchers. The researcher first gave the first draft of the questionnaire to the pre-service teachers and teacher educators from the Faculty, the latter were a science and English language specialists, to read and make comments about the clarity of the teaching scenarios. The Faculty members were also asked to make comments on two aspects: firstly, the extent to which they thought the teaching activities were representative of what could take place in a Swaziland science classroom; and secondly their potential to elicit the desired evidence. Comments received at this stage indicated that the questionnaire was clear and was suitable for the desired purpose of the study

The questionnaire was subsequently given to experienced researchers to check the extent to which the questionnaire represented the different features of IBST in accordance with the conceptual framework of IBST adopted in the study. Feedback received indicated that some items needed to be revised for either clarity or to cover more elements of IBST. For example, scenario item #4 in the first draft of the questionnaire did not clearly point out whether participants would conduct the different elements of the lesson described individually, as a group, or as a class, as it can be noted below:

> *Teacher Futhi is teaching her Grade 1 class how to make a simple bar chart. She begins her lesson by handing out sets of blue and red blocks and asks them to draw*

> *pictures that show how many blocks of each colour they were. After discussing their pictures, she then passed her own drawing of a bar chart (Figure 1) and has students discuss how each picture might also represent how many blocks of each colour they were.* (*POSTT 2 #3).*

One of the critical reviewers pointed out the need to add more detail on how learners interacted so the item could better help elicit the participants' understanding of different domains of IBST, in line with inquiry-based science teaching conceptual framework adopted in the study. Pointing out in the revised version that learners discuss the pictures in groups was meant to elicit a better understanding of pre-service teachers' understanding of the social domain of science. Often teachers associate group work in IBST with the goal of learning of science content or process skills, or just sharing either the learning materials or the workload; and often overlook the role of group activities in promoting interaction and collective reasoning and decision-making (Abd-El-Khalick, 2012; Furtak et al., 2012). The researcher accordingly revised the item so that it then read:

> *Teacher Futhi is teaching her Grade 1 class how to make a simple bar chart. She begins her lesson by handing out two sets of blocks to learners, and asks them to draw pictures that show how many blocks of each they were. Learners then go into their groups, where they discuss and select what they regard as the best representation. After a class discussing of the group pictures, she then passes her own drawing of a bar chart to learners (Figure 1) and has students, in their groups again, discuss how the picture might also represent how many block of each color they were.* (*POSTT 2 #3*)

Similarly, item number 7 was also revised to include the discussion about the nature of science, which was not very evident in any of the items. The added section is indicated in bold:

> Mrs Fakudze wants her Grade 3 learners to be able to recognize different types of earth materials, namely rock, mineral, clay, sand and soil samples, which he has available for use in the lesson. She starts her lesson by engaging students in sorting and describing the various earth materials displayed on their tables, according to their

> unique characteristics. She then guides a class discussion about different types of soil materials and how the activity they have been doing is similar or different from how science functions. **At the end of a lesson, Mrs Fakudze, refers them to the article that they read in earlier lessons about how scientists work; and leads a class discussion about how the activity they have carried out is similar or different from the ways scientists do their work**. [POSTT, 2#4]

Table 4.2 shows the representation of the different domains in the questionnaire items after validation by critical researchers.

Table 4.2 *Representation of different features of IBST in the questionnaire*

Doman of IBST	Description	Items
Procedural	Asking scientifically oriented questions	2,3, 6, 8
	Designing investigations	6, 8, 9
	Carrying out investigations	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
	hands-on	1,2
	Documenting data	2, 9, 10
	Representing data	10
Epistemic	Nature of science	7, 8
	Drawing evidence-based conclusions	6, 9, 10
	Generating and revising scientific theories	3, 8,
Conceptual	Eliciting learners’ ideas	3, 5, 6, 8
	Drawing on learners’ prior knowledge	2, 8,
	Providing conceptually oriented feedback	3, 7, 10
Social	Participating in class discussions	4, 7, 9, 10
	Debating ideas	6, 8, 9
	Presentations	6, 8, 9
	Working collaboratively	1, 3, 4

A second stage of piloting involved a smaller group of pre-service teachers, who did not take part of the main study. The pilot study’s results indicated that in responding to some teaching scenarios, participants focused their attention on only a few aspects of the teaching activity: either the first or the last portion of the teaching scenarios, in categorizing the teaching activities. The researcher then adjusted lesson scenarios where this problem had been most evident (items 9 and 10), and divided those items into two sections in order to prompt the pre-service teachers to consider more aspects of each lesson scenario in their categorization and characterizing of inquiry-based science teaching. In addition, the pilot study indicated that an hour would be enough to respond to the questionnaire; the pilot study participants answered the questions within an hour.

For example, the original questions 9 read as follows:

> Mr. Mavundla Grade 3 class has been doing an investigation on earthworms. Besides teaching students about the basic needs of earthworms, she also wants them to develop skills of observing, investigating, recording and seeking patterns. After carrying out investigations on the earthworms in groups by following teachers' instructions over some time, she requests different groups to present their data to the whole class so they could search for patterns in their observations. During the data analysis, one student points out that the data collected by one group seemed to contradict data collected by another group. The teacher asks students to suggest ways of addressing the issue, accepting any response that relied on evidence. For example, re-examining recorded data, or comparing data collecting procedures, or repeating or taking more observations (POSITT).

The following are some examples of the participants' responses based on the above version of the question. While the term consisted of a number of features of IBST, participants were generally very brief as indicated in the following example:

> The learners are conducting research and analyzing data. (Participant X, pilot study)
>
> It is inquiry because the learners will be redoing the experiment to try to find out what made the other group's data to be different. (Participant Y, pilot study)

It is evident that in responding to the questionnaire the first participant focused on the first part while the second only on the latter. After the pilot study, the question was split into two to enable participants to consider several terms in classifying a lesson scenario as inquiry or non-inquiry based in order to improve the items' strength in eliciting learners' understanding of essential elements of IBST.

(a) Mr. Mavundla Grade 3 class has been doing an investigation on earthworms. Besides teaching students about the basic needs of earthworms, she also wants them to develop skills of observing, investigating, recording and seeking patterns. After carrying out investigations on the earthworms in groups by following teachers' instructions over some time, she requests different groups to present their data to the whole class so they could search for patterns in their observations. [POSITT]

(b) During the data analysis, one student points out that the data collected by one group seemed to contradict data collected by another group. The teacher asks students to suggest ways of addressing the issue, accepting any response that relied on evidence. For example, re-examining recorded data, or comparing data collecting procedures, or repeating or taking more observations (POSITT).

The following are examples of responses of one of the participants after this modification:

> It is inquiry because the teacher first told learners to make observations and then communicates their findings. (Participant 1: 9a, main study)

> It is inquiry because when a contradiction was encountered the teacher did not interfere with it or gave learners the correct answer; instead, he encouraged them to suggest ways of solving the problem. (Participant 1: 9b, main study)

> The teacher grouped the learners and allowed them to observe and present their data to the whole class. He then guided them to search patterns among the data. (Participant 15, item 9a, main study)

> A question was raised by a learner and he allowed them to suggest ways to address the issue and encouraged them to base their ideas on evidence. (Participant 15, item 9b, main study)

4.4.1.3 Administration of the questionnaire

Prior to administering the questionnaire, participants were given letters inviting them to participate in the research. The letters stated that participation was voluntary, and that the collected data would only be used to for the purpose of the study. Participants who were willing signed and returned letters of consent. All participants who agreed to participate answered the questionnaire together in the presence of the researcher, during their 2-hour long lecture. Even though the pilot study indicated that an hour was enough, the length of time allowed to answer the questionnaire was unlimited. However, most participants answered the questionnaire within the first hour. Participants were supervised in not obtaining information from a relevant document, and in not sharing answers. This was to make sure that the data gathered represented their personal construction of IBST. However, the researcher assured them that they were no wrong responses and that the data gathered would only serve the purpose of the study (Nhlengethwa, 2013).

4.4.2 Semi-structured interviews

Questionnaires, on their own, may not lead to dependable study findings (Nieuwenhuis, 2007c). Thus in order to provide multiple sources of data, the researcher followed up the administration of the questionnaire with interviews. Interviewing is the most frequently utilized method in gathering data in qualitative research (Gill, Stewart, Treasure, & Chadwick, 2008). An interview is “a two-way conversation in which the interview asks the participant questions to collect data and to learn about the ideas, beliefs, views, opinions, and behaviours of the participant” (Nieuwenhuis, 2007c, p. 87). As a result, a number of studies assessing participant teachers’ understanding of inquiry-based science teaching, such as Kang et al., 2008; Mugabo, 2005) have used them in conjunction with other data collecting strategies. This study employed semi-structured interviews. Semi-structured interviews are guided by an interview schedule that enables the interviewer to ask all interviewees the same basic set of questions. But, the researcher is also free to then ask individual “follow up questions to probe and help participants clarify their responses” (Nieuwenhuis, 2007c, p. 87). The purpose of semi-structured interviews in this study was twofold. Besides providing another source of data and contributing to data triangulation, through the interviews the researcher could gain deeper insights into the pre-service teachers’ understanding of IBST as is fitting for a case study.

The interview protocol for this study is given in Appendix B. The researcher carried out the interviews with eight of the 34 pre-service teachers who had shown willingness to take part in the second stage of the study. During the individual interviews, participants described what they regarded as essential elements of IBST. The interviewer used further questions to get clarification of their questionnaire responses. A digital audio tape was used to record all interviews. The interviews occurred over a period of two weeks and each session took 45-60 minutes.

Even though, the sample of eight participants was small and formed a voluntary sample, based on their questionnaire responses they had demonstrated varying understanding of IBST. The interview responses also indicated data saturation, in that no new ideas were generated. This could be judged because data analysis of the earlier interviews occurred while data collection was still taking place. The researcher documented the pre-service teachers' demonstrated understanding about IBST and noted repetitions among the teachers' conceptions. By the time the researcher reached the eighth interview no new information was evident regarding the participants' understanding of IBST. Pre- and post-interviews: were also conducted. These are described later in Section 4.3.4.

4.4.3 Document analysis

This study also used documents as another source of data regarding the participant pre-service teachers' enactment of IBST. When you use documents as a data collecting strategy, Nieuwenhuis (2007c) asserts that "you focus on all documents that can offer some light on the phenomenon that you are investigating" (p. 82). In this study, pre-service teachers had prepared lesson plans for every lesson they intended to teach. The researcher therefore gathered a copy for each of the observed lessons; examples are provided in Appendix C. This action was aimed at finding out how pre-service teachers had planned their inquiry-based lessons as part of understanding the manner in which they enact IBST.

4.4.4 Classroom observations

Classroom observations, as a form of data collection have been used extensively to study teachers' inquiry practices and classroom orientations (Crawford, 2007; Lehane et al., 2014;

Windschitl, 2002). Observation is defined by Nieuwenhuis (2007c, p. 83) as a "systematic process of recording the behavioural patterns of participants, objects and occurrences without necessarily communicating with them". As a non-participant observer, the researcher observed each of six participants twice during their 6 weeks teaching practice in school. This provided first-hand information rather than only relying on teachers' self-reporting or lesson plans about how they employ inquiry-based science instruction in presenting their science lessons.

Like questionnaires and interviews, observations "can either be structured or unstructured, or fall in-between the two extremes" (Nhlengethwa, 2013, p. 52). In this study, guided by the framework developed by Furtak et al. (2012), the researcher made use a semi-structured observation schedule (see Appendix E) to guide her on what to observe with regard to the pre-service teachers' enactment of IBST. Observation and recording was, however, not restricted to this framework. Any other observation the researcher viewed as valuable in understanding the manner in which the pre-service teachers enacted IBST was also noted.

Each observation session occurred within a 60 minutes lesson period. These were video recorded using a cell phone and described in writing. A cell phone was chosen rather than a full-scale camera on tripod in an attempt to make the recording process as less intrusive as possible to the teaching and learning process. However, the researcher needed to move around to catch each activity. In line with the interpretivist perspective of the study, the researcher presented a detailed description of the teacher's actions and the classroom situations related to those actions (Nieuwenhuis, 2007c). Soon, after the observation, the researcher reflected on the lesson based on the notes and video. Participants were also encouraged to reflect on the observed lesson on their own and to write down comments that would be useful in a later discussion with the researcher. Even though holding immediate discussions with participants would have been more useful, this was not possible due to time limitation on the side of the participants.

In addition, six of the eight pre-service teachers participated in pre- and post-lesson interviews (see Appendix D). Pre-lesson interviews were used to determine the teachers' planning for inquiry-based science teaching (lesson planning strategies and teaching activities) and their understanding of the ideas to be addressed. The researcher asked participants to explain the ideas they were going to teach and how they intended to go about teaching them using inquiry-based science teaching. The purpose of the post-lesson interview was to determine the teachers' reasons for teaching and learning activities that had been observed, and their ideas of learners' learning difficulties (if any). Lesson interviews were recorded with an audio tape. However, not all six participants were interviewed twice as some only participated in the post-interviews. During the course of interviews, some participants hinted that the pre- and post- interviews was taxing for them thus interviewing them once was a means of minimizing pressure on participants. Therefore, in total, only ten instead of 12 interviews were conducted in total.

4.5 DATA ANALYSIS

In this study, both deductive and inductive data analysis approach were used as guided by the research questions. The inductive analysis approach ensured that the findings reflected the participants' main ways of understanding of IBST from their perspective (Creswell and Plano Clark, 2007; Hsieh & Shannon, 2005). The deductive or directed approach on other hand, helped to provide an understanding of the extent to which their understanding and enactment of IBST matched an existing conceptual framework consistent with the desired outcomes of the programme. A cross-case analysis of six pre-service teachers help to generate textual data that allowed a deeper understanding of the larger single case of the pre-service teachers and the influence of the different schools and other related personal attributes on their enactment of IBST (Baxter & Jack, 2008).

In order to ensure clarity, presentation of the data analysis process is in three sub-sections in accordance with the research questions. Table 4.2 presents an overview of the whole data analysis process for all three-research questions.

Table 4.3 *Summary: Research questions, data collection and data analysis*

Research Question	**Data Collection Method**	**Data analysis**
What do pre-service primary school teachers understand by inquiry-based science teaching at the end of a 3 years' experience in science courses?	Questionnaire with 8 semi-structured questions	Searched each participants' questionnaire and interview data for recurring statements about IBST in order to identify the main ways by which each participant understands IBST Recurrent codes were used to create categories, which were subsequently merged into themes representing the major ways in which the group understand IBST. Both sets of data were subsequently searched for their understanding of different dimensions of IBST using *a priori* codes taken from Furtak et al. (2012).
How do pre-service primary school teachers enact inquiry-based science teaching during their final-year (3rd) teaching practice in schools?	Lesson plan Lesson interview Observation schedule	Evaluation of lesson plans, Lesson interviews and observation transcripts for dimensions of IBST guided by the framework of IBST developed by Furtak et al. (2012).
What factors influence pre-service teachers' enactment of IBST?	Semi structured individual interviews after administration of survey questionnaire, pre- and post- lesson interviews and observations of lesson presentations during teaching practice.	Triangulation of themes on teachers' enactment of IBST and personal profiles regards understanding of IBST, themes developed from lesson interviews, and participants biographic and contextual factors.

4.5.1 Examining pre-service teachers' understanding of IBST

Data pertaining to participant pre-service teachers' understanding of inquiry-based science teaching was generated by means of a teaching activity-based questionnaire, supported by semi-structured individual interviews. The analysis was meant to establish both the meanings that participants attach to inquiry-based science teaching from their own perspective; and their understanding of the different dimensions of this pedagogical approach guided by a framework of IBST postulated by Furtak et al. (2012). Consequently, both inductive and a deductive analysis was used in line with the mixed methods approach adopted in this study.

4.5.1.1 Analysis of questionnaire data

Analysis of the responses participants gave to the lesson activity-based questionnaire (Appendix A) happened in three phases. The first phase aimed at establishing the kind of teaching activities that participants associated with inquiry-based science teaching. This involved initially classifying each teaching activity on the questionnaire as inquiry or non-inquiry, according to the definition of IBST put forth by Furtak et al. (2012), which was discussed in detail in Chapter 3: Section 3.1. Subsequently, the researcher used the hierarchy of inquiry-based science teaching constructed by Wenning (2005) shown in Table 2.1, to indicate the level of IBST involved in each activity. Participants' categorization of lesson activities as inquiry or non-inquiry was then analysed and used to construct a frequency distribution representing the kind of lesson activities that participants mostly associated with inquiry-based science teaching and those that they did not.

Secondly, based on the constructivists view about learning, the researcher used a phenomenographic approach to make sense of the pre-service teachers' conceptualization of IBST. Phenomenography, in this context refers to the different major classifications of ways in which pre-service teachers experienced inquiry-based science teaching (Cheng, 2016, p. 283). One way by which students (pre-service teacher) experience a concept is in terms of its essential aspects and it is the student who decides which aspects of the phenomenon are principal and which are peripheral (Cheng, 2016). In line with this perspective, the researcher searched for the feature of the lessons that was pivotal in their categorization of teaching-based scenarios. For example, participants who only classified lesson scenarios that engage learners in constructing knowledge themselves, regardless of the presence or absence of other elements of the lesson that they also regarded as inquiry features, indicated that this feature was central in their understanding of this pedagogical approach. The researcher therefore considered this element to represent a particular way in which the participant understood inquiry-based science teaching, which may differ from the way other people conceptualize this phenomenon. The researcher used participants' justifications for the way they classified their science lessons and semi-structured interview data to test the validity of the coding of participants' descriptions of IBST.

The researcher ultimately combined similar codes representing individual classification of understanding, into major themes called categories of understanding, which represent the important different ways in which pre-service teachers understand inquiry-based science teaching. For example, the researcher merged hands-on and minds-on categories of understanding into one major theme: active engagement-centred understanding of BST. Ireland et al. (2012) used this approach successfully in their investigation of elementary teachers' construction of IBST.

The researcher then reported, in a table, the number of participants that demonstrated different categories of understanding of IBST in order to indicate the distribution of the pre-service teachers' understanding. See Table 5.2 in the next chapter.

Lastly, the researcher used what Hsieh and Shannon (2005) describe as a "directed approach to content analysis" (p. 1281) to analyse the questionnaire data for participants' understanding of the different dimensions of inquiry-based science teaching. In employing this approach, the researcher employed the conceptual framework of IBST proposed by Furtak et al. (2012) described in Chapter 3: Section 3.1. Furtak et al. (2012) acknowledge two dimensions of inquiry-based science teaching: the cognitive and the guidance dimension. They further categorize the cognitive dimension into to four domains: procedural, epistemic, conceptual and the social. The researcher chose this framework because of its detailed subcategories (descriptions) of the cognitive dimension, constituting the cognitive and social activities of the learners in inquiry-based science learning, as summarised in Chapter 3, Table 3.1. The analysis began by searching the questionnaire responses for statements that were in line with the features (categories of descriptions) of the different domains of the cognitive dimension presented in Table 3.1.

In making sense of the group's understanding of IBST, the researcher considered both the number of participants who referred to each subcategory (description) of IBST irrespective of the number of times he or she had mentioned the subcategory (Kang et al., 2008; Ozel & Luft, 2013) and then also the overall frequency with which participants referred to each sub-category. In order to make sense of the group's understanding of the cognitive dimension of IBST based on the questionnaire data, the researcher computed the group's representation of the different domains by dividing the total number of times the group referred to a domain by its number of subcategories.

Similar to many other previous studies (Capps et al., 2016; Demir & Abell, 2010; Kang et al., 2008), the researcher, later, examined the remaining questionnaire text for any new categories not covered by the framework by Furtak et al. (2012). The researcher also employed the same generic qualitative approach to establish participants' understanding of the guidance dimension by searching for classroom activities that participants believe learners should do themselves individually or as a group in an inquiry-based lesson, and those that the teacher should execute.

To ensure that the researcher's construction of participants' understanding of IBST was consistent with available data, the researcher employed three strategies: "member checks, stepwise replication, and code-recode strategy" (Anne, 2015, pp. 277-279). Firstly, during interviews with some of the participants, the researcher had an opportunity to check her analysis and interpretations of questionnaire data in order to control for any biases. Secondly, in ensuring stability of findings, the researcher coded the same data twice with a two weeks development period between each coding, she then compared the analysed data to note if they were any similarities or differences. Thirdly, a colleague in the department, who is conversant with coding data and the explored concept, verified the developed categories and themes by coding some of the data. The researcher and this assistant discussed the coding and resolved any differences by consensus (Kang et al., 2008; Ozel & Luft, 2013). A critical researcher, who is also a specialist in the field, also checked the results of the analysis, including the developed themes. The researcher used all such comments to reflect on and improve her data analysis and interpretation. To elaborate, there were initially, some disagreements regarding coding certain units of meaning in the data. For example, it was not clear whether the study should regard units such as classifying objects or analysing data as additional categories of the procedural and epistemic domains, respectively, or regard them as sub-categories of executing scientific procedures and forming evidence-based conclusions correspondingly. However, after a discussion with some critical researchers, the final consensus was that the activities (units of meaning), must been seen as forming part of the process of executing scientific procedures and forming evidence-based conclusions respectively.

4.5.1.2 Analysis of interview data

After the administering of the questionnaire, the researcher conducted follow up semi-structured interviews to provide data to corroborate the questionnaire data. All interviews were transcribed verbatim. The researcher listened to the audio recording and attempted to transcribe it as exact as possible. The researcher then proofread the document with the purpose of filling in any missing words and correcting grammatical mistakes. Participants who were available read and confirmed the transcripts as representing what they had pointed out. She then analysed the interview data in two phases. The purpose of the first phase was to construct meaning of the different main ways in which participants understood inquiry-based science teaching from their own perspective. Akin to the second phase of the analysis of questionnaire data, the researcher used a phenomenographic approach. She searched the interview transcript for what appeared central in each participant's discussion about inquiry-based science teaching. For example, the following extracts illustrate that learners' constructing of knowledge themselves was critical in the interviewees' understanding of IBST.

> The definition in inquiry should come at the end, because in inquiry we want the learners to be engaged in discovering the knowledge themselves based on their exploration rather the teacher telling them. The teacher can then add to what they have discovered.
>
> If the teacher gives them the answers, it is no longer an inquiry. But if the learners ask a question, the teacher should appear like he knows nothing and says let us try to find out together, make a plan on how we can answer the question and everyone discover herself or himself the facts rather than being told by the teacher

The researcher then combined related conceptions to form themes, which represent major ways in which interviewees understood inquiry-based science teaching, which is referred to as the outcome space. The researcher then compared the themes developed from analysing the questionnaire and interview data to find out if the two sets collaborated in their representation of how the group understood IBST. Where there was a contradiction, the researcher took the interview-based themes as a close representation of the participants' understanding.

Figure 4.1 represents the inductive process employed to analyse both the questionnaire and interview data for the different main ways in which pre-service teachers understand inquiry-based science teaching.

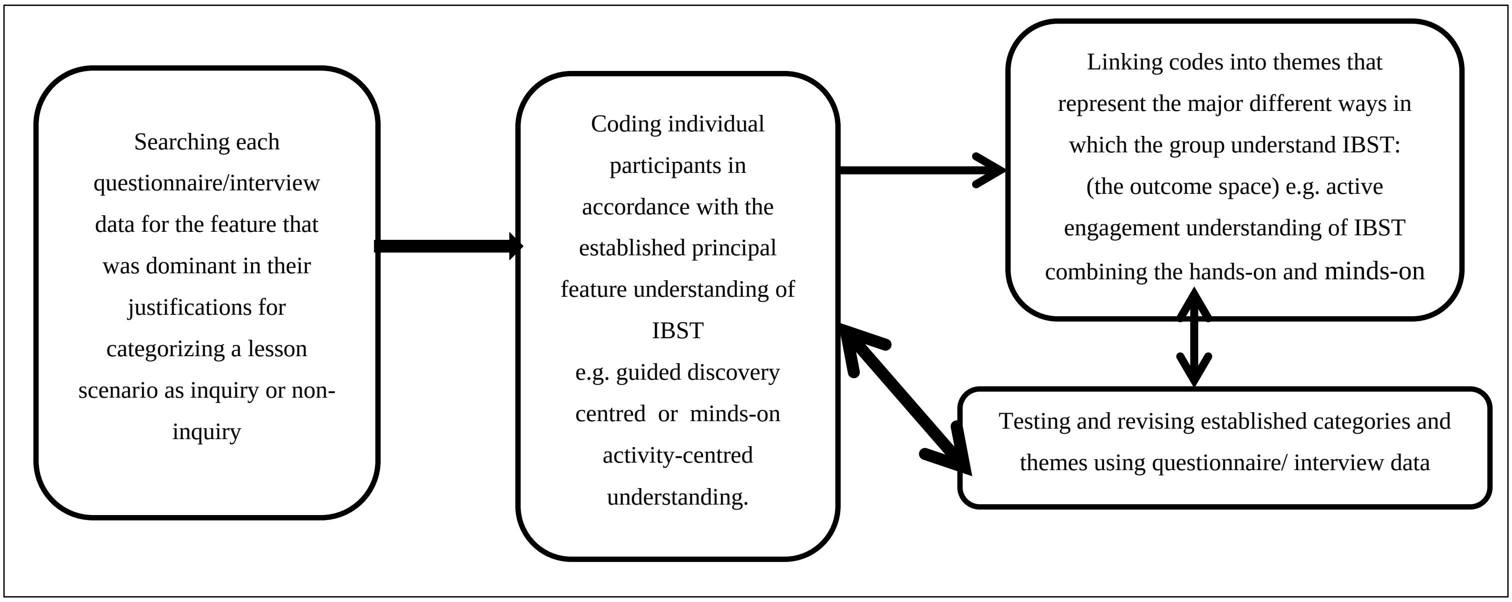

Figure 4.1 *Analysing questionnaire data for the different ways in which participants understand IBST*

4.5.2 Examining participants' enactment of IBST

The study used lesson plans (documents), pre- and post-lesson interviews (previously transcribed), as had been the semi-structured interviews) and classroom observations as data sources for addressing the question about pre-service teachers' enactment of IBST. The researcher employed the same framework as before in Section 4.4.1, Furtak et al. (2012), to analyse the various data sources for evidence of pre-service teachers' enactment of this pedagogical approach. Table 3.1 presents this framework for the different domains (categories) and subcategories of one of the two dimensions of IBST as conceived by Furtak et al. (2012): the cognitive and social activities of the learners. The researcher begins by defining how the researcher analysed the data for participants' enactment of this dimension of IBST.

4.5.2.1 Analysing data for participants' enactment of the cognitive dimension of IBST

For this phase of data analysis, the researcher first used *a priori* coding to analyse the data. She used pre-set codes: the conceptual, procedural, epistemic and social domains as coined by Furtak et al. (2012). For each of the four categories of the cognitive dimension, Furtak et al. (2012) identified subcategories, which the researcher refers as categories of description. The researcher used these categories of description to code the three sets of data that pertained to pre-service teachers' enactment for IBST; that is, from the lesson plans, lesson interviews and classroom observations. Subsequently, she compared the categories of description of each domain each participant mentioned in lesson plans and lesson interviews to determine how they corroborated each other. In preparing a profile about the participants' planning for inquiry-based science teaching, the researcher relied on aspects of the lesson plans that pre-service teachers also referred to in the interviews. To establish participants' representation of the different domains in their planning of IBST, the researcher counted the total number of lessons among the six participants that exhibited each of the categories of description of each domain.

Then, for only the pre- and post-lesson interviews, she used an inductive approach to code and categorize other features that participants may have mentioned in their description of how they had planned their science lessons with inquiry in mind. The inductive approach was applied to only lesson interviews because, unlike lesson plans, they specifically refer to features of the lessons that participants associated with IBST. These themes are presented in Table 6.3.

Participants' observation transcripts were similarly analysed and used to prepare a summary of each participant's implementation of IBST. To establish a picture for the whole group's classroom implementation for the different domains, the researcher used the words *absent, inadequate or adequate* as an estimate of the extent to which each participant had attempted to execute each of the learning activities (categories of description) in their actual teaching. *Absent* means, the pre-service teacher did not attempt to engage learners in the activity. A feature was categorized as *inadequate* if though attempted, it did not encompass all its facets; for example, if in designing an investigation, the participant only focused on making decisions regarding the data needed to address a question. If however, all aspects had been present, such as also discussion how data had to be organized and analysed, then the enactment was categorized as *adequate.*

4.5.2.2 Analysing data for participants' enactment of the guidance dimension of IBST

As pointed out in Chapter 3, this study regards inquiry-based science teaching as an instruction where learners take a more "active role in constructing scientific knowledge under the guidance of the teacher " (Furtak et al., 2012). To understand the pre-service teachers' enactment of the guidance dimension of inquiry-based science teaching, the researcher inductively analysed the three data sources: lesson plans, lesson interviews and observation transcripts for aspects demonstrating learner self-directedness in inquiry-based science teaching. Akin to the method in Kang et al. (2008), the researcher searched for statements indicating what the teacher left to learners to do. By examining what the teacher expects learners to do, the researcher could infer the degree of guidance a teacher provided. In other words, a teacher who left everything up to the learners provided zero guidance. A teacher who did everything for them gave 100% guidance. The participant then counted the total number of lessons out of the 12 that demonstrated each aspect of learner-directedness. The results are provided in Table 6.5.

In addition, the researcher also wanted to find out the aspects of learner-directedness that were common to all or most of the participants. She established this by counting the number of pre-service teachers who executed each aspect in at least one of their two lessons, and this information is presented in Table 6.6.

4.5.3 Examining data for factors influencing participants enactment of IBST

Triangulation of data collected by means of all the data sources: questionnaires, follow up interviews, lesson plans pre- and post-lesson interviews and observations was useful in understanding factors that had a bearing on the way teachers had enacted IBST. The researcher carried out the analysis in two stages.

In the first stage, the researcher used an inductive approach to construct themes pertaining to the group's enactment of IBST. For this, she generated themes from the lesson interview data. The analyses began by reading the transcripts carefully line by line. The researcher then searched the interview transcripts for statement that pertained to the manner pre-service teachers had planned and implemented their inquiry-based lessons in order to identify and develop a code list. To establish categories, she read the identified codes and grouped recurrent related codes into categories. The researcher then used the categories to label the coded data. This iterative process involved the generation of new categories and revision of existing ones. Subsequently, the researcher developed broader themes that encompassed a number of related categories, which represented the main factors influencing the manner in which the group enacted their inquiry-based science lessons.

The researcher, in the beginning of the process asked a colleague and a science educator who was conversant with this analysis approach and an experienced researcher to check whether the constructed categories were meaningful and consistent with the data. She also requested the colleague to label some of the coded data to check for inter-rater agreement. Critical researchers also confirmed the final list of categories and themes.

In the second phase, the researcher sought to understand the themes that would be useful in explaining the similarities or differences among the manners in which the pre-service teachers had carried out this pedagogical approach. In order to achieve this goal, the researcher used a cross-case analysis. Taking each pre-service teacher as a single case, she compared his or her individual planning and successful implementation of inquiry-based science teaching. This comparison was in terms of the main factors that she had found from the thematic analysis of the interview data to have a bearing on the participants' enactment of IBST. In addition, she matched each participant's enactment of IBST with his or her biographic and contextual factors in order to establish other factors that could account for the way the group had enacted IBST in schools. A similar method of analysis has been used successfully by Crawford (2007) in explaining a group of secondary pre-service teachers' implementation of IBST.

Figure 4.2 summarizes the process involved in analysing the collected data for factors that influenced the pre-service teachers' enactment of IBST. It shows that the process was an iterative meaning making process involving firstly, the coding of lesson interview data, the generation and revision of themes; and finally, a cross case analysis to develop factors that were useful in explaining differences in the way pre-service teachers enacted IBST.

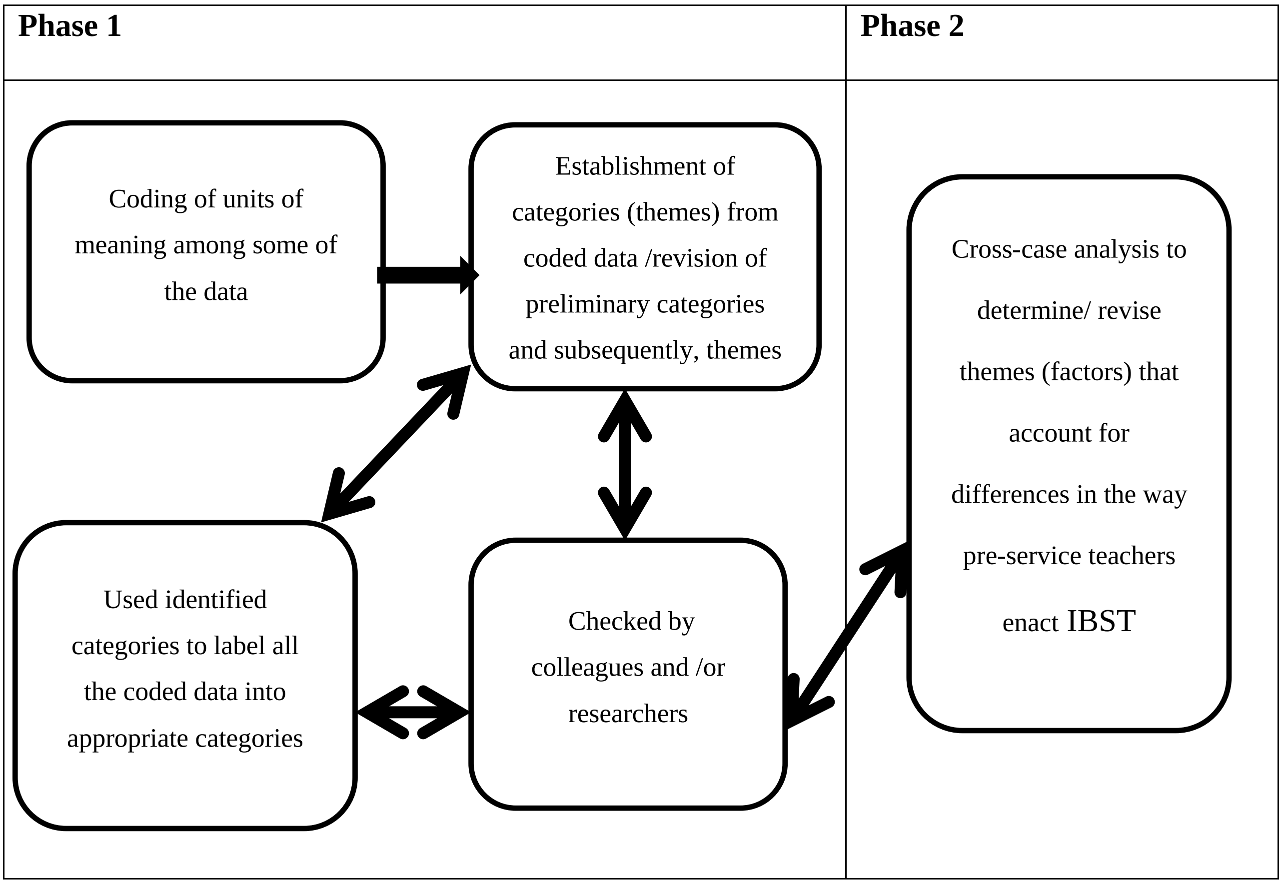

Figure 4.2 A summary of the process of the analysis of data for factors that influenced the participants' enactment of IBST

4.6 METHODOLOGICAL NORMS: TRUSTWORTHINESS

In the pragmatism paradigm, knowledge is regarded as constructed for a particular functional purpose rather than as a copy of reality. Pragmatism does not completely refute the correspondence view of truth; but only regards it as appropriate for simple claims about parts of reality (Goldkuhl, 2012). In line with Sandelowski (1993), trustworthiness, from this perspective is regarded more of an indication of how one practiced good science than a measure of whether or not findings match reality. Cohen et al. (2011) describes the concept of trustworthiness as “honesty, depth and richness, and scope of the data achieved” (p. 79). Although there are some disagreements among researchers with regard to quality assurance strategies in a study that is based on this perspective about knowledge (Maree & van der Westhuizen, 2007; Porter, 2007; Rofe, 2006), nevertheless Lincoln and Guba (1985 in Cohen et al. 2011) present four standards of trustworthiness of a study: credibility, confirmability, dependability and transferability. These are discussed next.

Credibility is the measure of whether study findings are in line with participants’ construction of the studied social phenomenon (Cohen et al., 2011; Moon, Brewer, Januchowski-Hartley, Adams, & Blackman, 2016; Shenton, 2004), and thus as defined by Graneheim and Lundman (2004, p. 109) is also a measure of the “extent to which collected data and data analysis processes meet the research objectives”. Confirmability therefore denotes the extent to which a reader can establish the credibility of the study findings. Dependability has to do with the consistency or reliability of study findings and the extent to which given details of data collecting strategies enable the examination and appraisal of the research process (Moon et al., 2016). Transferability relates to the extent to which findings can be applied to other contexts (Graneheim & Lundman, 2004; Moon et al., 2016). The next five sub-sections discusses the means by which the researcher endeavoured to ensure a trustworthy study.

4.6.1 Ensuring that data gathered meet the study objectives

One of the goals of this research study was to make policy and practice recommendations. Consequently, credibility and dependability were of particular importance. One way to ensure these aspects was to employ data collecting strategies that had been used successfully for other studies in addressing similar questions. The study employed a scenario-based questionnaires, semi-structured interviews, lesson plans, and classroom observations, which are all methods that had been used previously to assess either pre-service teachers’ understanding or enactment of BST (Chabalengula & Mumba, 2012; Kang et al., 2008; Mokiwa & Nkopodi, 2014; Mugabo, 2015). Initially, the researcher had intended to use a non-contextualized open-ended questionnaire to generate textual data regarding the group’s understanding of IBST. However, as already noted, studies such as Mugabo (2012) indicated that this approach may not be good in eliciting teachers’ ideas about IBST as they tend to write very brief responses. The researcher thus opted for a teaching scenario-based questionnaire, which studies such as Kang et al. (2008) and Chabalengula and Mumba (2012) have documented as giving a greater level of success in generating data about teachers' understanding of characteristics of IBST. The approach was found to provoke participants' thinking about inquiry-based science teaching whilst also allowing them to express their understanding about IBST in their own words.

As was outlined in Section 4.3.1, the questionnaires were extensively validated by science education and language experts for their appropriateness in meeting the research goals and for the pre-service teachers in Swaziland. This necessitated some changes to the questions that required greater explanation of the scenario. The questionnaires were also piloted among 10 other pre-service teachers. This indicated that fuller responses would be generated if some scenarios were split in two. The questionnaires were completed under controlled conditions; thereby ensuring the pre-service teachers gave only their own opinions. Furthermore, the researcher made an effort to ensure that all recorded data matched what really occurred on site. The use of audio and video recordings guaranteed the preservation of the voices and actions of the participants. The researcher also transcribed the data verbatim, thus ensuring that data remained a representation of what participants had said.

4.6.2 Ensuring that research findings emerge from the data

To further enhance the credibility of the study, the researcher made sure that all interpretations about the investigated phenomenon were consistent with the collected data (Maxwell, 1992). During inductive coding, she made sure that generated categories and themes fitted well with the data; meaning that it neither excluded relevant data nor included unrelated data (Graneheim & Lundman, 2004). This she addressed, firstly, by employing an experienced colleague who coded some of the data text independently. The two sets of generated categories were compared and checked for inter-coder agreement, with disagreements being resolved by discussion to get consensus. The inter-coder agreement was above 90% for the various coding connected to the different goals of the study. The details of this process and the type of discussion that ensued are given in Section 4. 4.

Another aspect of ensuring that the findings emerged from the data, was encountered when an expert in the area of study checked the developed categories and themes and modified some of the them to ensure that they were more coherent with the available data (Nieuwenhuis, 2007a). For example, in analysing data for participants' understanding of dimensions of IBST using predetermined codes, the researcher generated some additional categories, which, however, after discussing with the expert, they reached an agreement that some of them were in fact, subcategories of the *a priori* codes rather than new categories.

A further aspect of ensuring that research findings emerge from the data was the use of member checking. During the semi-structured interviews, after studying questionnaire responses, the researcher had the opportunity to confirm questionnaire data and her interpretations with the pre-service teachers concerning their understanding of IBST. This therefore means the researcher was only able to check with the eight interviewees. However, because the pre-service teachers represented a range of understanding of IBST, the researcher presumed that their responses were typical of that level of understanding. During the pre-and post- lesson interviews, she also was able to verify any other interpretations based on previously collected interview data, either about their understanding or about their enactment of IBST. She was also able to talk informally with some of the participants who did not participate in interviews, which enabled her to verify her interpretations of the group's conceptualization of the inquiry-based science teaching approach.

4.6.3 Data triangulation

In this study, using a variety of sources of data was another aspect of enhancing all four aspects of trustworthiness. "Triangulation is a measure of whether the indicator (or set of indicators) used to measure a concept actually does measure the concept" (Moon et al., 2016). In this study, the researcher employed triangulation, firstly by following up the administration of the teaching scenario-based questionnaire with in-depth individual semi-structured interviews with eight of the 34 pre-service teachers who had indicated their interest in participating in the second phase of the study. During interviews, participants described what they regarded as essential features of IBST and clarified their understanding of IBST to give more depth to their responses in the questionnaire. Even though, the interview sample was a small, as it constituted of voluntary participants, the data collected indicated that data saturation had been attained. Data analysis, which occurred whilst data was collected, revealed certain repetitions, and by the time the researcher reached the eighth pre-service teacher, no new information was evident regarding their understanding of IBST.

Moreover, the distribution of the themes and categories derived from the questionnaire data was almost similar to those derived from the interview data, which further substantiated the questionnaire data and consequently the trustworthiness of the study findings.

A second aspect of triangulation was that rather than relying only on lesson plans and classroom observations to ascertain pre-service teachers' enactment of IBST, the researcher also employed pre- and post-lesson interviews. Thus for data used to prepare a profile about the participants' planning for inquiry-based science teaching, the researcher relied on aspects of the lesson plans that pre-service teachers also referred to in the interviews. For example, some participants included group work and classroom discussions in their lesson plans, but did not refer to this feature when describing how they planned their lessons with inquiry in mind, indicating that collaboration and interaction among learners was not one of their learning goals. In fact, some of these participants talked about the sharing of limited learning materials as reasons for letting learners work in groups rather than in individually.

The researcher also used both her observation and interview transcripts to develop a single profile of participants' implementation of IBST. Observations of what people actually say or do are generally more dependable than self-reports. However, a researcher cannot observe the intentions behind the participants' behaviours (Nieuwenhuis, 2007b). Therefore, in the post-lesson interview, the participant could explain his or her decision-making and classroom actions. Participants' stated reasons for what they were doing always took precedence over the researchers' perceptions. This helped enhance the dependability and credibility of the study findings.

4.6.4 Rich descriptions of the study context, the methodology and study findings

To promote confirmability and transferability, the researcher transcribed interviews word for word and substantiated all her claims about the group's understanding and enactment of IBST with raw data as direct quotes from transcripts and questionnaire responses. Moreover, to allow the reader to evaluate confirmability, the researcher has provided a full description of the research process: that is how data were generated, analysed and interpreted (Moon et al., 2016). To enhance this rich description, the researcher kept a journal where she recorded her decisions with regard to data collection and analyses. Though a case study aims at understanding a single situation, the researcher provided a detailed description of the study site in order to allow the reader to make decisions regarding the applicability of the findings to other contexts. The researcher described the participants fully, gave the sampling criterion, described the teacher education programme, as well as the schools where they did their teaching practice. The researcher also discusses the degree to which the findings may be valid in other contexts.

4.7 ETHICAL CONSIDERATIONS

Research ethics have become an important issue in research in education and in social science in general (Khan, 2016; Ramrathan, Grange, & Shawa, 2017). Cohen et al. (2011) define ethics as the “individual and communal codes of conduct based upon a set of explicit or implicit principles which may be abstract and objective or concrete and subjective” (p.87). A number of authors on this topic agree that informed consent, privacy, safety and objectivity are the main pillars of an ethically sound research (Cohen et al., 2011; Ramrathan et al., 2017)**.**

The first ethical necessity was to ensure that participation in the study was strictly voluntary, so the researcher sought informed consent by first by writing letters to gatekeepers. These were the faculty dean at the university under study and the director in the Ministry of Education and Training (MoET) requesting permission to conduct research in the faculty and teaching practice schools, respectively. These letters stated the purpose of the research and other relevant information about the research and the researcher. The researcher also received permission from the Humanities and Social Sciences Research Ethics Committee of the University of KwaZulu-Natal, clearance number: SB423 D04111020409201 (Refer to Appendix G).

Next, the researcher wrote letters to all the pre-service teachers who were part of the purposive sample, inviting them to participate in the study. Those who were willing to participate signed letters of consent, which were collected by a different lecturer separately from the questionnaire to ensure anonymity. The letters clearly stated that their participation was voluntary and that they could withdraw from the research at any time. To ensure that students did not feel coerced because of the researcher’s position as their educator, she did not participate in their assessment of the group’s academic performance. In keeping with the agreement of voluntary participation, the researcher did not coerce any of the pre-service teachers who had at the outset decided not to participate, or those had originally consented to participate but subsequently withdrew at later stages of the study. Moreover, the researcher made every effort to be receptive to participants' unspoken desires to opt out of the research.

The purposive study sample initially consisted of 41 pre-service teachers, to whom the researcher sent letters of invitation about the study. However, only 34 of the potential participants signed letters of consent indicating their willingness to participate in the study. Since the questionnaire was completed during class time, participants who had not previously signed letters of consent were excused. A person unknown to the students did the distribution of the questionnaire to aid with power differential. Then only 10 of the 34 participants also indicated willingness to participate in the second phase of the study, where the researcher was to interview and observe them during their teaching practice in schools. Nevertheless, of the 10, only eight were able to honour their appointments for post-questionnaire interviews, and later the researcher was able to observe and conduct the two lesson interviews with only six of them; two having declined after the first lesson observation encounter.

The third ethical consideration is that it is the duty of the researcher to ensure that the study does not expose participants to any harm. In this regard, the whole research process in this study, including data collection, did not pose any form of danger or harm to participants. However, after two participants withdrew after the first lesson observation and interview, the researcher investigated the reasons behind this action. Participants expressed their uneasiness about the exercise. Seemingly, as some hinted, the pre-and post- interviews had been taxing for them and accordingly, in an attempt to minimize the pressure on participants, the researcher later on interviewed the participants only after their lesson presentations.

Lastly, the researcher made all necessary effort to ensure that the research was as objective as possible: in its design, execution and reporting. In posing questions during interviews, the researcher made all efforts to allow participants to say what they wanted to say, rather than what she wanted to hear. With regard to privacy, the researcher did not mention the names of the participants to anyone, or in her research report. Where necessary, she has used pseudonyms. She gave colleagues and researchers who helped in checking the analysis process duplicated questionnaire data that did not bear the name of the participant.

4.8 SUMMARY

This study was interpretive in nature and used a case study design to explore pre-service teachers' experiences of IBST. It employed a questionnaire and semi-structured interviews to determine the pre-service teachers' understanding of inquiry-based science teaching. Six pre-service teachers who indicated willingness to partake in the second phase of the study were observed during their teaching practice in schools in order to find out how they enacted inquiry-based science teaching. The researchers also used their lesson plans and interviews about the lesson to find out how they planned their lessons with inquiry in mind and to gain an understanding of factors that had a bearing on the way they implemented their lesson plans in the classroom. She then employed a cross-case analysis method to gain an in-depth understanding of factors that explained different ways in which pre-service teachers enacted IBST. The next three chapters present the results of the study.

CHAPTER 5

PRE-SERVICE TEACHERS' UNDERSANDING OF IBST

The previous chapter described the research methodology. This chapter together with Chapters 6 and 7 provide analysis of data and findings. The researcher presents the chapters in accordance with the research questions. This chapter answers the first research question:

> What do Swaziland pre-service primary school teachers understand by Inquiry Based Science Teaching (IBST) at the end of a 3-years' experience in science courses?

To address this research question, the researcher used data from second section of the semi-structured questionnaire and individual semi-structured interviews. Sub-section 5.1 presents the characteristics of the questionnaire and interview participants. Both Sections 5.2 and 5.3 present the analysis of data for participants' understanding of inquiry-based science teaching. Section 5.2 focuses on the most common ways in which participants understood inquiry-based science teaching based on their categorization of the lesson scenarios. Section 5.3 describes their understanding of the cognitive and guidance dimensions of inquiry-based science teaching in accordance with the conceptual framework of this pedagogical approach as adopted in this study.

5.1 CHARACTERISTICS OF PARTICIPANTS

Table 5.1 groups the participants by means of the location of the school where they completed their secondary education, their experience in teaching science prior to enrolling for the teacher training programme, their experience with carrying out an independent scientific inquiry project and their self-assessment of their confidence in teaching science (see Appendix A). The researcher viewed these characteristics as important for explaining the pre-service teachers' understanding of inquiry-based science teaching.

Table 5.1 *Characteristics of participants*

Biographic Characteristics	**Groups**	**Number of Pre-service Teachers**
Gender	Female Male	19 15
School where participant completed high school	Rural Urban Semi-urban	21 7 6
Teaching experience	Yes No	12 22
Previous teaching qualification	Yes No	0 34
Previous participation in independent scientific inquiry	No Yes	34 0
Self-professed level of confidence in teaching science	Low Average High No response	0 29 3 2

Table 5.1 shows that the sample consisted of slightly more females than males. Most of the pre-service teachers had completed their high school in a rural setting, and about one third of them had some experience in teaching science prior to enrolling in the teacher education programme, although none of them had any formal training in teaching prior to enrolling to the programme. This seems to link with the significant proportion who reported only an average level of confidence in teaching science. It is noteworthy that not even a single participant pre-service teacher had any previous experience of an independent scientific inquiry task or project.

Among the 34 participants who participated in the questionnaire, eight also participated in follow up individual semi-structured interviews. All eight interviewees had completed their secondary schooling in a public school, four from rural schools, three from semi-urban schools and only one from an urban school. Only one interviewee had some prior experience in teaching science as a temporary teacher; he was also the only participant who expressed a high level of confidence in teaching science. These elements may influence the way these pre-service teachers understand inquiry-based science teaching.

5.2 PARTICIPANTS’ CATERGORIZATION OF TEACHING BASED SCENARIOS

This section portrays the results of the analysis of the questionnaire based on the participants’ categorization of the 10 teaching scenarios as either inquiry-based or non-inquiry-based. Section 5.2.1 presents the analysed data and the resultant findings regarding the 34 participants’ categorization of inquiry-based science lessons. Section 5.2 .2 presents the different ways pre-service teachers understand inquiry-based science teaching constructed based on an inductive analysis of their reasons for the way they classified the teaching-based lesson scenarios.

5.2.1 Pre-service teachers’ categorization of inquiry-based lessons

The teaching scenario-based questionnaire required the participants to classify each teaching activity as characteristic of inquiry- or non-inquiry-based science teaching and to provide justifications for their choices. The researcher then labelled each option as consistent or not consistent with the understanding of IBST adopted in this study. Table 5.2 provides the results of this analysis. It includes the researchers’ evaluation of each lesson as inquiry and non-inquiry, based on the definition according to guided inquiry adopted in this study and discussed in Chapter 4. Experienced researchers and critical readers checked and validated the questionnaire to ensure content validity as described in Chapter 4 (Section 4.3.1.2).

Table 5.2 *Number of participants that classified each lesson in line with the study's conceptualization of inquiry-based science teaching (n=34)*

	Number of classifications that were in line with the guided discovery view of inquiry	**Number of classifications that were not line with a guided discovery view of inquiry**	**No response**	**Total**
1.	21	13	0	34
2.	34	0	0	34
3.	24	10	0	34
4.	24	9	1	34
5.	21	13	0	34
6.	33	1	0	34
7.	31	3	0	34
8.	34	0	0	34
9.	26	5	3	34
10.	22	10	2	34
Total	270 (79%)	64(19%)	6(2%)	340

It is evident from the Table 5.2 that in classifying the teaching scenarios, most of the lesson classifications (79%) as being inquiry-based were consistent with a guided discovery view of IBST. However, a noteworthy number (64) of classifications of the 340 classifications were inconsistent with this guided discovery view, and in six of the 34 instances, participants were undecided. This indicates that some participants either held alternative conceptions about, or were not very clear about, the meaning of this pedagogical approach.

To attain a deeper understanding of the kind of teaching activities that participants associated with inquiry-based science teaching, the researcher employed the conceptualization of levels of inquiry-based teaching approaches, as developed by Wenning (2012) (see Table 2.1) to indicate the level of inquiry involved in each of the lesson activities designated as inquiry-based. The researcher labelled the teaching activities she classified as non-inquiry as confirmatory learning, because they all involved the teacher presenting science concepts or principles to the learners prior to their being engaged in hands-on activities illustrating the concept.

Table 5.3 *Teaching activities and number of participants that classified each lesson activity as inquiry or non-inquiry-based*

Lesson activity	**Teaching activities (Wenning, 2005; Cobern et al., 2010)**	**Participants' evaluation**			
		Inquiry	**Non-inquiry**	**No response**	**Total**
1.	Confirmatory learning	13	21	0	34
2.	Guided Discovery learning	34	0	0	34
3.	Interactive demonstration	24	10	0	34
4.	Guided discovery learning	24	9	1	34
5.	Confirmatory learning	13	21	0	34
6.	Bounded inquiry laboratory activity	33	1	0	34
7.	Guided discovery	31	3	0	34
8.	Free inquiry laboratory	34	0	0	34
9.	Guided discovery learning	26	5	3	34
10.	Guided discovery learning]	22	10	2	34

As is evident from Table 5.3, some participants were more able to recognize a particular type of inquiry activity than others. The table indicates that almost all of the participants associated inquiry-based teaching with both free inquiry (lesson 8) and bounded inquiry (lesson 6) laboratory activities. However, results for guided discovery were mixed. As shown in the table, while all participants categorized the guided discovery lesson number 2 as inquiry, between 5 and 10 participants, which is a significant number, however did not classify similar activities (lesson scenario numbers 4, 9 and 10) as such. It is also notable that about one third of the participants regarded the two confirmatory hands-on activities as being inquiry-based. Furthermore, a similar number of participants viewed interactive teacher demonstrations as being non-inquiry-based. These responses indicate that participants held varying understanding of inquiry-based science teaching.

5.2.2 Different ways by which pre-service teachers understand inquiry-based science teaching

To understand the reasoning behind the different ways in which participants understand IBST, the researcher analysed the participants' classifications of teaching scenarios in order to construct meaning of the main ways participants understand IBST. This analysis focused on determining the particular aspects of the teaching scenarios that participants focused on when categorizing the lesson scenarios. For example, participants who classified only the lesson scenarios that incorporated hands-on activities as inquiry, regardless of whether learners had used the activity to construct or confirm knowledge, indicated that *hands-on learner engagement* was the crucial element in their thinking about inquiry-based science teaching.

Table 5.4 presents the different ways by which the pre-service teachers understood inquiry-based science teaching, the criteria used for categorizing the responses and the frequency of each category. Participants' justifications for their categorizations of their lessons corroborated this construction of the participants' understanding of IBST. Another science education colleague validated the categories in Table 5.4.

Table 5.4 *Pre-service teachers' understanding of IBST*

	Codes	**Criterion for such coding**	**Number of participants**	**Created themes**
1.	Constructing understanding themselves based on any evidence	Categorized direct lessons as non-inquiry and all other teaching activities that engage learners in constructing knowledge themselves based on evidence regardless of whether or not the learners are hands-on.	9	Guided discovery-centred construction of IBST
2.	Constructing knowledge specifically based on hands-on experiences	Categorized only activities whereby the teacher guided learners in constructing knowledge based on hands-on practical activities.	5	
3.	Cognitive engagement	Used cognitive engagement as the main criterion for categorizing lessons as inquiry.	8	Active engagement-centred understanding
4.	Hands-on engagement	Categorized only activities with a hands-on element, regardless of the purpose of the engagement and level of cognitive engagement.	2	
	Experience-centred understanding	Categorized activities as inquiry based in that they actively engage learners in their learning in one way or the other.	8	
5.	Addressing a science question	This group categorized only activities led by a science question as inquiry-based science teaching.	2	Question-centred understanding

It is evident from Table 5.4 that pre-service teachers understood inquiry-based science teaching in terms of three different essentials: learners' constructing their own understanding; active engagement of learners in instruction, or an instruction that engages learners with a science question. While about half of the 34 participants associated inquiry-based science teaching with learners constructing knowledge for themselves based on their experiences, the remaining participants associated this pedagogy with different forms of learner engagement, including hands-on, minds-on, with any form of learners' experiences of the phenomenon under consideration. It is also noteworthy from Table 5.4 that while a significant number (10) of the participants regarded learners' hands-on experiences as an indispensable aspect of inquiry-based science teaching, only a few of them regarded a science question as critical.

A similar analyses of responses from interviews indicated understanding of IBST that was comparable to the categories constructed from the questionnaire responses. Individual interview responses were searched for key features indicating understanding of IBST. The following direct interviewee quotations are evidence of participants' varying constructions of IBST.

Guided discovery-centred understanding of IBST

Two of the interviewees associated IBST with learners constructing knowledge based on their experiences, as indicated in the following interview extracts:

> The definition in inquiry should come at the end, because in inquiry we want the learners to be engaged in discovering the knowledge themselves based on their exploration rather than the teacher telling them. (Pre-service teacher 8, interview)
>
> I think it should be child-centred. You have to involve the learners. This means learners should be hands-on in whatever activity they do. They should be directly involved in manipulating the learning material and discover concepts themselves rather than being told. The teacher must guide learners to ensure that learners carry out the activity correctly. Therefore, my role is just to facilitate. (Pre-service teacher 6, interview)

Active engagement-centred understanding

Two other interviewees indicated that they associated IBST with learners' active engagement in the learning process, as demonstrated in the following quotations:

> I think inquiry constitute active participation in the questioning, carrying out investigations and the rest of the processes. (Pre-service teacher 5, interview)

> The learners should be involved in manipulating objects or doing a practical. The teacher must be the facilitator in everything to guide not just to tell them what they must do. They must investigate for themselves and talk about their investigations. (Pre-service teacher 4, interview)

> Yes, I would still regard it as inquiry because of the fact that they have carried out an investigation. In addition, because if you observe something there are questions that can be raised which can lead to more investigations. (Pre-service teacher 7)

Question centred conception of IBST

The following two extracts indicate that these pre-service teachers regarded learner questions as a critical aspect of IBST.

> In inquiry-based teaching, they should be investigations. The investigations are based on questions that need to be answered and the learners should raise those questions. In short, the teaching should be learner-centred. (Pre-service teacher 3, interview)

> An inquiry lesson should have a question to be investigated. I will make an example when the teacher comes to class, the teacher will bring all the required material, then it is the learners that would come up with the questions they would like to investigate on the basis of the materials provided to them. (Pre-service teacher 2, interview)

5.3 PRE-SERVICE TEACHERS' UNDERSTANDING OF DIMENSIONS OF IBST

In order to further explore participants' understanding of IBST, the researcher searched participants' responses for characteristics of inquiry-based science teaching that fell into one of two dimensions: the cognitive or the guidance dimensions of IBST, as identified by Furtak et al. (2012). Section 5.3.1 presents the results pertaining to the characteristics that fell within the cognitive dimension of IBST. The results for the guidance dimension are presented in Section 5.3.2.

5.3.1 Pre-service teachers' understanding of the cognitive dimension of IBST

The cognitive dimension of inquiry-based science teaching constitutes the *cognitive* and *social* aspects of this pedagogy. To understand participants' understanding of the cognitive dimension of IBST, the researcher searched participants' justifications for characteristics of IBST that fell into four domains, namely, the *conceptual, procedural, epistemic and social aspects* of the cognitive dimension of inquiry-based science teaching, as postulated by Furtak et al. (2012). Table 5.5 presents the results of the analysis. It provides the frequency in participants' responses for each of the categories describing a domain, and the number of participants who referred to each of these categories. Lastly, it indicates the average representation of each domain in the group's characterization of IBST. The researcher worked out this representation by dividing the total number of mentions of a domain by the number of its categories of description.

Table 5.5 *Frequency distribution of participants' understanding of the four domains of the cognitive dimension of IBST*

Cognitive Dimension	**Categories of description of each domain**	**Number of participants who mentioned this category at least once**	**Frequency of each category of description in participants' responses**	**Average representation of each domain in participants' responses**
Conceptual Domain	Drawing on prior knowledge	15	33	30
	Eliciting learners' ideas/ mental models	14	33	
	Providing conceptually oriented feedback	13	24	

Procedural Domain	Posing science questions	33	133	74
	Designing investigation procedures	27	60	
	Executing scientific procedures	34	191	
	Recording data	12	15	
	Making data representations	4	5	
	Hands-on	23	42	
Epistemic Domain	Drawing conclusions based on evidence	26	54	29
	Creating /revising theories.	22	32	
	Nature of science	0	0	
Social Domain	Participating in class discussions	17	30	21
	Presentations	24	39	
	Argue their ideas	7	10	
	Working Collaboratively	3	3	

The results in Table 5.5 indicates, firstly, that the *procedural* domain was most popular among participants' depictions of inquiry-based science teaching. Secondly, the representation of the *epistemic* and *conceptual* were comparable, while the *social* domain was the least represented.

The data also indicate that whereas the different categories of description within the *conceptual domain* were approximately equally represented, some categories of description in the other three domains were more prevalent than others in participants' utterances about inquiry-based science teaching. For example, within the *procedural domain*, all participants mentioned several times carrying out scientific procedures, yet they only rarely talked about making data representations. Furthermore, even though the *epistemic domain* was the second popular domain, none of the participants associated inquiry-based science with discussions about scientific inquiry and the nature of science. In addition, the data in Table 5.5 indicate that participants generally do not associate inquiry-based science teaching with debating scientific ideas and working collaboratively.

During the interviews, the researcher asked participants to talk about what they regarded as key characteristics of inquiry-based lessons. They also could clarify their reasons for classifying some lesson scenarios as inquiry or non-inquiry in the questionnaire. As outlined in Section 4.4.1.2, interview transcripts were analysed verbatim and a profile of what teachers regarded as features of classroom inquiry was prepared. This profile was then coded and the results are presented in according to the themes identified by Furtak et al. (2012). The pre-service teachers' understanding of the domains of inquiry-based science teaching derived from the semi-structured interviews with eight participants corroborated the questionnaire results, as indicated in Table 5.6

Table 5.6 *Distribution of interviews' understanding of the domains of IBST*

Domain of inquiry (Furtak et al., 2012)	**Identified feature of inquiry**	**Interviewees who mentioned each feature**	**Number of participants**
Procedural	Addressing a scientifically oriented question	2, 3, 5, 6, 7, 8	6
	Designing investigations	8, 5, 7, 2, 4, 3	6
	Carrying out scientific procedures	8, 5, 1, 7, 2, 4, 6, 3	8
	Recording data	8	1
	Making data representations Hands-on	_______	0
Epistemic	Formulating evidence-based conclusions	8, 5, 7, 4	4
	Generating explanations	8, 5, 4	3
	Discussing the nature of science	_______	0
Conceptual	Builds on learners' prior knowledge and ideas	8, 5, 4	3
	Eliciting learners' content related ideas	8, 1, 3, 6	4
	Provide conceptual- oriented feedback	8, 5, 7, 2, 6	5
Social	Discussing	8, 4	2
	Presentations	8, 1, 4	3
	Argue/ support their ideas	8	1
	Collaborating	8, 4	2

Table 5.6 indicates that during their interviews, all eight interviewees again associated inquiry-based science teaching with the four domains of inquiry. They were evidently more knowledgeable of the procedural domain and were least informed about the social domain. In addition, the leading features in each domain were also comparable to those indicated by questionnaire data. However, as shown in Tables 5.5 and 5.6, in contrast to the whole group questionnaire data, interviewees' mention of the epistemic domain was minimal.

The following interview direct quotes illustrate what the participants said concerning each domain of inquiry-based science teaching. I present these in order of their popularity in participants' responses.

5.3.1.1 Procedural domain

The following interview citations illustrate what participants said that illustrate their understanding of the procedural domain of inquiry-based science teaching.

> An inquiry lesson must have a key question on which learners must base their investigation followed by planning an investigation in order to find facts necessary to address that key question. (Pre-service teacher 7, interview) [Posing scientifically oriented questions, Experimental design, Executing scientific procedures]
>
> There should also be investigations where the learners should be the one carrying out the investigations. The teacher will just be the facilitator. (Pre-service teacher 3, interview) [Executing scientific procedures; Hands-on]
>
> They must be a time whereby the learners are conducting these investigations and are observing and recording what they observe. (Pre-service teacher 8, interview) [Executing scientific procedures; Recording data]

The extracts indicate that as a minimum, some interviewees associated inquiry-based science teaching with an instructional strategy that engages learners in asking scientifically oriented questions, designing and carrying out scientific investigations, and recording data.

5.3.1.2 Epistemic domain

The following justifications for categorizing some lesson scenarios as inquiry point out pre-service teachers' understanding of the epistemic domain of inquiry-based science teaching, as follows:

> Lastly, carrying out the investigation to collect data from which conclusions are drawn. (Pre-service teacher 7, interview data) [Drawing conclusions based on evidence]
>
> Then they try to make some explanations on the observations or the results of the investigations, they come up with a conclusion about what they have discovered, what it means to them. (Pre-service teacher 8, interview) [Generating theories]

The quotes indicate that these interviewees regarded inquiry-based science teaching as involving the interpretation of data in order to form evidence-based conclusions or formulate explanations for their findings, or both.

5.3.1.3 Conceptual domain

The following extracts illustrate participants' understanding of the conceptual domain of inquiry-based science teaching.

> The teacher should discuss the findings with the learners. This will help the learners because as they make conclusions, they may construct conceptions that may not be accurate. (Pre-service teacher 7, interview) [Providing conceptually oriented feedback]
>
> It is important to elicit learners' ideas and prior knowledge in the sense that it helps the teacher now to know the level of understanding of the learners and their beliefs so now he or she will be in a good position to guide the learners according to their level of understanding and their beliefs. He will be able to guide them in a way that their misconceptions will be changed into accepted scientific conceptions. (Pre-service teacher 8, interview) [Eliciting learners' ideas, drawing from learners' prior knowledge]

In addition to the description of the conceptual domain provided by Furtak et al. (2012), participants also talked about learners testing their own ideas, as the following quotes show.

> Then there must be some hypothesis made by the learners; and a plan to investigate those hypotheses if there are true or not. (Pre-service teacher 8, interview) [Testing their ideas]

These quotations indicates an understanding that inquiry-based science teaching should draw from what learners already know, provide them an opportunity to voice and test their ideas; and should ensure that learners construct an accurate understanding of target science concepts.

5.3.1.4 Social domain

The next sets of direct quotes indicate some of the participants' understanding of the social domain of inquiry.

> Inquiry, learners should communicate their findings. (Pre-service teacher 1, interview) [Presentations]

> In an inquiry lesson because learners are free to express their ideas, and correct them as they investigate or debate issues. (Pre-service teacher 8, interview) [Debating scientific ideas]

> It is important for them therefore to work as groups so they will collaborate and cooperate with each other, share their ideas, which enhance their learning. (Pre-service teacher 8, interview) [Working collaboratively]

These quotes indicate that participants understood collaboration and interaction among learners as aspects of inquiry-based science teaching.

5.3.1.5 Other characteristics of IBST identified by participants

In addition to the above-mentioned four domains of inquiry postulated by Furtak et al. (2012), analysis of both questionnaire and interview data indicates that participants also regarded problem solving and creative thinking as characteristic of inquiry-based science teaching. The following direct quotations support this claim.

> The teacher does not dictate the causes of the contradiction of the results but ask learners to suggest ways to solve the problem instead. (Pre-service teacher 32, item 9)

> I think they have to see that when they do the activity whether or not what they are doing is helping them. When they see an approach is not helping them and they realize that they are going to try another one. (Pre-service 2, interview)

> It is also inquiry because it is all about being creative. Firstly, they will have to observe the things and think of how they can present their data. (Pre-service teacher, 7, interview)

5.3.2 Pre-service teachers' understanding of the guidance dimension of IBST

In this study, the guidance dimension of IBST means: instead of the teacher or the learner taking all the responsibility, the teacher provides support to learners as they reason out certain things themselves. Section 5.3.2.1 and 5.3.2.2 below presents an analysis of participants' understanding of the role of learners and the teacher in inquiry-based science teaching based on an analysis of both questionnaire and interview data. The analysis process is presented in Section 4. 4.1.

5.3.2.1 Participants' understanding of learner responsibility in IBST

This section reports results pertaining classroom activities that participants regarded as the responsibility of learners in inquiry-based science teaching. Accordingly, the researcher looked at participants' descriptions of inquiry-based science lessons to identify features that the participants indicated that learners rather than the teachers should carry out themselves, or at the least be involved in their execution. Table 5.7 displays the results of this analysis based on the teaching scenario-based questionnaire. The total number of responses in the table is more than the number of questionnaire respondents, because participants could associate learners' responsibility with more than one feature of classroom inquiry. For example, the same participant could classify a lesson scenario as non-inquiry because learners are not constructing knowledge themselves, and because learners are not carrying out the investigation themselves.

Table 5.7 *Pre-service teachers' understanding of learners' responsibilities in IBST from Questionnaire*

Codes	**Themes**	**Number of participants who mentioned this feature**	**Frequency of each aspect in participants' responses**
Learners posing own questions	Learners must investigate their own questions or ideas	12	20
Learners testing their own ideas			
learners must be involved in designing the whole investigation themselves	Learners must plan some aspect or the whole investigation.	12	35
Learners must decide what observations to use in addressing a question or a task			
Learners must select materials to use to investigate a question			
Learners decide on how to represent or organize their data			
Conduct investigation themselves / collect data themselves	Learners must carry out activities themselves or at the least, make their own observations.	13	30
Learners must make their own observations			
Learners answering science questions	Learners should construct understandings themselves	17	55
Learners forming evidence-based conclusions/ explanations themselves			
Learners should evaluate their findings independently by consulting other resources.	Learners should evaluate their findings themselves	7	7

The data in Table 5.7 indicates the most common view about inquiry-based science teaching was that learners should construct knowledge claims themselves, based on evidence. Although half of the participants mentioned this aspect, its high frequency in their responses indicates its centrality in their understanding of IBST. Learners designing and conducting investigations were the second and third most popular views about IBST. Only a few of them connected IBST with learners evaluating their finding independently.

The analysis of interview data corroborates this result. The eight interviewees also associated IBST mostly with engagement of learners in formulating evidence-based knowledge claims. However, unlike the questionnaire data, none of the participants associated inquiry-based science teaching with learners making their own connections between their findings and scientific knowledge; rather they asserted that the teacher should help learners evaluate their conclusions.

The following direct interviewee quotations are evidence of participants' understanding of different aspects of learners' tasks in inquiry-based science teaching.

> One characteristic of inquiry is that learners draw conclusions themselves with the help of the teacher rather than the teacher giving them the conclusion. (Pre-service teacher 5, interview)
>
> You need to make conclusions, they must conclude for themselves according to the evidence they have collected. (Pre-service teacher 8, interview)

The above quotations illustrate participants' association of inquiry-based teaching with engagement of learners in constructing conclusions themselves, based on evidence. The next set of extracts is a demonstration of participants' connection of IBST with engagement of learners in designing investigations rather than merely following prescribed procedures.

> For me it is very critical that the learners design the investigations on their own because the learner may come with a different way of investigating the question, which is simple enough to accommodate all the learners. It is therefore important that the learners design the investigations themselves. (Pre-service teacher 8, interview)
>
> It is not an aspect of inquiry when the student comes with the question and the teacher gives them the method or the procedures when answering that question. What is best is that when students pose a question, the teacher also asks them what they think they can do to come with a conclusion based on evidence. (Pre-service teacher 5, interview)

The following pair of quotations show that some participants also linked IBST with teaching and learning that actively engages learners in conducting investigations themselves.

> According to me, an inquiry lesson should be learner-centred where the learners should be involved in manipulating objects or doing a practical. They must investigate for themselves. (Pre-service teacher 4, interview)

> No, I would not consider that one as an inquiry lesson. The learners must collect the data themselves. (Pre-service teacher 3, interview)

Interviewees did not seem to regard the posing of questions for investigations as an obligation for learners. Only one participant seemed to regard learner-centeredness in IBST to be based on learners addressing their own questions. His direct words were:

> In inquiry-based teaching, there should be investigations. The investigations are based on questions that need to be answered and the learners should raise those questions. In short, the teaching should be learner-centred. (Pre-service teacher 3, interview)

Even though participants rarely referred to learners posing questions themselves, some of them pointed out that learners should investigate their own ideas as demonstrated in the following to extracts:

> Investigating on their own means they should be given the chance to, of course with a given question, test if the ideas they hold are correct or not. **(**Pre-service teacher 1, interview).

> I think an inquiry lesson should first have a science oriented question that is raised by either the learners or the teacher, then there must be some hypothesis made by the learners; and a plan to investigate those hypotheses if there are true or not. (Pre-service teacher 8, interview)

Although, in the questionnaire responses, 12 of participants (see Table 5.6) had also referred to learners testing their own ideas, they did not seem to regard this feature as critical, as shown by their also classifying teaching scenarios as inquiry-based where investigations were led by teacher questions.

5.3.2.2 Participants' understanding of teachers' role in IBST

This section describes results pertaining classroom activities that participants regarded as the responsibility of the teacher in inquiry-based science teaching. The researcher searched participants' descriptions of IBST to identify features that participants viewed as the responsibility of the teacher. Table 5.8 presents the result of an inductive analysis of questionnaire responses for what participants viewed as the teachers' management practices in inquiry-based science teaching.

Table 5.8 Participants' understanding of the teacher's role in IBST

Codes	**Theme**	**Number of participants who mentioned this aspect**	**Frequency of the aspect in participants' responses**
Teachers must elicit learners' prior knowledge Teacher recommend specific reading resources to learners Teachers coach learners on how to carry out certain inquiry activities	Teachers must ensure that learners have the necessary knowledge base to perform intended activities.	16	31
Teachers prompt learners by posing the question to be investigated Teacher prompts and guide learners in answering their own questions and carrying out other inquiry activities.	Teacher must guide all learners' activities through appropriate prompts.	21	67
Teacher s simply tell learners what to do to answer their questions rather than giving them the answers. Teacher provides learners with materials to manipulate so they can discover knowledge themselves.	Teachers must support learners' construction of their own answers by providing them with the science materials and procedure. .	5	7
Teachers must provide learners with feedback on their ideas through classroom discussions. After learners' investigations, teacher should directly provide feedback on their ideas and names of scientific terms to learners.	Teacher should ensure that learners receive feedback on their ideas.	11	15

The data in Table 5.8 indicates the most common view about inquiry-based science teaching was that teachers guide learners' inquiry activities by means of questions and other prompts. More than half of the participants mentioned this aspect; its high frequency in their responses indicates its significance in their understanding of IBST. Ensuring that learners have the knowledge base needed to perform intended activities, and providing them with feedback were the second and third most popular views about IBST. Very few participants connected IBST with teachers providing learners with procedures and materials.

Analysis of interview data agrees with this data. Akin to the results generated from questionnaire data, the most common understanding about the responsibility of the teacher in IBST among the eight interviewees was teachers guiding learners' activities through appropriate prompts. Similarly, the least popular view was the need to provide learners with materials and scientific procedures. Only one participant associated IBST with the need for teachers to provide learners with methods for addressing their science questions.

The following extracts illustrate participants' understanding that the role of the teacher in IBST is to guide learners by means of appropriate prompts:

> If the learners ask a question, the teacher should appear like he knows nothing and says *let us try to find out together, make a plan on how we can answer the question* and everyone discover herself or himself the facts rather than being told by the teacher (Participant 8, interview)

> To me the teacher's questions are just a guide. May be if they are not on the exact track, approach or concept then the question must follow just to direct their thinking. (Participant 4, interview)

> I think the learners should be given a chance to think and to investigate something. They should also be given a chance to communicate their findings the way they understand it. All this done under the teacher's guidance by means of questions he or she asks during the lesson. (Calsile, interview)

Some participants also connected IBST with the need for teachers to ensure that learners have some knowledge to draw from when performing inquiry activities. While others argued that the teacher should rely on learners' prior knowledge and ideas, others pointed out a need to provide learners with some background knowledge before carrying out an investigation to ensure that they have the necessary knowledge base. The following pair demonstrates participants' understanding of the need to connect to learners' previous knowledge and ideas:

> The teacher need to know the level of understanding of the learners and their beliefs so now he or she will be in a good position to guide the learners according to their level of understanding and their beliefs. (Participant 8, interview)

> It should begin with an idea that learners have that they are however not sure of. Let me say that learners believe there is air in the soil, but are not certain, they can then carry out a practical activity to investigate whether or not there is air in the soil. (Participant 4, interview)

> **Interviewee**: I think you must ask them to define the concept themselves rather than the teacher defining it.
> **Interviewer**: What do you think would be the value of providing them an opportunity to define the concept themselves?
> **Interviewee**: I think it would help find out their prior knowledge of the concept.
> **Interviewer:** Why do you think it is important to for a teacher to know learners' prior knowledge in an inquiry lesson?
> **Interviewee**: so that you know what they know before you bring what they are going to do. (Participant 4, interview)

The next sets of quotations illustrate an understanding of the need to provide learners with some background knowledge prior to performing some inquiry activities:

> **Interviewer:** What if you carry out the investigation first and then clarify the terms later based on the investigation?
> **Interviewee:** Yes, you can do that but not all the terms need to be clarified at the end, some of the terms need to be clarified at the beginning of the lesson in order for learners to carry out the investigation. (Participant 7, interview)

> **Interviewer:** So you believe they are situations where it might be necessary to provide definitions at the beginning before learners engage in inquiry.
> **Interviewee:** Yes, that might be. Like in the case of my young learners, I am teaching now. The learners may find it difficult to use the scientific language to communicate so you may give them the definition in order to emphasize the use of the language as well as if you can see that the learners are unable to come up with that definition. (Participant 1, interview)

> I think more examples should be given to them so that they get more information because when you come to class and say you are going to classify magnets and you give them materials. I think it is a bit shallow, so I would not consider it inquiry. (Participant 2, interview)

The following pair of quotations illustrates participants' understanding that after learners have performed some inquiry activities, it is the teacher's responsibility to provide them with feedback on their ideas either directly or through engaging them in classroom discussions:

> After learners have explored and discovered the knowledge themselves now the teacher must help them in the evaluation of their conclusions**.** (Pre-service teacher 8, interview)

> The teacher should discuss the findings with the learners. This will help the learners because as they make conclusions they construct conceptions, which may not be accurate. (Pre-service teacher 7, interview)

The next quotation demonstrates participants' association of IBST with teachers providing learners with procedures for addressing their science questions:

> **Interviewer**: Could you give me an example of what a teacher does in the classroom when he acts as a facilitator?
>
> **Interviewee:** To find out their ideas and suggest activities they can do to eliminate misconceptions. (Participant 6, interview)

When connecting this section with the rest of the chapter, it is evident that participants understood IBST as instruction whereby learners carry out certain cognitive and social activities under the guidance of the teacher. Although, they recognized other certain learner activities in inquiry-based science teaching such as learners posing questions or planning their investigations as being aspects of IBST, most of them did not seem to regard these as essential characteristics. Nevertheless, participants generally associated IBST with the teacher using appropriate questions to guide learners towards evidence-based conclusions. This knowledge is valuable as it can help explain the manner in which pre-service teachers enact this pedagogical approach. It also provides some insights about the strengths and weaknesses of the teacher education programme.

5.4 DISCUSSION

Developing learners' investigative skills and scientific attitudes is an objective of the primary science curriculum (Ministry of Education and Training, 2012) and their understanding of how scientists develop and modify scientific knowledge in line with one of the general education goals of the Kingdom of Eswatini (Ministry of Education and Training, 2018b) is founded on an inquiry-based approach to teaching science. It was therefore necessary for the researcher, as a science teacher trainer, to understand the knowledge pre-service teachers can develop about IBST in the context of our science education courses.

The principal research outcome arising from analysis of the data gathered by means of a questionnaire and interviews was that, although the pre-service teachers had experienced the same teacher education programme and there were some similarities in their conceptualization of IBST, they generally associated IBST with three different forms of learner engagement. Constructivism seems to provide the best explanation for this finding from the study. According to constructivism, learning is not passive reception of knowledge in its final form; instead, learners "negotiate meaning in light of their experiences in the new learning situation" (Amineh & Asl, 2015, p. 10), which is a process that partly depends on their prior knowledge, experiences and beliefs (Amineh & Asl, 2015; Richardson, 2003). This assertion implies that while the nature of the teacher education programme can help explain common features of the pre-service teachers' construct of IBST, it is reasonable to suppose that their different school backgrounds and personal beliefs could explain differences in the meaning participants made of this pedagogical approach (Crawford, 2007).

Although the study participants underwent a common school science curriculum and none had participated in authentic scientific inquiry, differences in how they learnt science in different schools and classrooms could influence their beliefs about an ideal mode of teaching, and consequently their conceptualization of inquiry-based science teaching (Eick & Reed, 2002). Other studies have indeed found that the pre-service teachers' past learning experiences shaped the meaning they made of IBST from their teacher education programme (Eick & Reed, 2002; Ghosh, 2015). For example, pre-service teachers who learnt science mostly through practical activities may be more likely to associate IBST with learners' hands-on engagement.

From the constructivist perspective, pre-service teachers past learning experiences alone cannot fully explain the differences in their conceptualization of IBST. Constructivism views the classroom as an environment that provides learners an opportunity to reflect on and develop their knowledge within a cooperative learning environment. The pre-service teachers' commitment to science teaching, together with an ability to reflect deeply on their experiences is therefore another factor that seems essential for pre-service teachers to develop a more informed understanding of IBST. One of the participants in this study, who displayed a relatively more informed understanding of IBST, did indeed demonstrate these features during interviews. For example during interviews, unlike most of the participants, he displayed an ability to think deeply about the teaching scenarios and his enactment of IBST during teaching practice in relation to his understanding of this pedagogical approach. The following two extract indicates his commitment in learning about IBST and science teaching and his ability to reason deeply about issues.

> I think we did a lot here at school when we were taught about inquiry. Those experiences to me were enough because I want to be honest at the beginning I knew nothing about inquiry. I did not have a clue of what this inquiry is but the microteaching and the presentations that we did and the notes were helpful. I also did extensive reading about inquiry on my own. However, it was what we did in class that pushed me to research and read more about this inquiry; about what it is. So I think what we learnt in class therefore influenced me a lot. (Participant 8, interview)

> I think this is a good way of teaching science although it requires a lot of time and even when planning it takes a lot of time because you need to put your mind into it and you must know the group of learners you are teaching. You cannot teach using this approach to learners that you have never taught before. You must know their level of thinking, their prior knowledge, and their beliefs are or what you expect them to do. However, it is a good way of teaching science. I enjoyed it. (Participant 8, interview)

A number of previous studies indicate that such deep reflection can result in changes in teacher beliefs (Eick & Reed, 2002; Lebak, 2015) and, based on the constructivist learning theory, improvements in understanding of IBST.

The study found that more than half (18) of the participant pre-service teachers associated inquiry-based science teaching with different forms of active learner engagement; which they saw as being mainly for promoting learning rather than representing the inquiry nature of science. The second most common understanding was an association of IBST with instruction whereby a teacher guides learners as they construct knowledge themselves, based on evidence; such a guided discovery-centred understanding was demonstrated by 14 of the 34 pre-teachers. Only two of the participants regarded an investigative question as a critical aspect of IBST. These two participants categorized some lesson-scenarios as non-inquiry because of their lack of a driving science question. Although the other participants generally referred to a science question in defining IBST, their questionnaire responses indicated that most of them also classified as inquiry-based teaching activities that did not have a steering science question. This indicated that they did not regard a question as a critical feature of IBST.

This ‘active engagement’ and ‘guided discovery’-centred understanding of inquiry-based science teaching held by the pre-service teachers has also been demonstrated in some other studies (Ireland et al., 2012; Young, 2013). It is indicative of a most basic understanding of inquiry-based science teaching. Some of the participants even regarded learners’ hands-on experiences as the most important aspect of IBST, as indicated in their questionnaire and interview responses. Asay and Orgill (2010), in their analysis of published articles for features of inquiry-based science teaching, found that teachers’ inquiry lessons often do not include the feature of a question. This current study’s result is therefore significant as it empirically supports Asay and Orgill (2010), in deducing that some teachers do not regard a question as being a critical element of inquiry-based science teaching. The participants’ demonstrated naive understanding about IBST is not in line with the country’s goal of developing learners’ investigative skills and their understanding of the process by which scientists develop knowledge.

A second analysis of participants’ responses showed that they associated inquiry-based science teaching with a number of features, most of which fell within four domains of inquiry-based science teaching as postulated by Furtak et al. (2012). In line with an active-centred view, participants characterized inquiry-based science teaching predominantly in terms of the procedural domain. Their understanding of the other domains was minimal.

Furthermore, with the exception of the conceptual domain, they associated this pedagogy with only certain categories of description of the different domains. Other aspects of the domains were either rare or absent altogether in the participants' characterization of this pedagogical approach, both in the questionnaire and interview data. The category that was most frequently cited in both questionnaire and interview responses was learners' engagement in executing scientific investigations. All the participants apparently regarded empirical investigations as necessary either for promoting learners' discovery of principles or for their active engagement in the learning process.

While questionnaire and interview data corroborated each other in many ways, there were also some observable differences in the distribution of the domains of inquiry between the questionnaire and interview data. Whereas for the questionnaire data, the epistemic domain was the second most popular domain, it was the least often mentioned in interview responses. Nevertheless, for the eight individuals who participated in the interviews, their responses from both sources corroborated each other. This seems to suggest that the interviewees' understanding of the epistemic domain was generally weak. It is worth noting that participation in each phase of the study was voluntary so the interviewed sample was not necessarily representative of the whole group of 34 pre-service teachers. Based on the interview data, participants' understanding of the domains of IBST was weak. While they all associated IBST with learners conducting investigations, half of them were evidently not aware of the epistemic domain; which encompasses engagement of learners in analysing data, interpreting evidence, and reflecting on the processes by which knowledge is developed. This indicates participants' lack of association of IBST with learning about the scientific inquiry process or a lack of understanding of the process by which knowledge claims are developed in science, which are both most likely a result of participants' lack of exposure to authentic forms of scientific inquiry. This assertion is also supported by participants' lack of association of IBST with the need to draw from learners' prior knowledge: an important aspect of making sense of evidence when constructing knowledge claims about natural phenomena. This lack of understanding of the science process is also evidence in their lack of knowledge of the social aspect of arguing ideas. This finding is disturbing as it indicates a possible hindrance to the achievement of the country's education goal of developing citizens who are knowledgeable of the "processes by which scientists construct and modify such knowledge" (Ministry of Education, 2018d, p. 6).

Additionally, interviewees left out some of the categories of descriptions of each of the domains they had mentioned in their questionnaire responses. This finding concurs with those of Kang et al. (2008), who also found that teachers referred to a science question more in their scenario-based questionnaire responses than in their written narratives of an inquiry-based lesson. The study therefore supports the claim that, while a narrative data approach may be useful in investigating participants' understanding of prominent features of IBST, a scenario- based questionnaire is most relevant when seeking a broader account of features that participants associate with IBST (Kang et al., 2008).

A third finding was that participants' responses indicate that they associated learner engagement with different aspects of learner responsibility; however similarly to the study carried out by Kang et al. (2008), participants' view of inquiry-based science teaching was more teacher-directed than learner-centred. Participants mainly associated IBST with any instruction that lets learners to formulate knowledge claims themselves based on evidence. The next most frequently mentioned feature pertaining to learners' responsibility in IBST was that of learners' executing scientific procedures themselves. Only one participant-associated engagement of learners in IBST with learners addressing their own questions; and only eight of the questionnaire responses indicated that engaging learners in planning their own investigations was an indispensable element of IBST. This finding supports that of Ireland et al. (2012), who in their study also found that a number of elementary teachers did not associate inquiry-based science teaching with learners' addressing their own questions.

From the above three findings, the researcher concludes that the pre-service teachers have an inadequate understanding of IBST, despite three years study in a science focused teacher education course. This conclusion is in line with those from previous studies (Capps et al., 2016; Chabalengula & Mumba, 2012; Kang et al., 2008; Mokiwa & Nkopodi, 2014; Mugabo, 2015; Ozel & Luft, 2013; Young, 2013), which have also shown that teachers hold varying but inadequate conceptions of IBST. Participants in these studies, as with the current one, were also aware of only a few features of IBST and associated the pedagogical approach with a more teacher-directed than a learner-directed mode of teaching.

The current study has found that a comparatively high proportion of the participants regarded the IBST approach as a teaching method aimed at promoting learning of science concepts.

This contrasts with findings from a number of studies (Kang et al., 2008; Ozel & Luft, 2013; Wallace & Kang, 2004) that have shown that teachers, in general, do not associate IBST with learning of science concepts. For example, in the study by Kang et al. (2008), less than 2% of respondents talked about evaluation of learners' explanations in light of scientific knowledge, in the current study, an average of 38% (13 out of 34) participants cited conceptual elements. Some interviewees specifically connected learning by inquiry with conceptual change.

From the constructivist perspective, one could account for the participants' relatively better understanding of the conceptual domain of IBST and their more teacher directed understanding of inquiry than found in other studies, as being related to the nature of the Swaziland school science curriculum and the teacher education programme. Nevertheless, participants' prior experience with teacher-directed forms of inquiry, which links to a more content knowledge driven science curriculum, could be a major influence on their lack of association of IBST with the more open forms of IBST. As already mentioned, none of the participants had had any prior experience with authentic scientific inquiry. This inference is in accordance with other study findings that have indicated a relationship between pre-service teachers' prior experiences with learning science and their conception of IBST (Eick & Reed, 2002; Windschitl, 2004; Young, 2013).

The participants' lack of exposure to authentic forms of science and content-driven curriculum could also account for their association of inquiry with executing scientific procedures while however lacking an understanding of some essential aspects of IBST such as learners addressing science questions or creating evidence-based explanations for phenomena. This also indicated either the participants' lack of association of IBST with promoting scientific inquiry skills or a poor understanding of the scientific inquiry process. Participants' failure to connect IBST with learning about the nature of science also indicates a possible lack of association of IBST with learning about the nature of science. This is supported by the fact that only a very few of the participants demonstrated an understanding of this goal of teaching science. This finding is not in line with the country's education goal of developing citizens who are knowledgeable of the "processes by which scientists construct and modify such knowledge" (Ministry of Education, 2018d, p. 6).

Participants’ general understanding of IBST could also be a result of the 5E model of inquiry-based instruction (Bybee, 1997), employed during their tertiary studies when developing their knowledge and enactment of inquiry-based science teaching. This inference is in line with an observation made by McHenry and Borger (2013), who also found that when using this model of science instruction, teachers did not usually engage learners in more learner-centred, higher order inquiry activities. The 5E instructional model emphasizes the stages of finding out and discussing learners’ prior knowledge and ideas regarding science concepts, learners investigating their ideas, and learners communicating and sharing their conclusions while receiving conceptually oriented feedback (Duran & Duran, 2004) and it thus incorporates all the four domain of IBST. Ireland et al. (2012), however, argue that the model does not support a learner-centred approach to IBST as it “does not explicitly show how students’ questions could be used to structure and guide inquiry teaching experiences” (p. 170).

5.5 SUMMARY

In this chapter, the researcher attempted to address the first research question, which pertains to pre-service teachers’ understanding of inquiry-based science teaching. The researcher collected the necessary data using a semi-structured, teaching activity-based questionnaire supported by data from semi-structured interviews. The findings based on analysing these data sources indicated that the pre-service teachers held an inadequate understanding of inquiry-based science teaching. While a significant proportion of participants associated inquiry-based science teaching with learners constructing their own understanding, they described inquiry-based science teaching mainly in terms of only one of the four domains of IBST identified by Furtak et al. (2012); the procedural domain. They were not fully cognizant of the other three domains: the epistemic, conceptual and social domains. Interviewees were particularly weak with regard to the epistemic domain of inquiry-based science teaching. However, compared to findings from previous studies, these participants were more conscious of the conceptual domain of IBST. The participants characterized inquiry-based science as instruction where learners take an active role in the learning process, with the teacher acting only as a facilitator. They however associated IBST more with teachers guiding learners in formulating evidence-based conclusions themselves than learners addressing their own questions or ideas, which indicates a more teacher-guided than a learner-directed view of IBST. In more learner-directed IBST "learners decide what they want to study and how they will do so and what they will present" (Dobber et al., 2017, p. 197).

These findings are likely to influence the way the pre-service teachers enact this pedagogical approach; some studies have linked teachers' understanding with their enactment of IBST. In the next chapter, the researcher addresses the first part of the second research question: How do the pre-service teachers enact inquiry-based science teaching during their final year teaching practice in schools.

CHAPTER 6

PRE-SERVICE TEACHERS' ENACTMENT OF IBST

The previous chapter presented findings pertaining to pre-service teachers' understanding of the concept of inquiry-based science teaching. Participant pre-service teachers generally understood inquiry-based science teaching in two main ways. While some associated the pedagogy with active engagement of learners in constructing knowledge based on evidence, others linked it with active engagement of learners in any sort of instruction. Consistent with Furtak et al.'s (2012) conceptualization of IBST, as described in Chapter 3, the participants considered inquiry-based science teaching to be comprised of cognitive and guidance dimensions. They however associated inquiry-based science teaching mainly with the procedural aspects of the cognitive dimension of inquiry-based science teaching. The current chapter presents results of the study addressing the first aspect of the second research question:

> How do pre-service primary school teachers enact inquiry-based science teaching during their final-year teaching practice in schools?

The researcher collected data necessary to address this research question from six pre-service teachers selected from among those who answered the questionnaire (Appendix A) and the post-questionnaire interviews (Appendix B). Although eight pre-service teachers had initially accepted to take part in this stage of the study, two of them chose to withdraw after their first classroom observation. As outlined in Section 4.3, other data sources for answering this research question were lesson plans (Appendix C) supplemented with pre- and post-lesson interviews (Appendix D), and lesson observations schedule and recordings (Appendix E &F).

In preparation for their teaching practice, the researcher had asked participants to prepare and implement some lessons that the researcher would observe consistent with their understanding of inquiry-based science teaching. The researcher did not conduct any specific workshop or discussion with the participants on IBST, as she wanted them to apply the conception they had formed of it during their science methods courses, uninfluenced by prior discussion. She then observed and video recorded their lessons. Although the initial research plan had been to interview participants both before and after lessons, this plan was later put aside, as it seemed too stressful for participants: she later interviewed them only once, after the lessons presentations. This was done individually. The researcher again used a framework informed by the conceptualization of IBST proposed by Furtak et al. (2012) and presented in Chapter 3. This chapter thus presents the findings regarding the pre-service teachers' enactment of IBST, analysed in accordance with Furtak et al.'s two dimensions of inquiry-based science teaching. To begin with, in Section 6.1, the researcher presents a summary of the participants. This is followed, in Sections 6.2 and 6.3 by a report of the participant trainee teachers' representation of the cognitive and guidance dimensions, respectively, in their enactment of inquiry-based lessons. Lastly, the discussion of the findings and the chapter summary are provided in 6.4 and 6.5 respectively.

6.1 HISTORY OF PARTICIPANTS

Table 6.1 presents a summary of the histories of the six participants. It consists of the personal background information of the participants and that of the school where they did their teaching practice. The abbreviations P, C, S, and E signify, respectively, the four domains, procedural, conceptual, social and epistemic, that were evident in participants' characterization of inquiry-based science teaching.

Table 6.1 *Summary history of the participants*

Biographic Characteristics	**Groups**	**Pre-service Teachers Frequency**
Gender	Female Male	2 4
School where participant completed high school	Rural Urban Semi-urban	2 1 3
Teaching experience	Yes No	1 5
Previous teaching qualification	Yes No	0 6
Pre-service teacher's participation in independent scientific inquiry	Educational-based inquiry Science content-based inquiry	6 0
Level of confidence in teaching science	Low Average	0 5

Biographic Characteristics	Groups	Pre-service Teachers Frequency
	High	0
Conceptions of IBST	Guided self-discovery of concepts based on data Guided self-discovery of concepts and processes Instruction that engages learners in the inquiry activities of science	3 1 2
Main domains in their description of IBST (P = procedural, C = conceptual, S = social, E = epistemic)	PECS PES PEC PCS	2 1 2 1
Revealed attitudes towards IBST	Positive Negative None	2 0 4
Support from school		0
Availability of materials	Enough Not enough	1 5
Support from the school	Yes No	1 5

As evident in Table 6.1, the study sample had more males than females and all but one of the participants had no previous experience with teaching science prior to their enrolment in the teacher education programme. With regard to their confidence in teaching science, five of them described it as average and only one believed he had an above average level of confidence. All of them, at the time of the study, had completed a science education related research project but had not participated in any authentic research in science content courses.

The group held two different views about inquiry-based science teaching; five viewed the pedagogy as instruction that guides learners in discovering knowledge while one of them regarded it as instructional approach that serves to promote learning the process of science. In line with the general view of inquiry-based science teaching as concerned with learning of science concepts, all except one of the participants highlighted the conceptual aspects in their characterization of this pedagogy. Only two of the participants revealed attitudes about inquiry-based science teaching and both of them demonstrated positive attitudes.

The next two sections present how the group enacted IBST during their teaching practice in schools. The researcher presents these results in terms of the cognitive and guidance dimensions of IBST as postulated by Furtak et al. (2012).

6.2 REPRESENTATION OF THE COGNITIVE DIMENSION IN PARTICIPANTS' ENACTMENT OF IBST

This section portrays the group's planning and classroom presentation of the cognitive dimension of inquiry-based science teaching. The results came from a qualitative analysis of the six participants' lesson plans, and the lesson interview and observation transcripts. As was described in Section 3.3, the researcher firstly coded the data in accordance with the features (descriptions) of the inquiry-based science teaching which fell into one of two dimensions; the cognitive and the guidance dimensions of IBST identified by Furtak et al. (2012). Section 6.2.1 presents results related to the aspect of participants' enactment that fell within the cognitive dimension of IBST.

6.2.1 Data for participants' representation of the cognitive dimension of IBST

To understand participants' enactment of the cognitive dimension of IBST, the researcher coded all collected data (Appendix C , D and E) that fell into the four domains of *conceptual, procedural, epistemic and social* aspects within the cognitive dimension of inquiry-based science teaching postulated by Furtak et al. (2012). Table 6.2 displays the results of this analysis. Lesson activities are described as *absent, inadequate* or *adequate* to represent the extents to which participants presented them in the classroom. Details of the meaning of these descriptions are presented in Section 4.5.2.1. As notable in the table, the sum total of the number of lessons that demonstrated some of the features during implementation is in some cases greater than the number of lessons that demonstrated the element at the planning phase; in some cases, participants implemented some features they had not referred to during pre-lesson interviews.

Table 6.2 *Representation of the different elements of each cognitive dimension in participants' enactment of IBST lessons*

Domain of IBST	Number of instances in 12 lessons			
	Planning	Implementation		
		Adequate	Inadequate	Absent
Conceptual				
Drawing on learners' prior knowledge	4	4	0	0
Eliciting learners' ideas	10	6	4	0
Providing conceptually oriented feedback	12	12	0	0
Procedural				
Posing a science question	10	5	0	5
Designing investigations	4	0	4	0
Executing scientific procedures	11	11	0	0
Hands-on	8	8	0	0
Recording data	4	5	0	0
Making data presentations	0	0	0	0
Epistemic				
Drawing conclusions based on evidence	8	5	3	0
Creating and/or revising theories	2	1	2	0
Nature of science	0	0	0	0
Social				
Participating in class discussions	11	8	3	0
Presentations	8	5	4	0
Argue/debate scientific ideas	0	0	0	0
Working in collaboration with others	9	5	3	1

It is worth noting from the table that while ten of the 12 planned lessons included the question feature, it was only presented in only five of these lessons in the classroom. Figure 6.1 below summarises the participants' enactment of the cognitive dimension of inquiry-based science teaching. It shows the relative representation of each domain of this dimension in the participants' planning and delivery of their lessons. The relative representation of each domain refers to the total number of features of the domain participants included in their planning in proportion to the total possible number of features belonging to the domain, as postulated by Furtak et al. (2012).

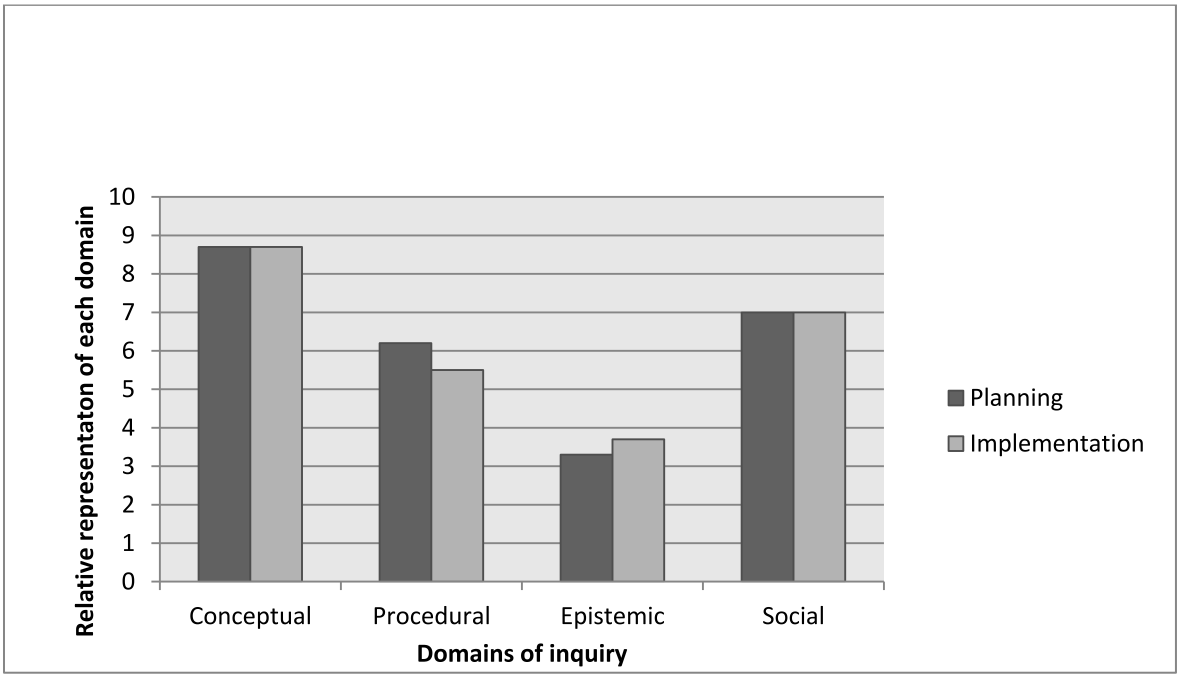

Figure 6.1 *Overall representation of the cognitive dimension of IBST in participants' lessons*

As Figure 6.1 shows, the conceptual domain was most prominent, followed by the social and procedural aspects, the epistemic domain was least represented. It can also be seen that in particular, the procedural aspect, was less apparent during classroom implementation than during their planning, indicating that some intended aspects of these domains were not implemented in the classroom. In contrast, participants implemented slightly more epistemic elements in the classroom than they had indicated during their planning.

Figure 6.2 portrays the group's ability to implement the different domains in the classroom. It is evident that in each domain, participants more often implemented features adequately than they did only partially. The figure also shows that participants' limited implementation of the cognitive dimension was most obvious with regard to the epistemic and social domains.

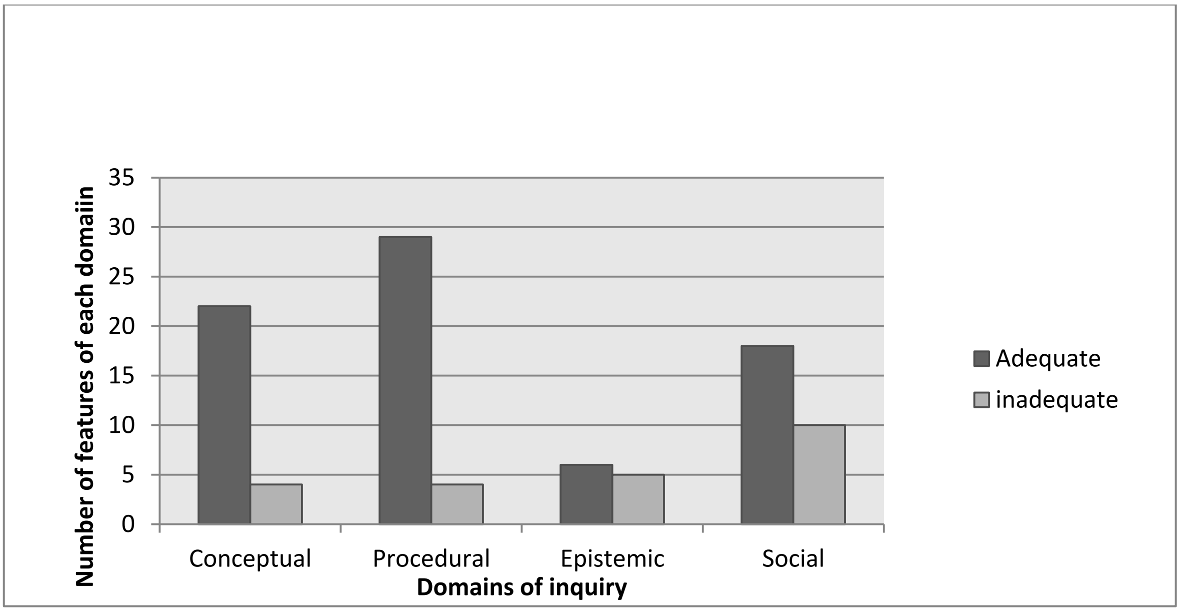

Figure 6.2 *Participants' ability to implement each domain of the cognitive dimension of IBST*

To understand the group's representation of each domain within the cognitive dimension, the researcher also analysed the collected data for features of each domain that were common in all or most of participants' planning and execution of their inquiry-based science teaching lessons. Figure 6.3 presents the results generated from this analysis; it indicates the number of participants that included the various elements of each domain in at least one of their two lessons.

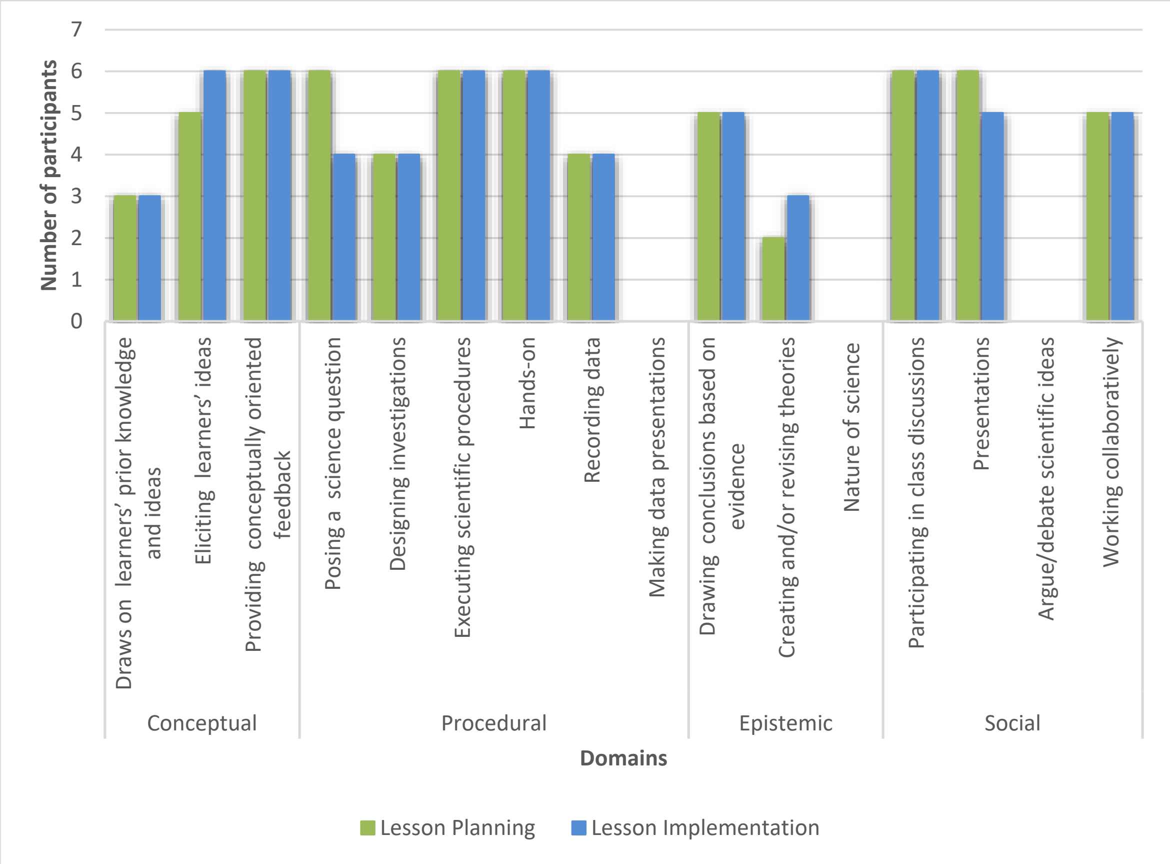

Figure 6.3 *Numbers of participants that portrayed different features (descriptions) of the domains in their enactment of IBST*

As is evident in Figure 6.3, although some of the features from each domain were evidently lacking, many were common. Connected to the conceptual domain, it is notable that the feature of drawing from learners' prior knowledge was seldom evident in the group's enactment of IBST. Instead, participants focused on eliciting learners' ideas and providing learners with conceptually oriented feedback. With regard to the procedural domain, the group focused on posing science questions, engaging learners in executing scientific procedures and learners' hands-on engagement, while less popular categories of this domain such as making data representation were entirely lacking. Categories within the social domain that were most frequently represented were engaging learners in class discussions and in making presentations. Not all participants included the epistemic domain and none discussed the nature of science. However, the prominent aspect of this domain was learners' engagement in drawing conclusions based on evidence.

Generally, participants' enactment of the cognitive dimension of inquiry-based science teaching lacked examples of drawing from learners' prior knowledge, engaging learners in making data representations, creating or revising theories and discussing the nature of science, and involving learners in arguing scientific ideas belonging to the conceptual, procedural, epistemic and social domains, respectively. The next section, 6.2.2 provides of the cognitive dimension in participants' enactment of inquiry-based teaching.

6.2.2 Participants' enactment of the cognitive dimension of IBST

This section illustrates how participants' lessons portrayed the different domains of inquiry-based science teaching. It focuses on the elements of each domain that were common to all or most participants. The first subsection presents how they incorporated the domains in their planning and lastly in their actual teaching.

6.2.2.1 Illustrations from participants' planning of the IBST lessons

This section uses data from participants' lesson plans and interviews to illustrate how the pre-service teachers planned for their inquiry-based science lessons.

Conceptual domain

Because all the observed lessons focused on promoting conceptual understanding, the conceptual domain was obviously the most prominent domain in participants' inquiry-based science lessons. The following statements illustrate what participants said in relation to this domain of inquiry-based science teaching:

> The teacher will ask learners questions in order to know their prior knowledge regarding what revolves between the sun and the earth and whether the moon revolves around the earth or the reverse is true. (Anele, pre-lesson 1 interview) [Drawing from learners' prior knowledge]

> My intention for telling that story was for the learners to take note of the differences in these two boys and come up with possible explanations for the differences. (Calsile, pre-lesson 1 interview) [Eliciting learners' ideas]

> After they have completed these sentences, the teacher will emphasize to the learners that matter can change from one state to another when cooled or heated and some substances, like water can exist as a solid, liquid or a gas. Also, matter changes its

> state through the following processes: melting, freezing, evaporation and condensation. (Fanelo, lesson plan 2, Appendix C_3) [Providing conceptually oriented feedback]
>
> The teacher will explain to the pupils that metals were attracted are iron, steel, and nickel. The teacher will then emphasize on the point not all metals are magnetic. (Dumsani, Lesson plan 1, Appendix C_2) [Providing conceptual oriented feedback]

The social domain

The social domain was the second most popular domain in the group's representation of inquiry-based science teaching. All six of the pre-service teachers referred to engaging learners in class discussions, and making presentations, as demonstrated in the following extracts.

> For every phenomenon learners have certain ideas, learners will therefore first *talk about their views* so I can know what conception they have about the concept. (Bandile, pre-lesson 1 interview) [Participating in class discussions]
>
> The teacher will tell learners to *discuss* with a partner what makes matter change from one state to another keeping in mind what they had observed. (Fanelo, lesson plan, Appendix C_3) [Participating in class discussions]
>
> Then I would allow the learners to *present the explanation* of what they have observed. (Bandile, Pre-lesson 1 interview) [Presentations]
>
> Let the learners go to their groups and find ways to investigate and answer the above question. They will write their suggestions in their science exercise books and share them with the whole class. (Anele, lesson plan 1, Appendix C_1) [Collaboration, Presentations]

The procedural domain

The aspects of the procedural domain mentioned by all six participants were *posing science questions, engaging learners in executing scientific procedures and learners' hands*-on *engagement.* The following extracts illustrate these three aspects in participants' planning of their lessons with inquiry in mind.

> Learners will group metals together. The teacher will ask if an aluminium block can be attracted to magnets and explain their answer. The *question that will arise* from this discussion is *"Are all metals attracted to a magnet?"* Then the teacher will let learners go into their groups to *find ways to investigate* and answer to the question (Anele, lesson plan 2, Appendix C_1) [Posing scientifically oriented questions, Designing investigations]

> The activity is also aimed at *addressing the question*, how is static electricity produced. Part of inquiry is to engage learners in activities other than you as a teacher doing it for them. I will therefore *allow them carry out the investigation themselves*. (Bandile, pre-lesson 1 interview) [Posing scientifically oriented question, Executing scientific procedures, hands-on]

> The teacher will then *pose questions for the investigation*: 'Are all metals attracted by a magnet'? The teacher will then put the pupils into groups of five and will provide each group with different material. *Each group will test every material given to them whether it is attracted by a magnet or not*. The teacher will then tell each group to *classify the materials into magnetic and non-magnetic materials* (Dumsani, lesson plan 1, Appendix C_2) [Posing science questions, Executing scientific procedures, hands-on]

The epistemic domain

The epistemic domain was the least fully represented domain in participants' lessons (see Figure 6.2). Although, all but one of the six participants referred to engagement of learners in formulating evidence-based conclusions, the other two elements: creating and revising theories and discussing the nature of science, were either rare or absent altogether. The following citations demonstrate the epistemic features in participants' lessons.

> During the investigation, they will write down their observations and *then answer to the question, Are all metals attracted by a magnet based on what they have observed* (Anele, lesson plan 2, Appendix C_1) [Drawing conclusions based on evidence]

> After recording their observations, *learners will then make conclusions* regarding how the thickness of the non-magnetic material affects the attraction force of a magnet. (Bandile, pre-lesson interview 1) [Drawing conclusions based on evidence]

> Learners will classify the materials into two groups; those the metal attracts and those that it does not. *The teacher will then ask the pupils whether a magnet attracted all metals or not.* (Dumsani, Lesson plan 1, Appendix C_3)

> I would first introduce the lesson to them then after that, I would do a brief investigation. Then I would allow the learners to *explain what they have observed*. (Bandile, Lesson 1 interview) [Creating and/or revising theories]

6.2.2.2 Illustrations of participants' implementation of the cognitive dimension of IBST

It has already been pointed out in 6.2.1 that participants' implementation of IBST in the classroom did not often match with their intentions as indicated in their lesson plans and interviews. This section thus describes the ways in which the pre-service teachers attempted to implement their planned lessons. In this account, the researcher focuses on domain aspects that were common to all or almost all six participants. In order to reveal variations in participants' implementation of the common domain aspects, the researcher selected two participants who displayed each identified feature in different ways. The variation in implementation was in terms of either the approach adopted or the level of competence.

Conceptual domain

The two conceptual aspects that were common to all six participants were eliciting learners' ideas and providing conceptually oriented feedback. The researcher uses the case of Anele, Bandile and Calsile to illustrate how participants attempted to incorporate these elements in their teaching. Anele, started his first lesson on eclipses by establishing that learners had an appropriate understanding of the prerequisite knowledge of revolution of planets around the sun, prior to eliciting learners' ideas about why sometimes the moon appear darkened. In addition, after learners had formulated an evidence-based explanation for this phenomenon, the teacher asked learners to use this framework to predict what would happen then when the moon was between the earth and the sun. In the explanatory phase of his lesson, he provided feedback on learners' conceptual ideas by introducing the terms lunar and solar eclipse to refer, respectively, to the phenomena whereby the earth blocks the light from the sun from reaching the moon and when the moon obstructs sunlight from reaching the earth.

Eyethu engaged learners in classifying, with justifications, some samples of matter on her desk as mixtures or solutions based on whether they were able to separate them. Even though Eyethu had not mentioned this is in her planning, she based this learner activity on what she believed they could do by drawing on their prior experiences as indicated in her answer when asked to clarify what she meant by solutions being not easily separable:

> Solutions are separable by means of distillation. However, I did not expect learners to know this based on their everyday experience, as the method is complicated. They will probably learn about it in higher grades. (Lesson 1 interview)

At the end of learner activities, in line with her lesson plan, she provided learners with conceptually oriented feedback. She told them the scientific names of the methods each group used to separate the assigned mixtures.

Bandile, also, in his second lesson about magnetic and non- magnetic materials, attempted to elicit learners' ideas about the main concept he wanted learners to investigate, which is the thickness of a non-magnetic material and the ability of a magnet to act through it. He asked them to hypothesize how the thickness of a non-magnetic material can affect the ability of a magnet to act through it. Bandile, however, did not ensure that learners had the necessary base to form such claims; in a preliminary discussion, he did not address the crucial question of whether a magnetic force can act through a non-magnetic material. His failure to base his question on this prerequisite knowledge made it difficult for learners to engage meaningfully with the question. As a result, he could not successfully elicit learners' ideas regarding the subject under investigation. After learners had carried out the investigation and presented their observations and conclusions, Bandile attempted to provide conceptually oriented feedback. However, due to the teacher's improper use of the word thick in place of thin, he struggled to direct learners to the desired concept.

The procedural domain

All six pre-service teachers involved learners in executing scientific procedures and ensured that learners were hands-on in at least one of their two lessons. The researcher uses the cases of Anele, Calsile and Dumsani to illustrate the group's implementation of these elements.

Calsile's lesson aimed at developing learners' ability to classify foodstuff into three basic food groups. She involved learners in finding out the number of groups into which food can be categorized. She instructed learners to observe the pictures of food she provided and to then put food items into groups according to any observed similarities. After learners had presented their organization of the food, she asked them to state the number of groups into which they had sorted the food. She however did not inform learners of the purpose or goal of the hands-on activity. During the lesson interview, she however pointed out that the goal of the activity was for learners to find out what kind of food they need to eat in order to stay healthy. It was evident that the scientific procedure they carried out did not directly link to the goal she expressed.

Dumsani gave learners different metallic and non-metallic objects and asked them to work in groups in testing and grouping them according to whether a magnet attracted them or not. Unlike Calsile, Dumsani informed learners that the purpose of the activity was to find out whether or not a magnet attracts all metals. However, as already pointed out the objects he gave them also included non-metallic objects, which means, similarly to Calsile, the procedure learners executed did not totally correspond to the mentioned purpose of the investigation.

Unlike in the cases of Calsile and Dumsani, the scientific procedure that Anele engaged learners in was directly coherent with the stated purpose of the investigation. Anele engaged learners in a similar lesson to that of Bandile, where learners investigated whether a magnet attracts all metals. After stating the purpose of the question in the form of a science question, he gave learners different metals and instructed them to test if a magnet attracts each metal.

The epistemic domain

Only three of the participants, Anele, Bandile and Calsile attempted to incorporate the epistemic domain in their lessons. The element that was common to all three of them was forming conclusions based on evidence. I use these three cases to illustrate the group's representation of the epistemic domain.

Anele, in his second lesson specifically directed learners to use their observations to draw conclusion for the stated question about whether a magnet attracts all metals. However, he neglected to instruct learners to record data so they could not draw any further evidence-based conclusions.

In his second lesson, Bandile included the aspect of drawing evidence-based conclusions regarding how the thickness of a non-magnetic material affects a magnet's ability to act through it. Learners had to base their conclusions on their observations of the amount of iron fillings that a magnet pulls up through thin and thick glass vessels, using a test tube and a beaker.

Unlike Anele and Bandile, in her second lesson Calsile prompted learners to analyse data recorded in a table on the board. She first asked learners to state the pulse rate of the two learners before and after exercise. She then asked them compare the heartbeats before and after exercise and asked them whether it gets faster or slower. She therefore engaged learners in confirming findings based on evidence that indeed the heart beat faster after exercise. However, similar to Anele and Bandile, she did not direct learners towards making any other conclusions except the one that pertained to the stated research question. She however provided learners with an explanation for the observed relationship between pulse rate and exercise.

The social domain

Participants attempted to promote dialogue and collaboration. However, the aspect that was common to all six participants was involvement of learners in class discussions. The researcher uses the cases of Calsile Eyethu and Fanelo to demonstrate the groups' representation of this social aspect. In her second lesson, Calsile attempted to involve learners in whole class discussions regarding how exercise affects their body. The teacher however failed to direct the discussion towards the desired goal, which was establishing the question for investigation or the goal of the lesson. Similarly, in her first lesson, Eyethu prompted learners to talk about their prior conceptions of mixtures and solutions. Fanelo engaged learners in a class discussion of whether solids and liquids have a definite shape and volume. Fanelo provided clarification of scientific terms whenever learners seemed to hold misconceptions. For example, learners confused the terms: a definite and a regular shape, as they argued that a stone has no definite shape but a wooden block does not.

Five of the six participants also tried to promote collaboration among learners and engaged them in making presentations. Eyethu in her first lesson encouraged learners in their different groups, to discuss and agree on a method to use to separate some materials assigned to them. Learners also had to work together in implementing their agreed separation strategy, and subsequently categorizing the materials as mixtures or solutions. Learners finally made group presentations. Similarly, Fanelo asked learners to work in pairs in forming evidence-based conclusions and later they presented their ideas to the whole class. However, even though they gave learners an opportunity to communicate their views during whole class interaction and group presentations, none of the pre-service teachers involved learners in reacting to each other's opinions or ides.

6.2.3 Other activities participants included in their enactment of inquiry-based science teaching

An inductive analysis of participants' lesson plans and lesson interviews indicated that like their understanding of inquiry-based science teaching, in enacting this pedagogical approach, participants also planned and implemented activities that were not part of the features (descriptions) of inquiry-based science teaching specified by Furtak et al. (2012). The researcher coded these activities and found that they could be grouped into one theme, which is use of non-empirical approaches to learning science concepts. These participants did not engage learners in analysing data in order to form evidence-based conclusions or explanations. Participants used this approach in either achieving one or all of the conceptually oriented objectives in one or both of their lessons. Table 6.3 presents the codes the researcher used to develop the theme. Frequency in this context refers to the occurrence of the activity in the 12 lessons rather than number of participants.

Table 6.3 *Additional activities in participants' enactment of IBST*

Codes	**Theme**	**Supporting data**	**Frequency**
Learners using their own ideas to answer teacher questions and teacher provide conceptually oriented feedback before learners have empirically tested their ideas.	Using theoretical (non-empirical) approaches to address questions	The teacher will ask learners where light comes from? The teacher will then tell learners to find out where light comes from, from their books. (Participant 2, lesson plan)	2
Learners searching books for answers to teacher questions		After learners' attempts to define mixtures and solutions at the beginning of the lesson, the teacher gave them the correct answers. (Participant 2, lesson 1 recording)	
Proposing some strategies for carrying out a particular task.	Engaging learners in creative activity	Learners will be required to make their own light after reading from their books (Participant 2, lesson plan 1)	2
Learners make an artefact		Learners classify some stuff made of two substances into mixtures and solutions based on the definition she provided them earlier (mixtures: those they could separate and solutions (solutions: those they could not easily separate) (Participant 2, lesson 2)	
Total			4

From Table 6.3, it is evident that in both lessons, one of the pre-service teacher (Participant 2) engaged learners in their learning through non-empirical based teaching approaches, such as learners relying on the textbook for answers rather than on analysing data and also in engaging learners in making applying knowledge in making some artefacts.

Overall, the results of the analysis in this section indicate that pre-service teachers' planning and presentation of their lessons focused on certain domains of the cognitive dimension of inquiry-based science teaching. Their lessons encompassed mostly the conceptual domain while the epistemic domain was least represented. Their implementation of the different domains in the classroom was however generally poorer, except for the epistemic domain, which improved slightly. The noted decrease was significant with regard to the procedural domain.

The analysis also shows that participants' enactment of IBST concentrated only on certain features (descriptions) of the four domains of IBST. The least represented features in each domain were drawing from learners' prior knowledge: a conceptual feature, making data representations: a procedural feature, explicit discussion of the characteristics of science: an epistemic domain and involving learners in debating scientific ideas: a social feature. In addition to the features of inquiry-based science teaching described by Furtak et al. (2012), one participant engaged learners in other activities which only focus on promoting active learning of concepts rather than engaging learners in the different methods used to discover knowledge in science.

6.3 PARTICIPANTS' ENACTMENT OF THE GUIDANCE DIMENSION OF IBST

As earlier pointed out in Chapter 3, this study defines the guidance dimension in terms of the amount of guidance the teacher provides (Furtak et al., p. 306). This section provides the results generated from an inductive analysis of the lesson plans, lesson interviews and lesson observation transcripts for statements indicating what teachers left to learners to perform. This data as already pointed out in Section 4.4.2.2, allowed the researcher to make inferences regarding the amount of guidance the teacher provided. The sub-sections 6.3.1 and 6.3.2 focus on the quantitative and qualitative aspects of the data respectively.

6.3.1 Quantitative data for participants' enactment of the guidance dimension of inquiry-based science teaching

Three categories of learner-directedness emerged from the inductive analysis process for what the teacher allowed learners to carry out. These were *engaging learners in planning investigations; collecting data themselves, and constructing knowledge claims based on the gathered evidence*. These give an indication of the amount of teacher direction that the pre-service teachers provided, which is the guidance dimension of IBST. The results from the lesson plans and pre-lesson interview data sources corroborated each other, although participants generally included fewer inquiry features in their written lesson plans than they mentioned during interviews.

Table 6.4 below provides a frequency distribution of these aspects. The classification of "inadequate" signifies a deficient representation of the element. For example, I categorized activities involving only a few of the learners in collecting data as an inadequate demonstration of engagement of learners in collecting data themselves. Inadequacy with regard to the two other noted aspects of learners' directedness in the group's enactment of this teaching approach designates a failed or an incomplete attempt to guide learners through the process of carrying out the aspect.

Table 6.4 *Aspects of learner-directedness demonstrated in participants' enactment of IBST*

Level of learner directedness	Rate of occurrence in 12 observed lessons					
	Planning			Implementation		
	Adequate	Inadequate	Total	Adequate	Inadequate	Total
Planning investigations	4	0	4	0	3	3
Collecting data	7	1	8	7	1	8
Constructing knowledge claims based on evidence	7	0	7	2	4	6

As Table 6.4 indicates, the most frequent characteristic of learner self-directness in the enactment of inquiry-based science teaching was the teacher allowing learners to gather data themselves. Closely following, was the aspect of letting learners construct evidence-based conclusions themselves. The aspect of letting learners plan investigations was least evident in participants' inquiry-based science teaching lessons. The data in the table also indicate the only aspect participants were able to implement adequately was involving learners in conducting investigations. Participants showed limitations in terms of guiding learners in their planning of scientific procedures themselves, which was most noticeable, and in formulating evidence-based conclusions.

Table 6.5 presents the number of pre-service teachers who executed each aspect in at least one of their two lessons. The purpose of this analysis was to find out the aspects of learner-directedness that were common to all or most of the participants.

Table 6.5 *Number of participants that included the different elements of learner-directedness in their IBST lessons*

Level of learner directedness	Number of participants					
	Planning			Implementation		
	in one lesson	in both lessons	Total	in one lesson	in both lessons	Total
Planning investigations	4	0	4	3	0	3
Conducting investigations	4	2	6	4	2	6
Constructing answers to questions	3	2	5	2	2	4
Total	11	4	15	9	4	13

As is evident in Table 6.5, all six participants planned and implemented the aspect of engaging learners in conducting the investigations themselves in at least one of the lessons. Five of the six participants also planned to leave it to learners to formulate their own conclusions or answers to research questions in at least one of the lessons, but one of them did not carry through the plan during the actual lesson. Four of the six participants planned to let learners design the investigations, but only three executed the plan in the classroom. The data in the table also indicate that few participants included the different elements of learner-directedness in both of their lessons. Of note, is that none of them enacted the element of letting learners plan investigations themselves in both lessons.

The data in Table 6.5 concerning the guidance dimension of IBST indicates that participants planned and presented lessons that were more teacher-directed than learner-centred. The teachers decided the question or topic learners were to investigate. Although four of the six participants planned to leave it to learners to plan investigations, this was only with regard to one of their two lessons. Moreover, in one of the four lessons that included the planning of an investigation by learners, the pre-service teacher ended up telling learners the procedure for carrying out the investigation.

The next two subsections present illustrations of how the group of pre-service teachers planned and implemented their IBST lessons.

6.3.2 Qualitative data illustrating the representation of the guidance dimension in participants' enactment of inquiry-based lessons

This subsection attempts to demonstrate how participants' lessons portrayed the different characteristics of the guidance dimension of inquiry-based science teaching. It begins in the next subsection by representing how they incorporated these aspects in their planning and lastly in their actual teaching, and in the following subsections

6.3.2.1 Illustrations from participants' planning of IBST lessons

As already pointed out, three levels of learner directedness were evident in the group's planning for inquiry-based science teaching. These aspects are letting learners collect desired data themselves, allowing them to formulate conclusions based on evidence, and to plan investigations. Some aspects were however more common than others. An illustration is given next of how the pre-service teachers incorporated each of these aspects of learner directedness in their planning.

Learners carrying out scientific procedures themselves

In at least one of the two lessons, all but one of the participants planned to provide learners with an opportunity to carry out scientific procedures themselves. The following direct quotations indicate how participants included this aspect of learner directedness in their planning.

> The teacher will call two volunteers to come upfront to test if a magnet attracts all the metals. They must test one by one and let the whole class observe what is happening. (Anele, lesson plan 2, Appendix C_1)

> Part of inquiry is to engage learners in activities other than you as a teacher doing it for them. I will therefore allow them carry out the investigation themselves. (Bandile, lesson 1 pre-lesson interview)

> Each group will test every material given to them whether it is attracted by a magnet or not. The teacher will then tell each group to classify the materials into magnetic and non-magnetic materials (Dumsani, lesson plan 1, Appendix C_2) [Posing science questions, Executing scientific procedures, hands-on]

Learners formulating evidence-based conclusions themselves

Like the previous examples, all but one participant indicated an intention to leave it to learners to formulate conclusions based on evidence, rather than the teacher interpreting the data for them. The following lesson plans and lesson interview extracts illustrate this intention.

> During the investigation, they will write down their observations and then *explain the answer to the question,* "Are all metals attracted by a magnet" based on what they have observed (Anele, pre-lesson 1 interview)

> After recording their observations, learners will then make conclusions regarding how the thickness of the non-magnetic material affects the attraction force of a magnet. (Bandile, Lesson plan 2))

> I have a question for the learners to investigate. I have planned that learners will plan the investigation and later use data they will collect as a class to make conclusions about how exercise affects the heart rate. After learners have attempted to make conclusions, I will comment on their answers. (Calsile, lesson 2 pre-interview)

Learners designing investigations themselves

Four of the participants, Anele, Bandile and Calsile and Dumsani, revealed a plan to engage learners in designing investigations in at least one of their lessons as illustrated in the following extracts.

> Learners will group metals together. The teacher will ask if an aluminium block can be attracted to magnets and explain their answer. The *question that will arise* from this discussion is "Are all metals attracted to a magnet?" Then the teacher will let learners go into their groups to *find ways to investigate* and answer to the question. (Anele, lesson plan 2, Appendix C_1)

> Therefore, I have planned that I would organize the learners into groups of five. Then give them the materials that are a beaker and a test-tube, magnets of different sizes and iron flings. I wanted them to come with their own design, how they can compare the attraction of a magnet from the thickness of the test tube and the beaker of the same material. (Bandile, lesson 2 interview)

> I have a question for the learners to investigate. I have planned that learners *will plan the investigation* and later use data they will collect as a class to make conclusions about how exercise affects the heart rate. (Calsile, lesson 2 pre-interview)

6.3.2.2 Illustrations from classroom observations of participants' IBST

As the data in Table 6.5 indicates, participants attempted to implement the three different aspects of learner directedness that they had planned. This section points out of how the pre-service teachers carried out these aspects in the classroom.

Learners collecting data themselves

All six participants guided learners in conducting investigations themselves in line with their planning. The following reports demonstrate how three of the pre-service teachers incorporated this element in their teaching:

To gather evidence to address the question of whether magnets attract all metals, Anele asked two learners to come to the front desk. He asked them to test what happens when you bring a magnet to different the metallic objects so they could find out whether or not a magnet is able to attract each metal. The rest of the learners had only to observe what was happening in each case. Bandile, on the other hand, in seeking data to answer the question of how the thickness of a non-magnetic material affects the ability of a magnetic force to act through it, he organized learners into groups of six. He gave each group the set of materials and instructed them on what to do collect the required data.

In his second lesson, Dumsani wanted his learners to learn how to connect an electric circuit correctly. Similarly, to Bandile, he organized the learners into groups and allocated each group a set consisting of a bulb, wires and an electric cell. He then engaged learners in finding out how to cause the bulb to light by manipulating the provided materials.

Learners interpreting data themselves

Five participants made an effort to allow learners to draw conclusions or develop explanations based on evidence, or both, in at least one of their two lessons. As Table 6.4 shows, the researcher categorized participants' execution of this aspect as successful or limited. The following lesson descriptions serve to illustrate each of these categories of participant implementation of this aspect of learner directedness:

Anele, in his first lesson about eclipses, engaged learners in formulating explanations based on evidence. He effectively guided learners in interpreting evidence. He achieved this by directing learners in this manner: when the learners representing the three celestial bodies were in a straight line with the sun in the middle, he asked learners to state whether the torch light carried by the learner representing the sun was able to reach the moon. Anele then instructed learners to go to their groups and use their observations to explain the occasional darkening of the moon.

Dumsani's engagement of learners in this aspect of learners' directedness in his first lesson of magnetic and non-magnetic materials was limited. He only engaged learners in analysing the data, but then interpreted the evidence himself, as the following lesson presentation indicates:

> **Teacher**: From what you have tested and observed, are all the objects attracted metallic?
> **Learners:** No, they are not.
> **Teacher**: Now at the beginning you said a magnet attracts all metals but now we have come to a point where we have realized that not all metallic objects are attracted by a magnet.

Bandile's attempt to engage learners to draw conclusions themselves about the effect of the thickness of non-magnetic material on the ability of a magnet to act through it was ineffective. The following lesson extract demonstrates how Bandile's erroneous use of the words thick and thin and his failure to give learners time to think and discuss and support their point of view made it difficult for learners to construct evidence-based conclusions themselves.

Teacher: From which object are the iron fillings many?
Learner: From the test tube
Teache*r*: [The teacher records the relative amounts of filings collected from the test tube and the beaker on the board.] He then asks when you look at the amounts of the iron fillings, what can you say about the thickness of the non-magnetic material.
Learner*s*: No answer.
Teacher: In which object did the magnet attract more iron fillings?
Learners*:* the test tube
Teacher: The one, which is less thick or thicker?
Learners*:* Less thick
Teacher: Is the test tube less thick. No, it is thicker. (He says it again in SiSwati, which however translates as thinner). Then the beaker is less thick. Therefore, what can you say about the attraction force of a magnet. Looking at your iron fillings, through which one of them is the attraction the most, looking at your iron fillings? From the……. (Teacher wants learners to complete the sentence)
Learners: the test tube
Teacher: Yes, from the test tube is strong and then from the beaker is less strong. So what can you say now does the thickness of an object affect the attraction force of a magnet.
Learners: No answer and they looked very confused.

Learners designing investigation themselves

Only three of the four participants who expressed an intention to engage learners in planning investigations themselves attempted to do so in the classroom. However, none of these three participants was fully successful in this attempt. The participants failed in either or both of drawing from learners' prior knowledge and asking meaningful questions when directing learners in carrying out this inquiry activity themselves. The following narrations illustrate participants' inadequacy in guiding learners in this aspect of learner directedness in inquiry-based science teaching.

Anele, in his second lesson wanted learners to come up with a plan for investigating whether a magnet attracts all metals, but was not able to achieve this goal. He did not ask appropriate questions that would guide learners in deciding what materials they needed to include in their investigation and how they would analyse the collected data to address the research question. Instead, Anele provided learners with the necessary materials and asked them to state how they could see whether a magnet attracts metals, rather than how they could determine whether a magnet attracts all metals; a question he had stated in his lesson plan. When interviewed about this scenario, his response indicated that by planning an investigation, he actually only referred to what learners had to do to the materials rather than the minds-on aspects of deciding what evidence was necessary to address the question and how such evidence would be generated, as the following interview extract indicate:

> **Interviewer**: So your question was about finding out whether each metal can be attracted by a magnet and not how they could address the question “are all metals attracted by a magnet or not?”
> **Interviewee:** Yes, I asked them how we could investigate if a magnet can attract a particular metal rather than the scientific question that arose. I think after they had observed how each metal behaves when brought to a magnet, they need to make a conclusion based on the collected data about whether or not all magnet attracts all metals. (Post-lesson 2 interview)

The following lesson extract demonstrates how Bandile attempted, but failed, to direct learners’ thinking in carrying out this aspect. The extract also indicates that he did not provide learners with enough time to think and discuss how they could tackle the challenge he gave them. As a result, he eventually provided learners with the procedure they needed to follow in conducting the investigation:

> **Teacher**: What do you think you can do to investigate if the thickness of the material can affect the attractive force of a magnet? What do you think you can do using the materials that I have given you? [Even though learners had formed groups, he did not provide them an opportunity to discuss their ideas]
> **Learners**: [quiet and others busy playing with the objects that he has already distributed]
> **Teacher**: I can test the strength of a magnet by using this paper. If I put the magnet underneath the paper, do you see what happens? I am just giving you a hint on how you can use the test tube and the beaker to test if the thickness of the glass can affect the attractive force of the magnet.
> **Teacher**: Okay, let us do like this, which object, between the beaker and the test tube is thicker? [Without giving learners a chance to think or discuss the example, he had just provided].
> **Learner**: The beaker
> **Teacher**: Is the beaker is thicker than the test tube?
> **Learners**: Yes
> **Teacher**: No, the test tube is thicker than the beaker. (He also tried to say it in vernacular, which when translated into English, actually expresses the same fact as what learners had pronounced: The test tube is thinner rather than thicker.

> **Teacher**: So you know now that the test tube is thicker than the beaker. (Actually, he wanted to say the test-tube is thinner.) Therefore, now can you use the iron fillings, the beaker and the test tube to check if the attraction of the magnet can be affected by the thickness? (of the medium). Okay now, pour the iron fillings into the beaker. Everybody is doing that. Place the magnet where the iron fillings but outside, not inside the beaker then you try to drag the iron fillings up using the magnet. We want to check if the thickness of the beaker has an effect on the attraction force of the magnet. Do you see the iron fillings that are moving up with the magnet from inside? You collect them and pour them on the sheet of paper. Then again, you pour the iron fillings into the test-tube. Again, you bring your magnet and pull the iron fillings up. Then you pour again the iron fillings that the magnet attracted. (He describes this procedure while demonstrating)

Like Bandile, Calsile failed to address learners' prior knowledge and so could not effectively guide learners in carrying out this intended activity. She instructed learners to design an investigation of how exercise affect the heart rate before talking about the rate at which the heart normally beats and how we can measure it. She eventually also gave learners the procedure for addressing the science question herself.

In conclusion, the data analysis and citations indicate that in enacting the guidance dimension of inquiry-based science teaching, participants predominantly planned either traditional direct instruction, where learners were only actively involved in terms of manipulating materials, or more teacher-directed forms of inquiry-based science teaching. In addition, participants often failed to guide learners in implementing the level of learner directedness they intended.

6.4 DISCUSSIONS OF FINDINGS

This chapter addressed the second research question. Having established the participants' understanding of inquiry-based science teaching in Chapter 5, another subject of interest was how participants translated their understanding into classroom practice. In this regard, the study began by exploring how the participants planned their science lessons with inquiry in mind and, then next, how they executed their plans in the classroom. The researcher collected data regarding participants' enactment of inquiry-based science teaching by means of lesson plans, supplemented with pre-lesson interviews, and classroom observations. Subsections

6.3.1 and 6.3.2 present discussions of findings pertaining to pre-service teachers' planning and execution, respectively, of inquiry-based science lessons.

6.4.1 Pre-service teachers' planning for IBST

Firstly, the participants' enactment of the cognitive dimension of IBST centred more on the conceptual and social domains than it did on the two other domains: social and epistemic were least represented, with the epistemic domain being least so. All six participants attempted to find out learners' conceptions and provided learners with conceptually oriented feedback in at least one of their lessons, as could be expected in that all their lessons focused on achieving conceptually oriented goals. Participants' greater emphasis on the conceptual and social domains in comparison to the procedural and epistemic firstly, contrasts with a number of previous studies (Asay & Orgill, 2010; Demir & Abell, 2010; Ozel & Luft, 2013). Unlike the findings in these previous studies, participants in this study seemed to use inquiry-based science teaching more as a means of promoting conceptual understanding than for other important goals of science education (Eick & Reed, 2002; Furtak et al., 2012; Harris & Rooks, 2010; Keys & Bryan, 2001). However, in some lessons, participants used a non-inquiry approach to achieve the conceptually oriented goals. This is in line with the finding from the previous chapter that a notable number of the pre-service teachers in this study connected IBST with a variety of ways of actively engaging learners in their learning, rather than focusing on learners constructing knowledge claims themselves based on evidence.

Most of the participants had engaged learners in investigations, however, in most cases these investigations were not directed at addressing science questions. This is a similar finding to that noted by Asay and Orgill (2010). Moreover, in this study, some observed lessons were also not testing any specific idea, despite a significant number of the participants, in their questionnaire responses, having associated inquiry-based science teaching with eliciting and testing learners' ideas. Furthermore, learners were also observed to have barely participated, if at all, in carrying out processes of science such as recording data, making data representations, inferring (creating and revising theories), and discussing the nature of science. On the contrary, the science curriculum that the teachers are to teach eventually focuses on both knowledge and process skill objectives and its major goal is to develop a scientifically literate society (Ministry of Education and Training, 2012). Scientific literacy consist of elements that not only promote learners in-depth conceptual understanding, but also furthers their understanding of how to do science and the characteristic of the knowledge science generates (Furtak et al., 2012; Harris & Rooks, 2010; Lederman, Antink, & Bartos, 2014). Overall, the results of this study point toward that pre-service teachers are not able to create learning situations that would allow learners to learn all the facets of science.

During enactment, participants' focused more often on conceptual elements than all other aspects, which was at odds with the way they had talked about this pedagogical approach. While they described inquiry-based science teaching mainly in terms of its procedural and epistemic elements, their enactment was poorer for these two domains. These results are in line with several studies (Binns & Popp, 2013; Lebak, 2015; Lederman, 1999; Tobin & McRobbie, 1999) that have also found some mismatch between assessed teacher knowledge and their classroom practices, especially among less experienced teachers. This seems to indicate that it takes time to have confidence in learners developing good understanding through IBST and thus new teachers find it difficult to put their understandings into classroom practice.

With regard to the guidance dimension of inquiry-based science teaching, in consensus with findings from previous studies (Asay & Orgill, 2010; Binns & Popp, 2013; Mugabo, 2012; Ozel & Luft, 2013), participants engaged learners in more teacher-directed forms of inquiry-based science teaching. Even though most of the group, in describing inquiry-based science teaching, had referred to learners' asking science questions and planning investigations, none of the participants engaged learners in addressing their own questions or ideas and only a few planned to involve learners in designing investigations. Their enactment was, however, in line with that most of them regarded only two types of activity as indispensable aspects of inquiry-based science teaching: these were engaging learners in inferring knowledge claims based on evidence or engaging learners in hands-on activities.

Drawing from the theory of social-cultural constructivism, the observed variance between teacher knowledge of IBST and their enactment of this pedagogy could be a result of teacher beliefs (Keys & Bryan, 2001). Teachers' beliefs and values are socio-cultural factors as they often form because of their personal experiences within a particular socio-cultural context: a classroom or out of the classroom setting (Crawford, 2007; Wallace & Kang, 2004). Some studies have indicated that the teachers' beliefs, about students, how they learn, teaching and how science functions can impede the translation of their understanding into classroom practices (Chinn & Malhotra, 2002; Crawford, 2007; Wallace & Kang, 2004). A study carried out by Chinn and Malhotra (2002) suggested that teachers' beliefs about teaching were connected to their beliefs about learners' capability. In addition, science-teaching priorities in the school context seemed to be the most likely explanation for teachers' focus on the conceptual domain of IBST. Drawing from this implied relationship; one can argue that in the context of the school science curriculum they were teaching, the current study's participants regarded the conceptual domain as the most important aspect, which subsequently influenced their enactment of IBST. However, some external constraints, such as limited time due to standardized external examinations (Binns & Pop, 2013; Mkimbili, Tiplc, & Odegaard, 2017; Mugabo, 2012), and lack of mentors well versed in inquiry-based teaching for the pre-service teachers (Binns & Popp, 2013) can all impede teachers' translation of their understanding of inquiry-based science teaching into classroom practice.

6.4.2 Pre-service teachers' implementation of inquiry-based science lessons

The study also found that participants' representation of the different domains of the cognitive dimension, in particular, the procedural, was lower during classroom implementation than in their planning, indicating their inability to effectively guide learners in carrying out these activities.

The study findings also support the general assertion that pre-service teachers often find it difficult to enact the intended level of learner-directedness they advocate. This is similar to the results from Binns and Popp (2013). Some participants associated inquiry-based science teaching with learners testing their ideas or planning investigations, and highlighted an intention to engage learners in such activities during pre-lesson interviews; but they always failed to execute these plans in their actual teaching. Some of the participants also failed to implement their plans to engage learners in formulating conclusions. Participants' inability to guide learners in carrying out more learner-directed scientific activities seems to be linked to their general failure to draw from learners' prior knowledge and experiences in developing their lessons (Eick & Reed, 2002; Furtak et al., 2012; Harris & Rooks, 2010). This conceptual aspect, as shown in Figure 6.3, was evidently lacking in the group's enactment of IBST; which is contradictory to the constructivist's view of teaching that supports learners' construction of their own knowledge based on their prior knowledge and experiences.

The manner in which the participants in this study enacted inquiry-based science teaching therefore supports the contention that science activities taking place in the classroom in most cases misrepresent the character scientific inquiry (Schwartz, 2012). While inquiry-based science teaching is described as engaging learners in the cognitive practices similar to those carried out by scientist (Furtak et al., 2012; Harris & Rooks, 2010), it is argued by Chinn and Malhotra (2002) that rarely do learners in science classes "generate research questions, plan investigations, develop theories or investigate ideas" (pp. 180-182).

6.5 SUMMARY

This chapter presented the results that pertain to the pre-service teachers' enactment of IBST. Overall, the study has found that, contrary to their understanding of IBST, their enactment of IBST focused mainly on the conceptual and social domains of IBST. Participants also planned and presented lessons that were more teacher-directed; none of the lessons focused on learners' addressing their own questions and few engaged learners in designing investigations. Participants' inquiry-based science teaching therefore seems to focus more on promoting conceptual understanding than on developing learners' process skills, and an awareness of the procedures scientists use to develop knowledge. Participants also struggled to implement in their actual teaching the level of learner directedness that they had planned.

These findings indicate that certain factors limited the participants' enactment of inquiry-based science teaching. The third goal of this current study was therefore find out some factors that could explain the manner in which the current pre-service teachers planned and implemented inquiry-based teaching during their teaching practice in schools; these are presented in the next chapter.

CHAPTER 7

FACTORS INFLUENCING PRE-SERVICE TEACHERS' ENACTMENT OF IBST

In the preceding chapter, the researcher described and discussed the manner in which six of the pre-service primary school teachers selected from among those who participated in the survey (Appendix A) enacted inquiry-based science teaching during their teaching practice in schools. With regard to cognitive dimension of inquiry-based teaching, pre-service teachers' lesson planning consisted mainly of conceptual features; the epistemic domain was least represented. Their portrayal of the social and procedural domains was moderate. In relation to the guidance dimension, participants for the most part, planned either traditional direct instruction or more teacher-directed forms of inquiry-based science teaching. In the classroom, most of the time, participants implemented inadequately or not at all some aspects of the cognitive dimension and the level of learner directedness they had planned. Participants' implementation was particularly poor with regard to the procedural domain and engagement of learners in designing investigations themselves.

In discussing the participants' enactment of inquiry-based science teaching in Chapter 6, the researcher related their enactment to their portrayal of essential features of this pedagogical approach identified in Chapter 5. Though to some extent the pre-service teachers' understanding of characteristics of IBST, could explain the way they enacted the pedagogical approach, other aspects of the cognitive and guidance dimensions of their lessons did not match their theoretical characterizations of this pedagogy. The cognitive dimension of their inquiry-based lessons consisted of more conceptual and social elements than they had cited in their description of this pedagogy. In addition, most of them did not plan, or if they planned did not execute, some of the levels of learner directedness they associated with IBST in either of their lessons. Pre-service teachers' understanding of inquiry-based science teaching was therefore not the only factor influencing their enactment. The current chapter therefore seeks to address Research Question 2.2:

What factors influence pre-service teachers' enactment of IBST?

To collect data necessary to address this question, the researcher asked participants during lesson interviews to describe their lesson goals, the way they planned their lessons with inquiry in mind, their lesson goals, and to explain the manner in which they carried out certain activities in the classroom. Section 7.1 presents the results of the inductive analysis of participants' lesson interview responses. Section 7.2 attempts to make sense of factors influencing the way participants planned and executed their plans in the classroom.

7.1 ANALYZING INTERVIEWS FOR FACTORS INFLUENCING THE WAY PRE-SERVICE TEACHERS ENACTED IBST

The researcher used an inductive approach to analyse the participants' lesson plans and lesson interviews to construct an understanding of factors that influenced the way they had enacted inquiry-based science teaching. She carefully read their descriptions and explanations of how they planned and presented their lessons, then coded them and developed these codes into themes that served to explain the different ways in which participants enacted their inquiry-based science lessons. Table 7.1 indicates the codes and themes that resulted from this analysis.

Table 7.1 *Factors shaping the way pre-service teachers enacted inquiry-based science teaching*

Codes	**Categories**	**Themes**
Knowledge of the goals of the curriculum	Knowledge of and beliefs about purposes of science instruction	Orientations to science teaching
Beliefs about primary goals of the science curriculum		
Beliefs about the best approaches of teaching science	Knowledge and beliefs about appropriate approaches to teaching science	
Perceptions of learners' abilities	Beliefs of learners' abilities	Beliefs about learning ad learners' capabilities
Beliefs about how learners learn best	Beliefs about learning	
Understanding of scientific inquiry processes	Understanding of inquiry-based science teaching	Scientific inquiry pedagogical understanding and skills
Understanding essential features of IBST		

Codes	Categories	Themes
Pedagogical content knowledge	Pedagogical related skills	
Command of the language of instruction		
Limited lesson time	Educational department related constraint	Contextual factors
lack of space/ large class sizes	School related constraint	

As is evident in Table 7.1, the themes identified indicate that a combination of the pre-service teachers' knowledge and beliefs influenced their enactment of inquiry-based science teaching: that is, their orientations to science teaching, their knowledge and beliefs about learners, their understanding of essential features of IBST and related pedagogical understanding and skills. In the next four subsections, the researcher uses extracts from participants' interview responses to illustrate each of these four factors.

7.1.1 Orientations to science teaching

Participants' orientations to teaching science seemed to strongly influence the way all six pre-service teachers planned and presented their inquiry-based science lessons. An orientation to teaching science in this study refers to "knowledge and beliefs about the purposes and goals of teaching science"; here it is in the context of the Swazi curriculum (Friedrichsen, Van Driel, & Abell, 2011). While knowledge claims are rational and based on some empirical evidence (Crawford, 2007), beliefs refer to "assumptions thought to be true" (Lebak, 2015, p. 697) or "one's preferences for doing something" (Yilmaz & Sahin, 2011, p. 73). Below is a presentation of the two different categories of this factor found to have a bearing on the participants' enactment of IBS:

7.1.1.1 Knowledge and beliefs about the purposes of science instruction

Even though the science curriculum emphasizes teaching for the development of learners' conceptual knowledge, science process skills and attitudes, the analysis of collected data indicated that science content goals drove the participants' planning and instructional choices. This is illustrated by the objectives stated in their lesson plans and their interview responses when asked to describe the goals of their inquiry-based lessons.

> I wanted them to learn that a magnet attracts not all metals. That was the basic concept, I wanted them to grasp. I also wanted them to learn that a magnet can act through a non-magnetic material. (Anele, lesson 2 interview)

> By the end of the lesson, learners should be able to describe changes of state: melting, freezing, evaporation and condensation. (Fanelo, lesson 2)

> I wanted them to learn the kinds of food that give us energy, protects our bodies, and builds our body after they had classified them. (Calsile, lesson 1 interview)

> By the end of the lesson, learners should be able to describe some methods used to separate mixtures. (Eyethu, lesson 1)

Two of the participants indicated knowledge that inquiry-based science teaching also aims at achieving epistemic and process-oriented goals. The following extract illustrates this.

> I wanted them to understand how we address questions in a science setting. I think that they would gain that understanding when they are gathering evidence related to what the question posed and when they are giving the answers. (Anele, lesson 2 interview)

> I wanted to develop some of the inquiry skills some of which is observations. I wanted to make them see what happens when they do that activity and be able to know if my students are able to observe. (Bandile, lesson 1 interview)

However, Bandile demonstrated an understanding of the epistemic goal of IBST only during the interview, not in his classroom practice.

> I think as a science teacher, what I want is that the upcoming generation should be able to know what science is and how it operates. They would not know if we just continue using the older approaches telling them everything. (Bandile, post-questionnaire interview)

Similarly, Anele indicated that he associated inquiry-based science teaching with developing learners' life skills; but only during the interview on his understanding of and views about inquiry-based science teaching.

> In addition, since we are in science, we must be able to argue your stand; that I am saying this because of reason 1 and 2. Therefore, it is important because at the end

> we want the learners to be able to stand for themselves everywhere, not just in the classroom. Where are they going to gain these skills? They will gain them in the classroom, nowhere else. Therefore, there must get an opportunity to present and justify their conclusions. (Anele, post-questionnaire interview)

The extracts above indicate that while these two participants recognized other goals for inquiry-based science teaching, they interpreted the curriculum they are to teach as mainly aimed at promoting content goals. In support of this assertion, their lesson plans consisted mainly of content goals, as explained by Anele in the following interview extract.

> Just a little that I can point out. It is the issue of time. I think in the schools when we are teaching the time is not enough for the science lessons because this inquiry requires a lot of time. So here, we are pushing the syllabus, you want to meet the deadlines and the learners they will not when they are assessed more on what they have acquired themselves but you find that they are assessed according to the objectives of the syllabus. Yes, through the inquiry, you may achieve these objectives but not in a way that they will help them answer the questions during examinations because the examination is more theoretical and it is not asked in the context in which they learn. (Anele, post-questionnaire interview)

7.1.1.2 Beliefs about the appropriate approaches to teaching science

All six participants engaged learners in some form of activity. Their lesson interview responses however revealed that they had different purposes behind these activities, which consequently demonstrated their preferred approaches to teaching science. Two of the six participants demonstrated a guided inquiry orientation as represented in the following direct quotations.

> I believed that by observing the positions of the three when the light from the sun fails to reach the moon, they would be able to explain what causes the lunar eclipse. (Anele, lesson 1 interview)

> I will first introduce the lesson to them, and then I would do a brief investigation. Then I would allow the learners to give their explanation of what they have observed. Then at the end, I will guide them to the correct explanation of the observation. (Bandile, lesson 1 interview)

These extracts demonstrate that the pre-service teachers' intentions in engaging learners in activities was to involve learners in exploring a concept themselves, with the teacher only steering them to the target conception in the context of the learning activity (Cobern et al., 2013). Anele and Bandile both regarded the process of guided construction of knowledge as collaborative than an individual endeavour as indicated in their own words:

> When they are in groups they are judging themselves, no one is the boss. Another crucial point here is that the students do not fear each other hence they will be able to share and argue their ideas. By so doing, they are able to collaborate and form the knowledge together and they will be proud of themselves when they find out that what they have said is more in line with the teacher's explanation (Anele, lesson 1 interview).

> I wanted them to address the research question in their groups so they could have a chance to discuss the question (Bandile, lesson 1 interview).

The remaining participants seemed to harbour a principally active-engagement orientation. Their focus, when engaging learners in some activities was evidently on promoting learners' involvement in the lesson. Consequently, some of these participants engaged learners in hands-on activities other than hands-on investigations. These included process-based activities, engaging learners in reading the pupils' book, answering questions and other activities. The following interview extracts point out this focus.

> I wanted them to carefully observe the similarities and differences among the foodstuffs and let their minds work and think of how the food items can be classified. (Calsile, lesson 1 interview)

> I think that was also inquiry because they were involved. They did an experiment to find out what happens when you rub the plastic ruler on dry hair or cloth and bringing it to some pieces of paper.
> **Interviewer**: so you think it is inquiry even when the purpose of the activity is to demonstrate what the teacher has already explained.
> **Dumsani**: Yes, in my opinion it is. (Lesson 2 interview)

> Firstly, I had to come up with a question the learners had to investigate. Using the question that I came up with, I had to think of activities that learners would do and what learners were going to come up with. (Eyethu, lesson 1 interview)

In the follow up after questionnaire interview, the participants also revealed this active-engagement conception as indicated in the following excerpts:

> Yes, I would still regard it as inquiry because of the fact that they have carried out an investigation. In addition, because if you observe something there are questions that can be raised which can lead to more investigations. (Dumsani, post-questionnaire interview)
>
> I think the teacher should give learners a chance to think and to investigate something. They should also communicate their findings. All this done under the teacher's guidance by means of questions he or she asks during the lesson. (Calsile, Lesson 1 interview)
>
> I think it was not in line with my view of inquiry-based science teaching because the learners in their groups they could not come up with their own activities. (Eyethu, Lesson 1 interview)

In addition to an activity-driven orientation, Dumsani and Eyethu also demonstrated their didactic view about science teaching. They both began one of their two lessons by defining concepts. Dumsani's didactic view of teaching science emanated from a belief that learners learn better when taught in this manner as illustrated in the following interview extracts.

> **Interviewer**: So you believe the discussion of the meaning of the terms should always take place before learners carry out an investigation?
> **Interviewee:** Yes, because I think it makes it easy for them to understand.
> **Interviewer:** So if you do it the other way round you start with some investigation and prompt them to attempt to define the terms based on what they would have observed or discovered as they carry the investigation; do you think that would work?
> **Interviewee**: I think it cannot work because they will have some difficulty. Most of the learners would be asking you questions. For example, if I did not define the term electricity, I was going to spend a lot of time defining for each group what this means.

Eyethu's didactic-activity orientation linked to her belief that an activity in science had the purpose of providing learners with an opportunity to apply knowledge previously presented to them, rather than as a vehicle for constructing knowledge as indicated in the following interview extracts.

> **Interviewer:** As learners were engaged in the activity, I noted that you kept on emphasizing that learners should remember the definition of a mixture and a solution. What was the significance of these definitions in the activity?

> **Eyethu:** It was important for them to know at the beginning that when they are able to separate a sample, then it is a mixture. If they are not, then it is a solution so I had to remind them that frequently because you will find them classifying something that is not a mixture under mixtures.
> **Interviewer:** Discovering the different methods of separating mixtures was not part of the goals of the activity.
> **Eyethu**: It was part of my objectives, but the main objective was for them to be able to differentiate a mixture and a solution.

Her didactic stance evidently emanated from her belief that the order in which the teacher's guide presents the lesson goals prescribes the lesson development. This is demonstrated in her response to being asked why she began her lesson by defining terms:

> **Interviewer:** You started your lesson by asking learners to define mixtures and solutions and stating whether those samples provided were mixtures or solutions. Then you moved on to define what a mixture and a solution is from the book prior to engaging them in the activity. Can you explain why you followed that sequence?
> **Eyethu:** Actually, the teacher's guide directed my approach. The guide stated as the first objective that he learners should be able to define a solution and a mixture. Then they should know the difference between a mixture and a solution.

Fanelo, on the other hand, held a different view; his active engagement orientation was linked more to a belief in providing learners with opportunities to discover some target knowledge (facts or concepts) themselves.

> I think the purpose of science is to provide learners to opportunities to experience and discover knowledge about things themselves rather than me telling them the concept. (Fanelo, lesson interview 2)
>
> I think it should be child-centred. You have to involve the learners. This means learners should be hands-on in whatever activity they conduct. They should be directly involved in manipulating the learning material and discover knowledge themselves rather than being told. The teacher must guide learners to ensure that they carry out the correctly. Therefore, my role is just to facilitate. (Fanelo, post-questionnaire interview)

7.1.2 Beliefs about learning and learners' capability

In this study, it was evident that teachers' beliefs about learners' capability were closely linked to beliefs about how learners learn. Hence, these two beliefs were merged.

7.1.2.1 Beliefs about how learners learn

One participant, Dumsani, demonstrated that his belief in a didactic approach to teaching science was linked to his belief about how learners learn. The following response indicate that he believed learners understand better when the teacher presents concepts to them by direct instruction rather than them constructing such concepts based on analysing data.

> **Interviewer**: So you believe the discussion of the meaning of the terms should always take place before learners carry out an investigation.
> **Dumsani:** Yes, because I think it makes it easy for them to understand.
> **Interviewer:** So if you do it the other way round you start with some investigation and prompt them to attempt to define the terms based on what they would have observed or discovered as they carry the investigation. Do you think that would work?
> **Dumsani**: I think it cannot work because they will have some difficulty. Most of the learners would be asking you questions. For example, if I did not define the term electricity, I was going to spend a lot of time defining for each group what this means.

7.1.2.2 Beliefs about learners' capability

Beliefs about learners' abilities seemed to drive most of the participants' enactment of IBST. In their justification of how they enacted their lessons, it was evident that beliefs about what learners can do on their own was one of major factors influencing the manner in which they planned and implemented their lessons. The following direct quotes indicate that participants' opinions of learners' abilities is one of the reasons they planned more teacher-directed forms of inquiry-based science teaching.

> First, I thought of the level of the cognitive level of my learners. I just thought that they would not be able to come up with their own questions to investigate when they do not even know the term static electricity. Therefore, I thought I should just come with the question and the design of addressing it and at the end, they could explain. (Bandile, lesson 1 interview)

> In my view, the topic was difficult, so I thought they would have challenges. Maybe if it were a different topic I would engage them in designing their own investigations. (Anele, lesson 1 interview)

> The lesson should provide learners with a question that will guide them on what to seek. I do not think at their age, they can formulate their own. (Fanelo, follow up interview)

> Looking at their level, their ability, and the fact that they were not used to this method of learning, I thought that maybe they would stray from what we are doing. Therefore, I thought I should specify what I want them to do; they would be able to do without wasting time. (Anele, lesson 1 interview)

This factor also affected participants' confidence in implementing their lesson plans in the classroom. Three of the participants included some aspects they had not planned in the classroom due to their uncertainty about the learners' ability to carry out certain activities. Calsile, when asked about her goal in telling learners a story at the beginning of her lesson, pointed out that she wanted to elicit learners' ideas about food that they need to eat to be healthy. However, in the classroom, she included the ideas that were to come from learners when telling the story. When asked about this, her answer below indicated that she had a concern about learners' ability to follow the story when told in a second language:

> Learners' ability to follow a story when taught in English is sometimes a challenge so I thought maybe if I should relate the story to the balanced diet, learners would understand the focus of the story better. (Calsile, Lesson 1 interview)

Bandile responded similarly; although he planned that learners would work in groups in designing investigations, in the classroom he opted for a whole class discussion and indicated a lack of certainty in his learners' capacity to carry out this activity as indicated in his direct words.

> I thought I needed to guide them and I would not be able to do that in the different groups considering the time that was remaining and that they were many groups. (Bandile, lesson 2 interview)

7.1.3 Scientific inquiry pedagogical understanding and skills

This theme constitutes two categories: participants' understanding of the essential features of this pedagogical approach and related inquiry skills, and pedagogical knowledge and related skills. Participants' responses illustrating these categories are presented next:

7.1.3.1 Understanding of inquiry-based science pedagogy

The lesson interview responses indicated that participants generally lacked an understanding of several features of an inquiry-based lesson: that is, drawing from learners' prior knowledge, the need to interpret data when constructing knowledge, and the need for a question to drive learners' investigations:

Four participants showed a complete lack of appreciation of the need to draw from learners' prior knowledge and ideas when planning their inquiry lessons. Bandile, for example, in both his lessons indicated his lack of understanding of this feature of the conceptual domain of IBST. In his first lesson, he planned that learners would explain their observation of a rubbed ruler attracting some paper without considering the theoretical framework that learners needed to draw from in carrying out this process. His response below, when asked about how he planned to help learners formulate explanations indicates that he believed learners would, based on their observations alone, create the desired explanation.

> After they have done the activity and they had observed what happens, then they would come with the explanations by themselves. (Bandile, Lesson interview 1)

In the same way, Calsile and Fanelo were evidently unaware of the need to prompt learners to draw from their prior knowledge when classifying objects or interpreting data to form evidence-based conclusions. Both of them seemed to think that observations alone could lead learners to desired knowledge as indicated below.

> Well, I wanted them to classify just based on identified similarities and differences and thereafter give them the label of each food group e.g. energy giving foods. (Calsile, lesson interview 1)
>
> **Interviewer**: Did you however have a plan of helping them move from the observation to a generalizing about the behaviour of matter than just water?
> **Fanelo:** I did not think about that.

> **Interviewer**: You however wanted them to reach that conclusion based on the observations.
> **Fanelo:** Yes, that is what I wanted them to conclude. (Lesson interview 2)

Fanelo also indicated this lack of understanding of the role of prior knowledge in constructing new knowledge based on observations. When asked to say what he felt had the greatest influence on the manner in which he planned his inquiry-based lessons. He had this say:

> I think it was my understanding of the inquiry approach as being about engaging learners seeing themselves and discover how things really happen. (Fanelo, lesson 2 interview)

The following quotation also shows that instead of regarding learners' existing knowledge and ideas as valuable for inquiry-based learning, Dumsani believed this approach would divert the teacher from the goals of the lesson:

> It would be very dangerous to use their responses because it can also divert you from what you have planned. You may end up doing another thing that you have not planned. (Dumsani, lesson 1 interview)

Only one participant, Anele, indicated a clear understanding of the need to use learners' prior knowledge and ideas as basis for developing his inquiry-based lessons. The following quotations illustrate this understanding:

> Therefore, I planned that I will show learners objects made of different materials including metals and ask them to predict which of the metals can be attracted by a magnet. Then we will ask them to justify their predictions. I was expecting them to tell me that all a metal attracts all metallic objects will be attracted to a magnet. However, I was also expecting some of them to have it in mind that may be, a magnet will not attract some of the metallic objects. The disagreement will then draw us to the question: "Are all metals attracted to a magnet?" (Anele, lesson 2 interview)

> I think at this point, I will be extending their knowledge of what they had learnt about the lunar eclipse. In making the predictions, they were actually supposed to use that prior knowledge. (Anele, lesson 1 interview)

Calsile, when asked to explain why, after establishing a relationship between exercise and the heart rate, she did not also plan to involve them in creating explanations for the phenomenon. Her response presented below, suggested that she did not regard engaging learners in creating explanation for their observations (that they could later revise in light of evidence), as an indispensable characteristic of IBST.

> Telling the learners the reason for the change of the pulse rate during exercise was just some additional knowledge that they could investigate some other time. It was not the main objective of the lesson. (Calsile, lesson 2 interview)

This data analysis therefore indicated that participants' lesson planning and enactment were constrained by their lack of understanding of the epistemic and related conceptual features of inquiry-based science teaching.

Even though participants were aware of using a science question and the engagement of learners in designing investigations as both being essential features of IBST, some of them were unable to construct science questions for guiding learners' inquiry activities or an understanding of the meaning of designing investigations. For example, even though Eyethu pointed out in the follow up interview that a scientifically oriented question was an essential element of inquiry-based science teaching, neither of her lesson plans included a driving science question. In the first lesson interview, she revealed that she could not identify a science question in the context of the lesson she planned to teach, as illustrated in the extract below:

> It was hard for me to get a question from the lesson. (Eyethu, lesson 1 interview)

Calsile also displayed this inability; although, unlike Eyethu she did not seem to be aware of it. When asked about the science question she planned learners to address, she expressed a question learners would not have been able to address based on the activity they conducted. Calsile therefore evidently lacked an understanding of what constitutes a science question as the direct citation of her answer below illustrates.

> Yes, I have a question**.** It is **'**what kinds of food do we need to eat in order to stay healthy'. (Calsile, lesson 1 interview)

In addition, three participants who planned and attempted to engage learners in designing investigations were unable to do so adequately because of their limited understanding of this inquiry process. Participants seemed unaware that designing investigations constitutes more than just identifying what needs to be observed or measured, but includes identifying the variables that need to be manipulated and controlled and how the data collected would be analysed and interpreted to address the science question. The following extracts illustrate two of the participants' inadequate understanding of this aspect of inquiry.

> **Interviewer**: So your question was about finding out whether each metal can be attracted by a magnet and not how they could address the question "are all metals attracted by a magnet or not?"
> **Anele:** Yes, I asked them how we could investigate if a particular metal can be attracted by a magnet rather than the scientific question posed. I think after they have observed how each metal behaves when brought to a magnet, they need to make a conclusion based on the collected data about whether or not all metals are attracted by a magnet. (Lesson 2 interview)
>
> **Interviewer:** Learners pointed out that you can test the objects by using a magnet when you asked them how you could investigate the question. Do you think the response they gave was enough for them to answer the question of whether or not a magnet attracts all metals?
> **Dumsani:** Maybe that was not enough. By bringing the magnet close to each object, they must explain what they expect to happen.
> **Interviewer:** Do you think that would also be enough to address the question?
> **Dumsani:** I think so. (Lesson interview 2)

7.1.3.2 Pedagogical related skills

Participants' descriptions of how they planned their lessons with inquiry in mind and reasons for carrying out certain actions also revealed that their understanding of, and skills in, directing inquiry-based science teaching was also one of the factors that influenced the manner in which they enacted their inquiry-based science teaching. Whereas, for example, Bandile revealed that he knew he needed to find out learners' ideas, he did not know how to enact this conceptual element of IBST in the context of the topic he planned to address. He also indicated a belief in implementing this aspect of inquiry-based science teaching, he needed to refer to the concept he wanted learners to learn rather than by drawing from learners' everyday experiences of the investigated phenomenon. The following quotation demonstrates this lack in his ability to enact IBST.

> I did not determine their prior ideas about static electricity because that name was new to them. (Bandile, lesson 1 interview)

When probed about the possibility of using familiar contexts in eliciting learners' ideas, his response below indicates his inability to identify such contexts, which most probably relates to his poor understanding of the concept he was teaching. A good grasp of the target concept is necessary for identifying learners' experiences that relate to it.

> I did not think they could be something related to it that they could know although there is. (Bandile, lesson 1 interview)

Even though five participants referred to a science question in their explanation of how they planned at least one of their lessons, some demonstrated a lack of awareness of the guidance function of a question in an inquiry-based lesson; which therefore explains their neglect of the question in their lesson presentation. Calsile, for example, when asked about what she hoped would guide learners in carrying out some hands-on activity; indicated in her response that she did not intend to use the question she had specified as a means of guiding the learners' activity.

> Well, I wanted them to classify just based on identified similarities and differences and thereafter give them the label of each food group e.g. energy giving foods. If I would have told them the purpose of the classification activity, it means I would have to tell them to classify the food according to the three food groups, and in that way, they would not be that much involved in terms of thinking. (Calsile, lesson interview 1)

During the post-questionnaire interview on participants' understanding of inquiry-based science teaching, Calsile had revealed that she actually regarded a question as a way of informing learners about the knowledge they are supposed to learn rather than as a means of directing learners' inquiry activities, indicated by her words:

> **Interviewer:** what is the purpose of a question in an inquiry lesson?
> **Calsile:** The purpose of a question is to specify the objective of the lesson. What you want the learners to know. (Post-questionnaire interview)

Fanelo held the same view. He believed that by stating the topic of the lesson, learners would automatically know the science question they needed to address, without having the teacher point it out and using it drive the inquiry activity, thus:

> **Interviewer**: So, you believe the question was clearly stated to the learners.
> **Fanelo:** Yes, they knew, we wanted to see because the topic was changing forms of matter so the question was what causes matter to change its forms or states so, I think the question was there. (Lesson 2 interview)

Only one of the participants, Anele, had the ability to lead learners to the question that needed to be investigated. While, almost all of them attempted to elicit learners' ideas, they were not able to use these ideas to drive learners towards the science question. Anele, however, demonstrated, not only the knowledge of the need to draw from learners' ideas, but also an ability to use their ideas to drive them to the desired question as indicated in the following extract from his second lesson:

> Therefore, I planned that I will show learners objects made of different materials including metals and ask them to predict which of the metals can be attracted by a magnet. Then we will ask them to justify their predictions. I was expecting them to tell me that all metallic objects will be attracted to a magnet. However, I was also, expecting some of them to have it in mind that, maybe, some of the metallic objects will not be attracted by a magnet. The disagreement will then draw us to the science question: ***"Are all metals attracted to a magnet?"*** (Anele, Lesson 2 interview)

Fanelo, on the other hand, also elicited learners' ideas, but when asked about the purpose of this questioning; his answer indicated that he did not understand that he could use their ideas to drive them to the question he wanted them to investigate, as indicated below.

> **Interviewer**: You started your lesson by asking students to give examples of substances that can change from one state to another and what can cause these changes. What was the purpose of engaging your learners in that kind of discussion?
> **Fanelo:** I wanted them to note that changes in temperature can cause a substance to change from one state to another**.** (Lesson 2 interview)

Besides an inadequate understanding of inquiry-based science teaching, the results of this study indicate that lack of proficiency in the language of instruction can act as a barrier to effecting of an inquiry-based approach to teaching and learning. In IBST, rather than providing learners with answers, a teacher needs to guide learners meaningfully as they try to respond to questions themselves. The next interview extract provides an example of how the participant's language difficulty hindered his attempt to elicit learners' ideas:

> **Interviewer**: Prior to engaging learners with the research question, you asked them what affects the strength of a magnet. What was the aim of engaging them in that discussion?
> **Bandile:** I wanted to find out their prior knowledge about what can affect the strength of a magnet.
> **Interviewer:** Was the initial issue that needed to be addressed in this lesson, the strength of the magnet or whether a magnet can act through a non-magnetic material?
> **Bandile:** It was the attraction force of the magnet. Maybe I failed to explain what really I wanted, but I wanted to ascertain their knowledge about what can affect the pull of a magnet through a non-magnetic material. (Lesson 2 interview)

The presented data indicated that learners generally lacked the pedagogical knowledge and skills related to eliciting and using learners' ideas to direct the inquiry-based lessons towards the desired goals. However, for one of the participants, language difficulty seemed to be another major barrier.

7.1.4 Contextual factors

The following participants' lesson interviews responses indicate that time constrains and large class sizes hindered the pre-service teachers' employment of some more learner-directed activities:

> **Interviewer**: In our previous interview, you indicated that you value learners being hands-on or actively involved in the inquiry activities. Could you state your reasons for carrying out an investigation by using only a few of the learners rather than letting them play the game in their groups?
>
> **Anele**: Firstly, I can say *it was the issue of time*. Time was not on our side. Secondly, the space, in the classroom was small. (Lesson 1 interview)

> **Interviewer**: Learners were put into groups; however, they were not given time to design the investigation in their groups, instead, you decided to discuss it as a class. Can you explain why you changed your plan?

Bandile: I thought they needed guidance and I would not be able to do that in their different groups *considering the time that was remaining* and that they were many groups. (Lesson 2 interview)

Interviewer: Do you think it would have been part of inquiry if you listed the ideas revealed by learners' responses and then allowed them to test them?

Dumsani: Of course, but I did not plan to engage them in testing their ideas in that lesson because that would *have consumed a lot of time*. Yes, I could collect their questions, but their question could cause us to branch a little bit from what the objectives of the lesson. (Lesson 2 interview)

7.2 UNDERSTANDING THE PRE-SERVICE TEACHERS' ENACTMENT OF IBST

This section is in into two sub-sections. Section 7.2.1 focuses on making sense of pre-service teachers' planning of inquiry-based science teaching while Section 7.2.2 focuses on their abilities to execute their plans in the classroom. It compares the results from analysing lesson interviews with their understanding and their enactment of inquiry-based science teaching.

7.2.1 Understanding the ways participants planned their science lessons

The planning by the pre-service teachers for inquiry-based science teaching varied in terms their representation of the cognitive and guidance dimensions of inquiry-based science teaching, and their consistency in engaging learners in different learner-directed activities. Analysis of participants' lesson interview responses indicated that their knowledge and beliefs about science and science teaching had a major bearing on the manner in which they enacted inquiry-based science teaching. This section seeks to understand how such factors might have influenced the ways in which pre-service teachers planned their inquiry-based lessons. For this purpose, the researcher carried out a cross-case analysis. I took each pre-service teacher as a single case.

Table 7.2 below shows a comparison of pre-service teachers' orientations to science teaching with the maximum number of elements of each domain within the cognitive dimension evident in their planning for inquiry-based science teaching. The number of elements within each domain that they cited in their lesson outlines planned with inquiry in mind and pre-lesson interviews are included, in order to conclude about the degree to which their planning related to their understanding of essential elements of the IBST pedagogical approach. The four domains of the cognitive dimension of IBST are represented by acronyms: P=procedural, C=conceptual, E=epistemic and S=social. The letters Q and I stand for questionnaire and interviews respectively.

Table 7.2 *Participants' orientations to science teaching and their representation of the cognitive dimension of IBST in their planning for IBST*

Participant	**Demonstrated orientations to science teaching**							**Number of elements evident in their lesson planning**				**Number of elements evident in their description of IBST**							
	Content-driven	Nature of science	Guided inquiry-based	Active engagement	Discovery	Didactic	Promote collaboration and interaction	P	E	C	S	P		E		C		S	
												Q	I	Q	I	Q	I	Q	I
Anele	X	X	X				X	4	2	3	3	5	5	2	2	3	3	2	3
Bandile	X	X	X				X	5	2	1	2	3	3	1	1	0	0	1	1
Calsile	X			X		X		4	1	2	2	4	2	1	0	2	1	2	1
Dumsani	X			X		X		4	1	2	3	4	3	1	0	2	1	1	0
Eyethu	X			X		X		3	0	3	3	4	4	1	0	0	1	0	0
Fakazile	X			X	X	X		3	1	3	3	3	2	1	0	1	2	1	0
Total								23	7	14	16	23	19	7	3	8	8	7	5

As is evident from Table 7.2, participants' representation of the procedural and epistemic domains in planning was almost consistent with their understanding of inquiry-based science teaching. In their lesson plans, they referred to 23 elements, which was equal to the number of questionnaire responses, and comparable with the 19 interview mentions. However, for the social and conceptual domains the written lesson plans for inquiry-based science consisted 16 and 14 elements, respectively; but in narrating how they planned their lessons with inquiry in mind, the pre-service teachers mentioned only 5 and 3 elements, respectively for the two domains. This indicates that their representation of the social and conceptual elements in their lessons did no relate to their understanding of IBST.

The data in Table 7.2 also indicates that all participants held content-focused orientations to teaching science, which correlates with the conceptual domain being the domain represented most frequently in their lessons. Of the remaining three domains, the social domains good representation appears to link with the participants' activity-driven orientation to inquiry-based science teaching. Participants were mostly engaged in carrying out different activities in groups aimed at promoting their active engagement.

Anele and Bandile's lesson had slightly higher frequency (two elements each) of epistemic features, which is in line with their view of science as being also aimed at promoting learners' understanding of the characteristics of science, and their guided inquiry orientation to teaching science. The remaining participants had, at best, only one instance of the epistemic domain in line, which corresponds to their didactic and active engagement-driven orientations.

The above analysis indicates that participants' understanding of inquiry-based science teaching had a great influence on their enactment of the cognitive dimension of IBST. Its influence was most noticeable in their representation of the procedural and epistemic aspects of inquiry-based science teaching where the number of elements of these two domains in the lesson plans matched those in the teachers' descriptions of IBST. Their overall higher representation of the conceptual and social domains in their lessons seems to relate more to their orientations to science teaching than their understanding of IBST. These results therefore indicate that participants' orientations to science teaching acts as an important mediating factor: it explains how and why pre-service teachers' understanding of IBST translate into classroom practice, by influencing the domains of IBST that that pre-service teachers focus on in the classroom.

To understand further the way in which pre-service teachers planned for their inquiry-based lessons, in Table 7.3 the researcher compares their planning for the guidance dimensions of the inquiry-based science teaching with their demonstrated knowledge and beliefs about inquiry-based science teaching.

Table 7.3 *Pre-service teachers' planning of the guidance dimension of inquiry-based science teaching and associated beliefs and knowledge*

Participant	**Planning of the guidance dimension of IBST**					**Knowledge and beliefs evidenced in participants' reasons for planning their inquiry-based science lessons.**				
	Learners Conduct investigations themselves in one of the two lessons	Learners conduct investigations themselves in both lessons	Learners answer science questions themselves in one of the two lessons	Learners form conclusions themselves in both lessons	Learners design investigation themselves in one of the two lessons.	Teaching purposes other than content-focused goals	Science teaching beliefs	Demonstrated the need of the epistemic domain.	Demonstrated lack of certainty about learners abilities	Perceived time constrains
Anele	X			X	X	NOS and life skills	Guided inquiry-centred	X	Designing investigators	X
Bandile	X	X		X	X	NOS	Guided-inquiry-centred	X	Design investigations and posing science questions	X
Calsile	X		X		X	X	Activity-driven	X	Ability to form data presentations themselves	
Dumsani		X	X		X	X	Activity-driven	X	Ability to carry out activities before concepts have been clarified	X
Eyethu	X					X	Activity-driven		X	
Fanelo	X		X				Activity-driven with a discovery purpose		Posing questions and using unfamiliar materials to investigate a phenomenon	

As indicated in Table 7.3, participants' beliefs about science teaching and learners' capability had a bearing on the way they planned the guidance dimension of their lessons. Of the three pre-service teachers who held a guided inquiry orientation to science teaching, only two (Anele and Bandile) planned to guide learners in formulating evidence-based conclusions in both of their lesson. In line with this orientation, these participants also planned to engage learners in designing investigations in at least one of their two lessons. Their failure or inconsistency in engaging learners in higher levels of learner directed inquiry activities, such as posing questions and designing investigations, is consistent with their demonstrated lack of confidence in learners' capability to carry out this procedural aspect of IBST, along with their more content oriented view of science teaching.

The remaining four participants made few plans to engage learners in forming conclusions; it was included in only one, but sometimes neither, of the two lessons. Their lack of focus on engaging learners in drawing conclusions themselves connects well to their activity-driven orientation to IBST. Their focus was evidently more on engaging learners in observing or on activities that would facilitate their cognitive engagement with the concepts, rather than on demonstrating the discovery nature of science.

One of the participants, Fanelo (See Table 7.3) although also holding an activity driven orientation, evidently viewed such activities as a means of providing learners with opportunities to discover some knowledge themselves. Nevertheless, despite this orientation, his lack of consistency in engaging learners themselves in forming conclusions indicates an association of discovery with finding out factual knowledge; a belief he indicated in his first lesson where he planned to engage learners in hands-on activities aimed at finding out some factual knowledge. However, his lack of appreciation of this epistemic domain of inquiry-based science teaching may also indicate a belief that based on their observation alone; learners can reach the desired conceptual understanding. He demonstrated such a belief in his second lesson interview.

To further understand factors that might shaped the manner in which pre-service teachers planned their lessons, the researcher related the participants' biographic data and contextual data related to the school where the teacher carried out teaching practice, to find out if either had any bearing on the manner in which they planned their lessons.

As evident in Table 7.4, *availability of materials is the only contextual factor that seemed to relate with the participants' planning* for inquiry-based science teaching. Two of the participants who stated that the school had science materials were able to plan lessons that incorporated learners' engagement in conducting investigations themselves in both lessons, regardless of their orientations to science teaching. The other four of the participants were able to involve learners in hands-on investigations in only one of the two lessons. Even though participants' perception of learners' ability is one of the reasons behind the pre-service teachers' planning decisions, surprisingly, it did not seem to link to the grade level at which the pre-service teachers taught. This claim is backed by the data in Table 7.3, where one can note participants' intentions to engage learners in different aspects of learner directed activities was seemingly unrelated relate to the grade level of the learners, which ranged from Grade 2 to Grade 6. However, this relationship may have been masked by the small size of the sample.

Table 7.4 *Pre-service teachers' planning for IBST versus the context of inquiry and their biographic characteristics*

	Pre-service teachers' characteristics		**Context of IBST**				**Participants' planning for IBST**				
Participant	Experience	School background of the pre-service teacher	School location	Availability of materials in the school	Support from school	Grade level	Form knowledge clams in both lessons	Form knowledge clams in one lesson only	Conduct investigations themselves in both lessons	Conduct investigations themselves in one of the two lessons	Design investigation themselves in one of both lessons
Anele		Rural	urban	not available	none	6	X			X	X
Bandile	X	Urban	semi-urban	Available	none	6	X		X		X
Calsile		semi-urban	urban	not available	none	2		X		X	X
Dumsani		Rural	semi-urban	available	none	6		X	X		X
Eyethu		semi-urban	semi-urban	not available	none	5				X	
Fakazile		semi-urban	urban	available	none	5	X	X		X	

This research has shown in this section that even though pre-service teachers attempted to plan their lessons in accordance with their understanding of this pedagogy, their science teaching orientations and beliefs about learners' capability seem to have a greater influence on the cognitive domains and the aspects of learner-directedness that they focused on in planning inquiry-based lessons. . The only contextual factors that seemed to have an effect on participants' planning was availability or unavailability of materials, which, respectively, facilitated or inhibited participants' planning of hands-on activities. Even though some participants cited time constraints as another factor limiting their engagement of learners in learner-directed activities, their decisions regarding what to do in these situations appeared to again hinge on their beliefs about the primary purpose of teaching science.

The next section, 7.2.2, focuses on factors that influenced participants' ability to execute their planned aspects of inquiry-based science teaching in the classroom.

7.2.2 Understanding pre-service teachers' implementation of inquiry-based lessons

Findings in the previous chapter, Chapter 6, indicated that the study participants were not equally successful in terms of their ability to implement their lesson plans according to their intentions. The researcher therefore sought to understand factors that could help explain this state of affairs. Analysis of pre-service teachers' lesson interviews in Section 7.1 indicated that their ability to engage learners in different aspects of learner directedness of inquiry-based science teaching depended on their understanding of the scientific processes they planned to engage learners in, as well as their pedagogical understanding and ability to guide learners in carrying out these activities. Table 7.5 shows a comparison of this data pertaining to their understanding and skills related to inquiry-based science teaching and the participants' different ways of executing their planned activities during teaching practice. Crosses indicate the understanding or skill that had been evident in participants' interview responses.

Table 7.5 *Participants' realization of their inquiry-based lesson plans and their demonstrated understanding and skills related to inquiry-based science teaching*

Participant [Pseudonym]	**Lesson**	**Implementation of the learner directedness aspects of IBST**			**Demonstration of pedagogical understanding and skills related to IBST**			**Understanding of the theory-driven nature of scientific processes**	**Understanding of the process of designing investigations**
		Designing investigations	Executing procedures	Creating evidence-based knowledge claims	Understanding of and ability to elicit learners' ideas	Understanding of and ability to draw from learners' prior knowledge and ideas	Understanding of the epistemic domain of IBST.		
Anele	1	__________	_________	adequate	XX	XX	X	X	NA
	2	inadequate	inadequate as planned	adequate	XX	XX	X	X	inadequate
Bandile	1		Adequate	unsuccessful	X		X		NA
	2	unsuccessful	inadequate	unsuccessful	X		X		inadequate
Calsile	1	___________	Partially successful	___________	X		X		NA
	2	unsuccessful	_________	not attempted	X		X		inadequate
Dumsani	1	inadequate	Adequate	unsuccessful	XX	X	X		NA
	2	____________	Adequate	not attempted	XX	X	X		inadequate
Eyethu	1	___________	Partially successful	_________	XX	X			NA
	2	___________	_________	__________	XX				NA
Fakazile	1	___________	Adequate		XX	XX			NA
	2	__________	_________		X				NA

Firstly, as evident from Table 7.5, participants' successful engagement of learners in learner-directed forms of IBST relates to their understanding of the scientific inquiry processes and their understanding of, and skills related to, this pedagogical approach. The pre-service teachers' frequent inability to engage learners in designing an investigation on their own linked mainly to the teachers' marked lack of understanding of this inquiry process. Their ability to execute plans to engage learners in forming knowledge claims themselves based on evidence was mainly limited by either the teachers' poor understanding of the need to engage learners in interpreting evidence, or their ability to draw from learners' prior knowledge in carrying out this epistemic activity.

Only some of the lessons without the aspect of drawing from learners' prior experiences were successful in terms of learners carrying out scientific procedures. This indicated that the relevance of drawing from learners' prior knowledge could depend on the level of cognitive engagement demanded by the activity. In line with this supposition, the two hands-on activities that were not successful were at a higher cognitive level than the others were, as they required learners to make decisions regarding how to separate a given mixture and how to classify some food items. The other three that were successful despite the teacher's inability to draw from learners' prior knowledge were only so because they involved learners carrying out simple procedures or executing prescribed procedures. There was little cognitive demand

In order to determine if any biographic and contextual factors could help explain observed similarities and differences in the way pre-service teachers executed their plans in the classroom, such factors were compared with the pre-service implementation of IBST, as in Table 7.6. In the table, the terms "adequate" and "inadequate" indicate, respectively, that the planned activities were either successful or only partially successful. The phrase "not attempted" means that although the participant planned the learner-directed activity, he or she did not include it in the classroom presentation. An example of such a case would be a pre-service teacher providing learners answers when she had planned to allow them to form conclusions themselves based on evidence. A line across the entry indicates the category was not applicable to a case.

Table 7.6 *Pre-service teachers' classroom implementation of IBST versus their biographic characteristics and the context of IBST*

	Pre-service teachers' characteristics		**Context of IBST**				**Participants' implementation for IBST**				
Participant	Prior experience in teaching science	School background of the pre-service teacher	School location	Availability of materials in the school	Support from school	Grade level	Form knowledge clams in both lessons	Form knowledge clams in one lesson only	Conduct investigations themselves in both lessons	Conduct investigations themselves in one of the two lessons	Design investigation themselves in one of both lessons
Anele		Rural	Urban	not available	none	6	adequate in both	________	__________	adequate	inadequate
Bandile	X	Urban	Semi-urban	available	none	6	inadequate in both lessons		__________	adequate in one but inadequate in the other	unsuccessful
Calsile		Semi-urban	Urban	not available	none	2	_________	not attempted	inadequate	inadequate	unsuccessful
Dumsani		Rural	Urban	available	none	6	not attempted	_______	adequate	_________	inadequate
Eyethu		Semi-urban	Semi-urban	not available	none	5	________	________	inadequate	inadequate	_________
Fanelo		Semi-urban	Urban	available	some	5	not attempted	_______	__________	adequate	__________

The data in Table 7.6 indicate that differences between participants' biographic factors and the different contexts in which they practiced inquiry-based science teaching did not seem to influence their abilities to implement plans for IBST in the classroom.

This subsection has however shown that participants' understanding of scientific processes, their epistemic and pedagogical understanding and skills related to this approach of teaching science were the main factors facilitating or limiting their successful implementation of inquiry-based science teaching. The next section, Section 7.3, discusses the key findings regarding factors that had a bearing on the manner in which the pre-service teachers enacted inquiry-based science teaching.

7.3 DISCUSSION OF FINDINGS

In this chapter, the researcher attempted to answer Research Question 2.2. After addressing the question of how pre-service teachers enacted inquiry-based science teaching, it was essential to understand factors that had influenced such enactment. To address this question, the researcher used evidence generated by means of an inductive analysis of lesson interview data, followed by a cross case analysis to find factors that were helpful in explaining similarities among and differences between in the manners in which participants planned and implemented their inquiry-based science lessons. She took each participant as a single case.

Evidence generated from the analysis of the interview data indicated a number of internal factors that had a bearing on the manner in which the participants had enacted IBST: these were their orientations to science teaching, their beliefs about learners and learning, their understanding of inquiry-based science teaching and related pedagogical skills. A few contextual factors also had some bearing on the pre-service teachers' enactment of IBST. A cross case analysis in terms of these constructed themes indicated that participants' representation of the procedural and epistemic domains was consistent with their understanding of IBST, but was inconsistent with their understanding of the conceptual and social domains of IBST. The higher representation of the conceptual and social domains in their lessons related more to their orientations to science teaching than it did to their understanding of IBST.

These results therefore indicate that, participants' orientation to science teaching acted as a mediating factor: it influenced the domains of IBST where pre-service teachers focussed their teaching. Their lesson plans and reasons for their actions in the classroom indicated that the lesson planning centred on teaching science content. While two of the respondents also cited an intention to develop learners' knowledge of the epistemology of science, this goal was evidently secondary to the content-oriented goals. None of the participants, in their discussion, demonstrated any orientation towards teaching science process or inquiry skills, which, in their enactment of IBST, corresponded closely to their poor representation of the procedural and epistemic features of recording and analysing data, and making data representations. However, these elements had also been lacking in their description of IBST. These finding therefore also imply that pre-service teachers' orientation to science teaching not only mediated their translation of IBST understanding into classroom practice, but also influenced their understanding of the procedural and epistemic domains of IBST, and subsequently their enactment of these domains. The results of this study therefore corroborate Crawford (2007) in his statement: "teacher beliefs about teaching shape their interpretation of curricular and instructional approaches" (p. 617).

Although all six teachers demonstrated science teaching content oriented goals, in talking about their lessons they displayed two primary orientations to science teaching, didactic and active-engagement that were displayed by four of them. These also had a bearing on the way in which they enacted inquiry-based science teaching. By contrast, only two participants displayed a guided inquiry orientation. Among the four participants who demonstrated didactic and active-engagement orientations, there was more inclination to presenting concepts directly to learners (Cobern et al., 2013), even though they also actively involved learners through demonstrations, hands-on activities, textbook reading and answering questions. The strong representation of an activity-driven orientation among the current study participants is contrary to the finding made by Cansiz and Cansiz (2016) that among middle school pre-service teachers' an activity driven orientation to science teaching could not be identified. It is not clear, however, whether their understanding of an activity-driven orientation encompassed the use of other activities besides learners' direct manipulation of materials.

The orientations of pre-service teachers identified in the current study seem to influence mainly their conceptions of essential aspects of inquiry-based science teaching. For example, the two participants who demonstrated a guided-inquiry belief about teaching science made an effort to ensure that their lessons had an epistemic domain, and that they guided learners in forming conclusions themselves based on evidence. Noteworthy is that these were the two participants who had also demonstrated an interest in promoting learners' understanding of how the scientific inquiry is conducted. This indicates a relationship between teachers' insight of the purpose of science teaching, their teaching beliefs and their enactment of IBST. The findings are supported by other studies (Crawford, 2000; Lebak, 2015; Lotter, Harwood, & Bonner, 2007; Roehrig & Luft, 2004; Wallace & Kang, 2004) that have also identified teachers' understanding of the purpose of science teaching and their beliefs about effective teaching methods influencing the teachers' enactment of IBST.

The participants in this study were often primarily content driven, and more teacher-directed in their orientations to science teaching, which may consequently hinder, not only their enactment of IBST, but also their implementation of the science curriculum which aims at promoting both learners' content, skills, and attitude goals (Ministry of Education and Training , 2015; National Education Policy, 1997). The question then arises: what could be the major influences leading to pre-service teachers' orientations in teaching science? Perhaps it stems from their own school experience. Although, the science curriculum they had experienced also specified knowledge, skills and attitudes that learners have to gain, the examinations written and thus the science learning experiences throughout their own primary and secondary schooling history have focused on knowledge above other goals of science education (Refer to Chapter 1, Section 1.2 3). Pre-service teachers' own more content-oriented and teacher-directed experiences of learning science could have shaped their beliefs about the aims and pedagogy of teaching science, and ultimately their enactment of inquiry-based science teaching. Their declared lack of exposure to authentic scientific inquiry experiences is further evidence that their history of learning science was not one that supported the development of a process-driven and inquiry orientations to science teaching.

Some studies (Eick & Reed, 2002; Friedrichsen & Dana, 2005; Windschitl, 2004) have indeed indicated that teachers' past experiences related to learning or doing science can shape both pre-service and in-service teachers' orientations to science teaching and subsequently their understanding and enactment of IBST. In this regard, Eick and Reed (2002) noted that, despite their exposure to the same teacher education programme, their 12 participant pre-service teachers enacted structured inquiry differently, in accordance with their different histories in learning or doing science. Eick and Reed (2002) thus concluded, based on their study findings, that a pre-service teacher who benefits most from instruction on inquiry-based science teaching during teacher education is one who already has an inclination towards inquiry developed as a result of their prior experiences with science. Friedrichsen and Dana (2005) also showed in their study on biology in-service teachers, that non-teaching experiences of doing science can affect science teaching orientations. Their results connect well with that of Windschitl (2004) who also found that pre-service teachers who were most able to use inquiry-based science teaching were those who had more research experience in careers or in post-secondary school studies. The strong influence of pre-service teachers' background knowledge on their orientations to science teaching substantiates the call for teacher educators to elicit and address pre-service teachers' views about teaching as a central feature of their programmes (Cansiz & Cansiz, 2016; Crawford, 2007).

The study has also shown that beliefs about learners' capability had a significant impact on the pre-service teachers' decisions with regard to cognitive aspects of engaging learners and how the lessons should be structured. For example, the two participants who demonstrated a guided inquiry orientation did not engage their learners in posing questions and designing investigations in one or both of their lessons due to their lack of faith in learners' ability to perform these activities. Likewise, participants, who demonstrated an activity-driven orientation usually, began their lessons by explaining terms and concepts to learners or giving learners answers to science questions prior to engaging them in carrying out investigations. The most cited reason for this approach related to their beliefs about how learners' best learn science. Two of them believed learners could not effectively carry out hands-on activities if not provided with enough information relating to the target concept. Some other studies (Lebak, 2015; Lehane & Bertram, 2013) have also shown a link between teachers' enactment of IBST and their beliefs about learners' competency or how learners learn science.

Evidence gathered in this study also indicates that participants' ability to execute the intended inquiry activities in the classroom were affected by two teacher knowledge domains. Firstly, they were mediated by participants' understanding of scientific inquiry processes. In particular, all participants who had planned to engage learners in designing investigations were unsuccessful in this endeavour due to their naive understanding of this inquiry process. Secondly, a number of them also demonstrated a lack of pedagogical understanding or skills related to effective implementation of the different features of the cognitive and guidance dimensions of inquiry-based science teaching. For example, some participants' plans to engage learners in designing and executing inquiry procedures, and forming conclusions or explanations were thwarted by their failure to draw on learners' prior knowledge and their lack of awareness of the need to provide learners with guiding questions or theoretical backgrounds when carrying out these activities. Participants' expectation that learners would carry out these inquiry processes without providing them any context to draw upon indicates a lack of insight of the theory driven nature of these scientific processes (Abd-El-Khalick, 2012). This study findings, therefore also suggest that teachers' understanding of the character of science is a key aspect of teacher knowledge necessary for proper enactment of inquiry-based science teaching.

Figure 7.1 below shows how the factors that the researcher found to have a bearing on participants' ability to enact IBST relate to the four domains of this science pedagogy that were suggested by Furtak et al. (2012). She suggests the use of this framework as an element of a model for developing pre-service teachers' enactment of IBST. Figure 7.1 also indicates that in addition to this framework for IBST, pre-service teachers need to be provided plenty of opportunities to enact and reflect on IBST in the context that they are to teach in order to develop the necessary pedagogical content knowledge.

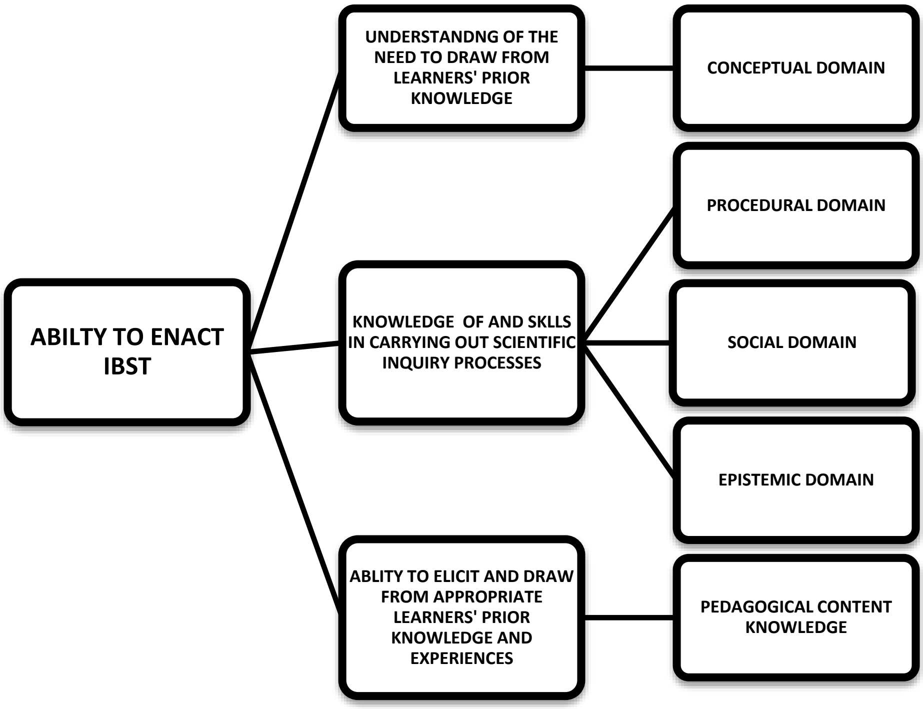

Figure 7.1 *Factors related to pre-service teachers' ability to enact IBST*

In addition to internal factors affecting the pre-service teachers' enactment of IBST, some participants also cited the influence of contextual factors in accounting for their failure to engage learners in certain more learner-centred activities, such as allowing learners test their ideas or giving them enough time to form their own evidence-based conclusions. These contextual factors were principally a lack of teaching resources and time constraints. Availability of resources, or the lack thereof, was helpful in explaining participants' decisions on whether or not to engage learners' in hands-on activities. Participants often also cited time constrains to explain their use of more didactic rather than learner-centred approaches. Moreover, in their explanations, it was evident that this decision related to their concerns of needing to cover as much content as they could, due to pressure from the external examination-driven curriculum. Even though, all the pre-service teachers pointed out that their mentor teachers did not dictate how they should teach, they are aware of the importance attached to examinations in the country. Schools are often judged in terms of their performance in the external examination, and learners gain admission to secondary schools based on their grades. Even though assessment in the new curriculum framework includes on-going assessment as pointed out in Section 1.1.1, emphasis in academic subjects at the upper primary phase is still focused on summative assessment; as notable in Table 1.4, 70% of marks at this level should be based on summative assessment.

Unlike many other studies in Africa (Mkimbili et al., 2017; Mugabo, 2012; Ssempala, 2017) that have identified mainly contextual factors shaping teachers' understanding of IBST, the current study has found that internal factors, mainly pre-service teachers' knowledge and attitudes, have considerable influence in shaping their enactment of IBST. For knowledge factors, the depth of the pre-service teachers' scientific inquiry pedagogical understanding and skills helped to explain their success or otherwise in implementation IBST. Concerning their beliefs, their orientations to teaching science and view of learners' capability influenced decisions that pre-service teachers made regarding their planning and execution of inquiry-based science teaching. Pre-service teachers' orientations to science teaching closely related to the educational system that they personally experienced in their own schooling. This is in line with the contention made by Wallace and Kang (2004) that beliefs represent "assumptions and choices about meaning" that are informed by people's cultural and social context (p. 938). Such culturally informed models of their orientations to teaching science and beliefs about learners' capability may, according to social constructivism act as a framework that influence teachers' interpretations of and enactment of IBST.

7.4 SUMMARY

In this chapter, we addressed Research Question 2.2 indicated below:

> What factors influence pre-service teachers' enactment of inquiry-based science teaching?

Based on analysis of lesson interviews and conducting a cross case comparison, it was concluded that the pre-service teachers' planning and classroom actions were mainly shaped by a combination of interrelated aspects of understanding and beliefs. The pre-service teachers' view of the purpose of teaching science was more content-oriented than inquiry-orientated, which explains their higher representation of the conceptual domain in their lessons and use of more teacher-directed forms of inquiry-based science teaching.

The analysis also indicates that the pre-service teachers' enactment of IBST was influenced principally by one important factor, namely, their beliefs about teaching science. Participants demonstrated two main beliefs about teaching science; four of the six participants held a learner activity-driven orientation, while the other two held a guided inquiry orientation. These two orientations had a bearing on both their representation of the cognitive and guidance dimensions of inquiry-based science teaching. The participant with a guided inquiry orientation planned lessons that included an epistemic domain and ensured that he left it to learners to formulate their conclusions. However, the activity-oriented participants either represented epistemic features poorly or the domain was absent altogether. Even when they did incorporate the epistemic domain, they mostly provided learners with the answers.

The participants' beliefs about learners' capability, perceived time limitation, and shortage of teaching apparatus were other factors that influenced their use of more teacher-directed inquiry-based teaching approaches. Their ability to guide learners in executing planned learner-directed inquiry activities was generally limited by their lack of understanding of the inquiry processes and naive views about the nature of scientific processes, which subsequently influenced their pedagogical understanding and skills related to teaching science using this approach. Time constraints also seemed to promote the pre-service teachers' content-driven orientations to teaching science.

The next chapter presents the conclusions, knowledge contributions and limitations of the whole study. The chapter ends with suggestions for future research as well as recommendations emerging from the current study findings.

CHAPTER 8

CONCLUSIONS AND RECOMENDATIONS

This chapter provides an overview of the study. It provides a summary of the methodology adopted and then shows a discussion of the findings and the conclusions drawn from the study. Lastly, it presents recommendations arising from the study and possibility for future work.

Inquiry-based science teaching (IBST) is recommended in many education reforms as an approach that not only promotes scientific literacy but also enhances competencies that learners need to cope with challenges in their future. Although disagreements persist among science educators with regard to this claim, several studies indicate that IBST has the potential to promote learners' conceptual understanding, their inquiry skills and their understanding of the how science works. Other studies have also linked inquiry skills with developing critical and creative thinking abilities. The purpose of this study was therefore to find out pre-service teachers' competencies with regard to this pedagogical approach at the end of their three-year teacher education programme. Specifically, it sought to explore their understanding and enactment of inquiry-based science teaching. It also attempted to construct a model in terms of identifying factors that influenced the way they enacted the pedagogical approach.

8.1 SUMMARY OF THE METHODS USED

Grounded in the interpretivist paradigm, the study made use of a qualitative approach to collect and analyse the data required to address the research questions. The study made use of a case study design in order to develop a deep understanding of the different ways in which pre-service teachers enact inquiry-based science teaching (IBST) within their specific context (Baxter & Jack, 2008; Cohen et al., 2011).

To collect the relevant data, the study employed three data collection strategies. Firstly, a semi-structured questionnaire based on lesson teaching scenarios was useful in collecting data pertaining to pre-service understanding of the meaning and features of inquiry-based science teaching. The questionnaire gathered biographic data, and data related to participants' understanding of inquiry-based science teaching (IBST). After administration of the questionnaire to 34 participants, then eight of the pre-service teachers (about 15% of the group) participated in individual semi-structured interviews for the purpose of validating the questionnaire results and further understanding factors that participants said had influenced their understanding of IBST.

To obtain detailed information of how they enact inquiry-based science teaching, the study used lesson plans and records from a semi-structured observation schedule as data sources pertaining to the individual participant's enactment of IBST during their 6 weeks teaching practice in schools during their second semester. Furthermore, the study used a pre-lesson interview schedule to ascertain the background information pertaining to the school and the class that each participant was teaching. In this interview, participants described how they had planned their lessons with inquiry in mind. In addition, a post-lesson individual semi-structured interview was used to establish pre-service teachers' reasoning and beliefs pertaining to observed classroom practices. Each participant's lessons were observed twice during their teaching practice. The study employed both deductive and inductive approaches in data analysis to generate evidence necessary to address the research questions.

8.2 CONCLUSIONS

The study explored pre-service teachers' experiences of inquiry-based science teaching at the end of a 3-year teacher education programme in one university in Swaziland. Two critical questions (with sub-questions) guided the study. Data necessary to address these questions were collected by means of a questionnaire, interviews, lesson plans and classroom observations. The following sub-sections provide a summary of the findings and conclusions presented according to the three research questions.

8.2.1 Summary of the findings and conclusion for RQ 1

RQ 1: What do pre-service primary school teachers understand by inquiry-based science teaching at the end of a 3 years' experience in science courses?

Data collected by means of a questionnaire based on teaching scenarios and semi-structured post-questionnaire interviews revealed towards the end of 3 years' experience in science courses, pre-service teachers held two main conceptions of inquiry-based science teaching. One group of participants (14 of the 34 participants) understood inquiry-based science teaching to be an instructional approach that, at the least, lets learners to construct knowledge claims themselves based on evidence. A marginally higher proportion (18 of the 34 pre-service teachers) of the participants, however, associated IBST with forms of active engagement of learners in instruction. Activities in this category included essentially any activity (hands-on or minds-on) that provided learners with direct experiences connected to the concept under study, rather than being activities focused on inquiry. This result can be explained by the theory of constructivism, which asserts that rather than simply receiving knowledge, individuals construct their own understanding based on their past knowledge and beliefs; and according to their potential (Amineh & Asl, 2015; Keys & Bryan, 2001; Serafín et al., 2015). Although these teachers had undergone the same science curriculum at university, and all had started with no experience in conducting open forms of inquiry, they came from different school backgrounds, implying the possibility of different previous learning experiences and beliefs.

Further analysis of the data also indicated that the pre-service teachers had limited understanding of inquiry-based science teaching; they saw it in terms of only some of the features belonging to the four domains of inquiry-based science teaching outlined by Furtak et al. (2012). In this regard, they focused mainly on characteristics belonging to the procedural domain. Moreover, they focused on only particular features (descriptions) within this domain. However, unlike several, previous studies such as (Kang et al., 2008; Ozel & Luft, 2013), a significant number of participants associated inquiry-based science teaching with conceptual features such as eliciting learners' ideas and providing conceptually oriented feedback. Their understanding of the need to provide conceptually oriented feedback could be influenced by a content-oriented view of science observed in the way a subgroup of the participants planned and presented inquiry-based lessons in the second phase of the study. However, the 5E instructional approach employed to train pre-service teachers in planning inquiry-based science lessons could have also had effect on pre-service teachers' understanding of IBST; the model emphasizes the need to assess learners' prior conceptions and for the teachers to further learners' understandings and skills after exploring their ideas (Bybee et al. 2006, 2009). This supposition is in line with the fact some of them also associated IBST with learners testing their ideas and promotion of conceptual change. In terms of the guidance dimension of IBST, participants held an understanding of IBST that was more teacher- than learner-directed. With regard to this, although some referred to learners posing questions, planning and carrying out investigations, the aspect that most participants associated with learner-centeredness in inquiry-based science teaching was the engagement of learners in constructing knowledge claims based on evidence.

The study findings therefore indicate that, at the end of a 3-years' experience in science courses, the pre-service teachers did not have an accurate understanding of what it means to teach science by means of inquiry; they mainly associated IBST with different ways of actively engaging learners in their learning, rather than with reflecting the inquiry-nature of science. However, in contrast to previous studies, the study findings indicate that pre-service teachers were more able to associate inquiry-based science teaching with learning of science concepts. The content-driven assessments participants were exposed to and the use of the 5E instructional model could be responsible for the pre-service teachers' association of IBST with conceptual features.

8.2.2 Summary of the findings and conclusions for RQ 2.1

> RQ 2.1: How do pre-service primary school teachers enact inquiry-based science teaching during their final-year teaching practice in schools?

As already pointed out, to understand the pre-service teachers' enactment of inquiry-based science teaching, the study employed a framework for IBST provided by Furtak et al. (2012). According to this framework, IBST consists of two dimensions: the cognitive and guidance dimensions. The results of analysing lesson plans, interviews and classroom observations indicated that only some domains within the cognitive dimension of IBST were evident in the groups' enactment of IBST. Their lessons mostly showed features belonging to the conceptual domain while those of the epistemic domain were minimal. The representation of the different features of the other two domains was minimal. The noted deficit was with regard to the procedural domain.

The group's enactment of the cognitive dimension of inquiry-based science teaching was specifically lacking with regard to drawing from learners' prior knowledge, engaging learners in making data representations, creating or revising theories, discussing the nature of science, and involving learners in arguing scientific ideas; these belong to the conceptual, procedural, epistemic and social domains, respectively. Worth noting is that the epistemic aspect of discussing the nature of science was completely absent in the group's enactment of inquiry-based science teaching; this was in line with absence of this feature in their description of this pedagogical approach.

The study found a mismatch between the pre-service teachers' enactment and their understanding of inquiry-based science teaching. While the conceptual domain was prominent in their enactment of inquiry-based science teaching, they described inquiry-based science teaching mainly in terms of its procedural features. This finding contradicts some previous work (Crawford, 2007; Ozel & Luft, 2013) where pre-service teachers' enactment of IBST matched their understanding or views about IBST. Participants' enactment of the guidance dimension, however, did correspond to their understanding of IBST. Participants enacted with more teacher- than learner-directedness forms of IBST: the common forms of learner-directedness were engagement of learners in conducting investigations themselves and forming conclusions based on their experiences. As with the cognitive dimension, participants in the classroom in most cases did not implement planned aspects adequately or sometimes not at all. Participants seemed to lack the knowledge of how to guide learners in carrying out the planned activities in the classroom. This inference links very well with the participants' general lack of knowledge of the need to draw from learners' prior knowledge and ideas, as evidenced by the absence of this feature in their lesson plans and descriptions of how they had planned their lessons with inquiry in mind.

These findings indicate that at the end of 3 years of science courses at the university pre-service teachers are not sufficiently competent in enacting inquiry-based science teaching. The findings indicate that the manner in which they enacted IBST cannot facilitate the achievement of the country's science education goals; that is development of learners' investigative skills, scientific attitudes and conceptual and epistemic understanding of science, which fall under the main education goals of developing a scientifically literate society with competencies desirable in a knowledge-driven economy. From the constructivist perspective about learning and teaching, their poor enactment of the epistemic domain and the feature of drawing from learners' prior knowledge and ideas is not in line with an instructional approach that promotes true learning (Harris & Rooks, 2010; Kock et al., 2015). Harris and Rooks (2010) assert that it is when learners are afforded an opportunity to reflect on and revise their ideas in light of evidence that they can develop deeper conceptual knowledge and further their understanding of the characteristics of scientific knowledge.

8.2.3 Summary of findings and conclusions for RQ 2.2

> RQ 2.2: What factors influence pre-service teachers' enactment of inquiry-based science teaching?

To answer Research Question 2.2, an inductive analysis of lesson interviews was followed by comparing and contrasting individual pre-service teachers' enactment with their understanding of IBST along with other themes generated from the interview data. This indicated that internal factors of their personal understanding, abilities, and beliefs had the most influence on the way the pre-service teachers planned and enacted this pedagogy. Firstly, as already noted, the teachers had an inadequate understanding of inquiry-based science teaching and related skills. Besides this, their science teaching orientations and beliefs about learners' capabilities seem to be the main factors influencing the cognitive domains and the aspects of learner-directedness they included in their planning of inquiry-based lessons. The main external factor that seemed to have an effect on participants' planning was availability or lack of materials; which facilitated or inhibited participants' engagement of learners in hands-on experiences. Even though, in lesson interviews some participants cited time as another factor that controlled their engagement of learners in some learner directed activities, their decisions on what to do when they felt time was limited appeared to depend on their beliefs about the primary purpose of teaching science.

As indicated in Chapter 6, participants in the classroom often did not implement the different elements of the cognitive and guidance dimensions that they had planned for. A cross-case analysis of the data indicates that participants' biographic factors and the different contexts where they enacted inquiry-based science teaching had no significant bearing on their successful implementation of their plans in the classroom. Instead, this analysis indicates that participants' understanding of scientific inquiry pedagogy and related pedagogical skills were a more important factor on their successful implementation of inquiry-based science teaching.

Participants generally lacked an insight of what it means to engage learners in some procedural and epistemic features of inquiry-based science teaching, and of how the teacher should guide learners in carrying out these activities. All six participants reported that they had no previous experiences in performing open investigations, which explains their lack of understanding, skills, and orientations related to teaching science by inquiry. Various studies on pre-service teachers (Boakes & Moorer, 2009; Eick & Reed, 2002; Windschitl, 2001, 2002, 2004) have shown that experience in conducting independent investigations was necessary to promote participants' orientations towards and ability to enact IBST. However, the current study, has found that in addition to an understanding of independent scientific inquiry, pre-service teachers also needed fundamental pedagogical skills, manly pedagogical content knowledge, to guide learners' inquiry activities.

From these findings, the researcher concludes that for the Swaziland pre-service teachers to be competent in enacting more learner-directed forms of IBST, they mainly require informed understanding and skills in performing independent investigations, inquiry teaching-oriented dispositions, and relevant inquiry pedagogical knowledge and skills.

8.3 LIMITATIONS OF THE STUDY

The case study methodology afforded an in-depth understanding of the pre-service teachers' experiences of the inquiry-based science pedagogy within their particular settings. Moreover, the data collecting strategies and the size of the sample were also useful in generating the evidence necessary to address the research questions. However, like every other empirical study, the study also had some limitations; some of which resulted from the research design, while others from challenges faced when carried out the study.

Firstly, the use of a single case of pre-service teachers (a single institution) brings in the issue of the extent to which the study findings can be generalised commonly referred to as external validity. However, unlike in survey research, the purpose of a case study is not to generalize findings to a larger population (Cohen et al., 2011). Rather, its purpose is to understand a single case and to make contributions towards the generalization and extension of a theory (Cohen et al., 2011; Yin, 2009). Cohen et al. (2011) argue, for example, that generalizations in case studies can be made from “features of the one case investigated to other cases with the same features” (p. 295). To enable this transferability, in addition to a detailed presentation of the group’s understanding and enactment of inquiry-based science teaching, the researcher has provided detailed descriptions of the participants and the general and specific contexts of the study.

The second drawback of the study is with regard to the failure of the research to adopt a purposive sampling strategy in its attempt to understand factors that had a bearing in the manner in which the pre-service teachers enacted inquiry-based science teaching. As was mentioned earlier, the study was planned to ensure that the sample targeted for this purpose was as heterogeneous as possible with regard to the main and secondary biographic factors that were disposed to shape the way pre-service teachers enacted this pedagogical approach. However, the number of participants who indicated willingness to participate was too small to allow this heterogeneity, and the researcher eventually worked with whoever was available, regardless of their biographic factors. This scenario might, to some extent, have limited the study in its endeavour to understand the group’s enactment of inquiry-based pedagogical approaches.

Thirdly, a greater number of observations of the participants during their teaching practice in schools would have provided richer data that would have most probably enhanced an understanding of the group’s enactment of IBST and other factors related to their classroom practices. However, the researcher could not observe the participants as many times as she would have wished due to the nature of the teaching practice exercise. As already pointed out, the pre-service teachers in this study were being trained to be classroom teachers rather than subject teachers. During a six-week period, primary pre-service have to teach all the subjects offered at the primary school. Consequently, the time that each teacher spends teaching each subject is about three weeks, with the last week, in most cases, set aside for revision and tests. Consequently, the number of observations that could be made was constrained by the curriculum time available for teaching science.

8.4 IMPLICATIONS FOR SCIENCE EDUCATION

Although science education in Swaziland does not prescribe to teachers the pedagogical approach to use, it does advocate using learner-centred approaches that aim to promote learners' conceptual understanding of science concepts, scientific processes skills and general skills necessary to participate meaningfully in a knowledge, science and technology driven society. Empirical studies have shown that inquiry-based science teaching can promote these desired goals. The current study has brought to light some Swaziland pre-service teachers' understanding and enactment of IBST at the end of a 3-year teacher education programme. It therefore indicates the potential of the teacher education programmes in meeting the Swaziland's desire to develop a scientifically literate society. The study also provides an understanding of the factors that have a bearing on the manner in which the pre-service teachers enact inquiry-based science pedagogical approaches in schools. The findings therefore have implications on teacher education programmes, in-service teacher education, science education management and science education in general.

8.4.1 Implications for science teacher education programmes

The results of the study have indicated that the pre-service teachers are lacking in terms of the expertise and beliefs necessary to enact inquiry-based science teaching effectively. The study found that pre-service teachers mainly associate inquiry-based science teaching with either direct, but active engagement of learners in learning or with more teachers directed forms of IBST. The pre-service teachers do not only lack comprehension of the different domains of inquiry, they also lack understanding of the features within each domain. They mainly define IBST in terms of only a few specific features, most of which belonged to the procedural domain. Moreover, participants lack the necessary knowledge, skills and beliefs needed to plan or execute more learner-centred inquiry-based approaches of teaching science. Most participants plan and enact lessons that are either confirmatory investigations or involve activities that do not mirror any of the cognitive and social activities associated with scientific inquiry. If a teacher education programme is to produce teachers that have necessary competencies and beliefs to support the enactment of more comprehensive learner-centred forms of inquiry-based science teaching, this study therefore recommends the need for revision of the science teacher programme.

Based on the results of the study, the researcher suggests an instructional model that is likely to promote the pre-service teachers understanding and abilities to enact inquiry-based science teaching. The study found that factors which related to participants' success or failure to enact inquiry-based science teaching was their understanding of the need to draw from learners' prior knowledge, their ability to elicit and draw from learners' ideas, and their understanding and skills in performing scientific inquiry skills. Based on these findings, the researcher suggests the science programme should therefore consist of the following elements:

- Engage pre-service teachers in dong authentic scientific inquiry in their content courses, coupled with an explicit discussion of the central features of a scientific investigation and its nature. This should include a discussion of theory-laden and social aspects of the scientific activities.
- Discuss the dimensions of an inquiry-based instruction. Furtak et al. (2012) seems to be the best model as it provides detailed description of this pedagogical approach.
- Engage pre-service teachers in planning and enacting their lessons using the framework of IBST by Furtak et al. (2012).
- Engage pre-service teachers in discussing and reflecting upon the success or lack thereof of their lessons during microteaching and teaching practice in schools.
- Engage pre-service teachers in using a pedagogical content knowledge lens to help pre-service teachers plan and implement explicit reflective teaching about the "nature of science (NOS) (Abd-El-Khalick, 2012, para 1).

Along with these activities, in science methods courses, efforts should concentrate on developing pre-service teachers' comprehension, orientations and abilities to enact IBST. According to the framework of inquiry-based science teaching adopted in this study, reflecting about NOS is one of the features (descriptions) of the epistemic domain of inquiry-based science teaching. Even though participants had learnt about NOS and the need to address it explicitly in their teaching of science, this teaching did not occur in the context of scientific investigations. Participants' subject matter knowledge orientations to teaching science and inabilities to address NOS could be some of the reasons why none of the participants associated inquiry-based science teaching with promoting learners understanding about NOS, nor enacted a lesson that incorporated this feature. Nature of science aspects are content embedded. A "pedagogical content knowledge (PCK) instructional model for NOS instruction" (Abd-El-Khalick, 2012, para 15) implemented in the context of inquiry-based lessons could be helpful in promoting appropriate orientations and enhancing abilities to plan lessons that incorporate an explicit discussion about NOS (Demirdöğen & Uzuntiryaki-Kondakçı, 2016; Lehane et al., 2014).

8.4.2 Implications for educational management

The Swaziland Education Sector seeks among other goals, to develop citizens' ability to think critically and analytically integrate and synthesize knowledge" and, their understanding of the natural and physical world, and the processes by which scientific knowledge is developed (MoET, 2018d, p.6).

An inquiry-based approach to teaching seems to be the best approach for achieving the above mentioned goals as well as other goals believed to be central in developing the country socially and economically. The current study has however indicated a number of factors that have a negative impact on pre-service teachers' ability to enact inquiry-based science teaching in schools. One major intrinsic factor the study has revealed is participants' beliefs about the purpose and goals of science teaching. These are most a result of their interpretation of the science curriculum they were themselves exposed to at school, which was not significantly different from the one they were implementing as pre-service teachers. In this regard, it should be noted that even though the Swazi science curriculum aims at developing scientific investigative skills and scientific attitudes, it is nevertheless more content- than inquiry-oriented. The bulk of the competencies that learners must acquire as prescribed by the curriculum are content based, which is carried through in the external examination. The study findings suggests that such a scenario influences pre-service teachers to believe that they need to focus more on the content than inquiry, in order to prepare learners for external assessments that focus more on examining conceptual knowledge. Moreover, participants' poor experiences in learning science seems to impact on their understanding of inquiry-based science teaching.

The results of the study, therefore, indicate that for teachers to enact IBST in a way that can promote scientific literacy and the country's socio-economic goals there is a need for the Education and Training Sector to adopt an inquiry-based science teaching approach as its philosophy. This demands a reduction in the amount of science content; and focus only on major relevant science concepts in order to allow time for the promotion of other scientific literacy goals. An inquiry-based science teaching approach has the potential of not only developing learners' understanding about how science is developed and the character of the produced knowledge (Abd-El-Khalick, 2012; Lederman et al., 2013), but also their general inquiry skills. Inquiry skills have been associated with cognitive skills such as creative and innovative thinking necessary in developing citizens that can participate in developing the country's socio-economic status (Anderson, 2002; Bodzin & Mitchell, 2003).

Education managers in Swaziland should also ensure that primary schools have enough science materials to allow teachers to teach science by means of carrying out scientific investigations. One of the contextual factors that impacted negatively on the pre-service teachers' enactment of inquiry-based science teaching was the lack of availability of science teaching materials. This situation suppresses teachers' use of more learner-centred pedagogical approaches, which is not in line with the demands of a competency-based education and consequently limits the achievement of the country's goals of developing desirable skills and competencies among its populace. Moreover, young peoples' interest in learning science is thwarted if they are not engaged in hands-on activities.

8.4.3 Implications for teacher professional development

Teachers who are new in the teaching profession require considerable support from mentor teachers to develop the necessary skills and knowledge. However, all participants reported having received no support from their mentors with regard to inquiry-based science teaching, although they were practicing in six different schools with varying contexts. This indicates that practicing teachers either, do not support the inquiry-based approach of teaching science, or they lack the necessary expertise. By inference, practicing teachers themselves do not use this approach, which some of the pre-service teachers did point out during interviews. This situation may hamper the education and training sector goal of developing a populace that not only understands natural occurrences but also the process by which scientists develop and modify scientific concepts (Ministry of Education and Training, 2018b). The in-service teacher education programme has therefore an obligation to organize in-service teacher development programmes that can help augment teachers' orientations towards inquiry and their understanding and ability to enact this pedagogical approach.

In addition, practicing teachers who are inquiry oriented and more competent at enacting this pedagogical approach are in a better position to support and mentor pre-service and new teachers. The collaboration between in-service and pre-service teacher education departments in developing learner-centred pedagogical competency among science teachers can go a long way towards promoting the general standard of science education in the country, specifically in developing core skills such as "thinking, creativity and innovation" skills; so necessary in a knowledge-based society" (MoET, 2018d, p. 11). Some studies provide evidence for the connection of these skills to inquiry-based science teaching (Anderson, 2002; Bodzin & Mitchell, 2003).

8.4.4 Contributions and implications for future research

This study makes three useful contributions to the body of knowledge regarding pre-service teachers' understanding and enactment of inquiry-based science teaching.

Firstly, the study has provided evidence for the value of the conceptual framework of IBST postulated by Furtak et al. (2012) in making sense of pre-service teachers' understanding and enactment of IBST. By detailing the constructs of IBST, the study has been able to establish a comprehensive understanding of the pre-service teachers' knowledge and enactment of IBST. Furthermore, by showing the relationship between teachers' successful execution of their planned inquiry-based science lessons and their understanding of the conceptual domain of IBST, the study found that teachers' knowledge of IBST goes beyond teachers' knowledge of scientific practices, but includes an understanding of how to guide learners in carrying out these practices. This is consistent with a constructivist view about learning, particularly in regards to pre-service teachers' understanding of the need to draw from learners' own ideas, knowledge and experiences, in the conceptual domain. A number of previous studies (Chabalengula & Mumba, 2012; Kang et al., 2008; Mugabo, 2015) that have employed the five essential features of IBST (NRC, 1996, 2000) as a conceptual framework. However, without detailed descriptions of the conceptual and social features of IBST, the five essential features of IBST do not provide a full description of a lesson grounded in constructivism or one that is in line with the nature of science. The researcher thus contends therefore that these prior studies, unlike the current study, have not been able to offer comprehensive understandings about how pre-service teachers conceptualize and enact IBST.

The finding that some participants' lacked an understanding of the need to draw from learners' background knowledge when engaged in learning by means of scientific investigations is contrary to the context-based approach inquiry stipulated by the country's science curriculum. While some studies (Lederman, 1999; Yoon & Kim, 2015) show NOS understanding as not automatically coherent with teachers' classroom practices, this study has provided some indirect evidence for the assertion made by other scholars (Abd-El-Khalick, 2012; Windschitl, 2004) that teachers' understanding of the function of background knowledge and theories in guiding a scientific study is essential in facilitating teachers' enactment of IBST. The pre-service teachers in this study seemed to think along the lines of the Clough and Olson (2004) statement that" data will tell learners what to think" (p. 2). This inference is derived from the finding that participants represented the epistemic domain poorly in both their description and enactment of IBST.

For its second contribution to science education body of knowledge, the study has identified factors that influence the way pre-service teachers enact IBST. Figure 8.1 below shows some factors established in different studies; those found by the current study are highlighted. Dark highlighted features indicate leading factors, while those that were less common are in italics. The number of asterisks represents the number of studies that cited each feature including the current study. Unlike most studies, as shown in Figure 8.1, this study has explicitly shown that pedagogical content knowledge (PCK) was a principal factor that affected pre-service teachers' successful implementation of their plans to engage learners in learner-centred inquiry-based science learning.

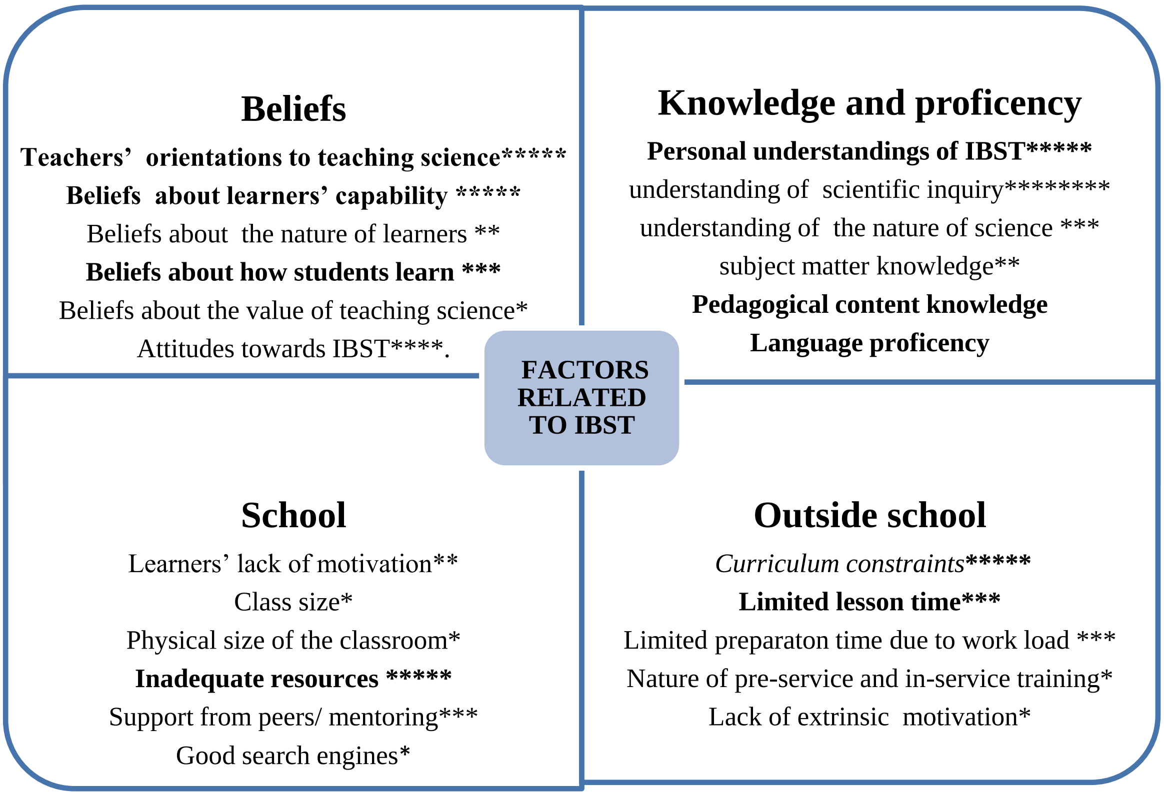

Figure 8.1 *Factors limiting teachers' enactment of IBST*

PCK, according to Shulman, the scholar who coined this concept, refers to "the blending of content knowledge with pedagogical knowledge into an understanding of knowledge of how particular topics, problems or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p. 8). While some participants knew that they needed to elicit learners' ideas and draw from learners' prior knowledge, they indicated that they lacked the necessary expertise to do so in the context of the topic they were teaching. One of them indicated that his inability to draw from learners' prior knowledge was linked to his poor knowledge of learners' prior experiences with the concept under investigation. While there are many learners' everyday experiences related to static electricity, the participant pointed out that he was not aware of such experiences, possibly indicating a poor understanding of the static electricity concept. A study by Boakes and Moorer (2009) also pointed out differences in PCK among two United States pre-service teachers that could explain the way they had enacted IBST. They based this claim on the manner in which the participants enacted this pedagogical approach, while in this study observational data supported by participants' explanations, indicates limited PCK affecting the way they planned or presented their lessons.

The third contribution from this study is that it adds understanding about appropriate approaches for investigating factors that influence teachers' enactment of IBST. The approach used in the study to address this question was useful in establishing both extrinsic and intrinsic factors shaping pre-service teachers' planning and enactment of IBST. However, the study found that similarities and differences in pre-service teachers' planning of IBST could be mainly a result of intrinsic, rather than extrinsic factors. In fact, the only contextual factors that appeared to influence pre-service teachers' enactment were time constraints and availability of teaching materials. However, most previous studies that have been conducted in developing countries as noticeable in Figure 8.2, reported mostly extrinsic factors. Furthermore, the prior research findings were often based on self-reporting; that is, what teachers themselves said had facilitated or constrained their enactment of IBST. In the figure, the number adjacent to each category of factors indicates the frequency of each category in the studies including the current one. The number in brackets denotes the number of times that category was mentioned in the current study.

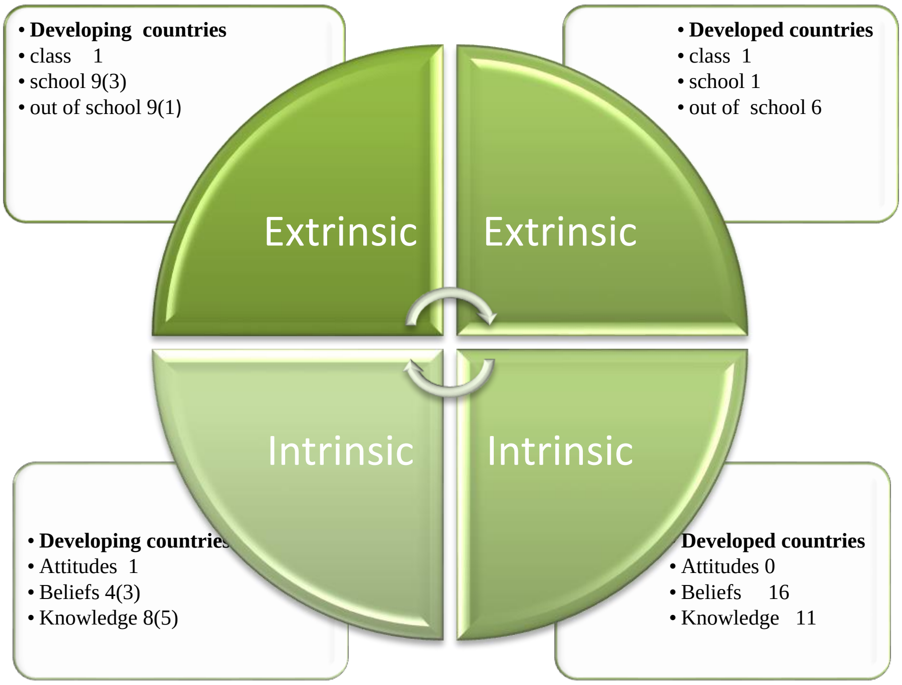

Figure 8.2 *Extrinsic and intrinsic factors influencing teachers' enactment of IBST*

Two explanations could account for these different results. Firstly, the researcher is of the view that, most likely, when teachers are asked to report on what factors shape their enactment of IBST, there are more likely to reflect on extrinsic than intrinsic factors. Another possible reason, which the researcher however views as less likely, could be that, all of the studies in developing countries were based on experienced teachers, while the current study seems to be the first one based on pre-service teachers, who are still in the course of acquiring various teaching knowledge domains.

There are, however, some studies from developing countries (Mokiwa & Nkopodi, 2014; Ssempala, 2017) that indicate teachers' enactment was influenced by an internal factor: the teachers' understanding of the characteristics of science. These two studies were carried out among in-service teachers with varying experiences and backgrounds. They employed an approach similar to that used in many studies from developed countries; that is they identified this feature by relating what teachers did in the classroom with their understanding of the nature science constructed, based on analysing their interview data. These study findings support the current researcher's aforementioned inference that the methodological approach has a bearing on findings pertaining to factors shaping teachers' enactment of IBST. Even though participants in Ssempala (2017) perceived that some other internal factors: their teaching experience and attitudes towards IBST had a bearing on their teaching, these were not useful in explaining particular approaches they had used in enacting IBST. The researcher thus proposes that relying on teachers' perceptions may provide contextual and general biographic factors that affect the employment of IBST. Nevertheless, to glean an understanding of internal factors shaping the way pre-service and in-service teachers enact IBST, future studies should adopt a more reflective approach. Researchers should base interviews on lessons teachers have planned or presented so they could inspire them to reflect on their reasons for having planned or presented lessons in a certain way.

The results of this study also add to the knowledge about the value of an appropriate research tool for eliciting teachers' ideas about inquiry-based science teaching. In this regard, while Mugabo (2012) found that when using an open-ended questionnaire, participants gave very shallow descriptions of inquiry-based science teaching, the current study has found that the use of teaching scenarios as context greatly enhances the likelihood of a questionnaire eliciting participants' ideas about IBST. In this study, the researcher compared teachers' understanding based on the scenario-based questionnaire, followed up with oral interviews that elicited participants' understanding of characteristics of IBST, and through engaging them in describing how they planned their lessons with inquiry in mind. The scenario-based questionnaire notably yielded more detailed responses than did the interviews, even though the interviews provided the researcher with an opportunity to probe participants' responses, consequently demonstrating the strength of an appropriate tool in eliciting teachers' ideas about teaching including their understanding of characteristics of IBST.

Contrary to many studies (Kang et al., 2008; Ozel & Luft, 2013; Wallace & Kang, 2004) that have shown that teachers mainly do not associate IBST with learning of science concepts, a comparatively higher proportion of the participants in the current study were found to comprehend IBST as a teaching method aimed at promoting learning of science concepts. To elaborate, while in the study by Kang et al. (2008) for example, only 2 out of 101 respondents talked about evaluation of learners' explanations in light of scientific knowledge; in the current study, an average of 13 out of 34 participants cited conceptual elements. Moreover, while most previous studies indicate that teachers' conceptualization and use of inquiry-based pedagogy often lacked the social domain of inquiry-based science teaching, in the present study all participants, at least in the planning phase, included engaging learners in class discussions and in making presentations. These findings are therefore significant as they indicate that the 5E-instructional model has potential for promoting pre-service teachers' comprehension of the conceptual and social characteristics of IBST. However, more studies, preferably using a pre-test and post-test evaluation design could be helpful in testing the potency of the model in developing teachers' understanding of the different domains of IBST in different contexts.

Despite the value of the 5E instructional model, the results of this study also substantiate the supposition made by Ireland et al. (2012) that it does not help guide teachers on how they could structure lessons based on learners' questions. As with other previous studies (Ireland et al., 2012; Kang et al., 2008; Mokiwa & Nkopodi, 2014), participants here held a more teacher- than learner-directed view of inquiry-based science teaching. Participants mainly associated IBST with any instruction that allows learners to formulate knowledge claims themselves based on evidence; an aspect that is more visible in the 5E-instructional model. This understanding was also evident in some of their lessons. Moreover, even though the participants in this study included social features in their enactment of inquiry-based science teaching, as already highlighted, similarly to teachers from other contexts, they did not seem to associate these elements with IBST. Most probably, they linked these features with the constructivist pedagogical perspective adopted by the 5E instructional model. Based on this finding and other factors found to limit pre-service teachers' ability to enact their inquiry-based ideas in the classroom, the researcher proposed an instructional model for training teachers in IBST. Further studies are required to test the potency of this model in helping pre-service teachers to develop pedagogical knowledge and skills associated with an inquiry-based approach to teaching science.

The study has also found that the pre-service teachers did not receive any help from their mentor teachers with regard to inquiry-based science teaching. This anecdotal evidence indicates the possibility that practicing primary school teachers in Swaziland do not use inquiry-based science teaching approaches. Due to the potential of inquiry-based approaches to meet the country's aspirations for science education and for education in general, this scenario indicates a need to investigate Swaziland practicing teachers' classroom practices, their knowledge of inquiry-based science, and their orientations to science teaching. All these knowledge domains are valuable in designing both pre-service and professional development programmes. Although a number of similar studies have been reported, this is the first study that has been conducted in the Swaziland context.

8.5 SUMMARY

This study attempted to explore the understanding and enactment of inquiry-based science teaching by pre-service primary teachers in one university in Swaziland. In this chapter, the researcher summarized the methods employed to answer the research questions and the findings and conclusions that had been made, on the grounds of the gathered data. In addition, the chapter included a consideration of the limitations and implications of the study. Primarily the study has indicated that the framework for IBST presented by Furtak et al. (2012) is, not only effective in revealing pre-service teachers' knowledge and ability to enact inquiry-based science teaching, but also its potential in guiding pre-service teachers in planning and classroom presentation of inquiry-based science instruction.

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APPENDICES

A **Scenario-based questionnaire**

CONCEPTIONS OF INQUIRY BASED SCIENCE TEACHING QUESTIONNAIRE

Instructions

The questionnaire is addressed to pre-service teachers.

1. Completing the questionnaire should take about 45-60 minutes.
2. The questionnaire consists of two sections. Section A requires you to tick the appropriate option. Section B requires you to first tick the appropriate option in each case and then provide a detailed explanation for your answer in the separate sheet provided.

Section A: Biographic Data

<table>
<tr><td>Name of Pre-service teacher</td><td colspan="12"></td></tr>
<tr><td>1. Gender</td><td colspan="12"></td></tr>
<tr><td rowspan="2">2. Age (Please tick)</td><td colspan="3">Below 20 Years</td><td colspan="3">20-25 Years</td><td colspan="3">25-30 Years</td><td colspan="3">Above 30 Years</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td rowspan="2">3. School where you matriculated. (Please tick)</td><td colspan="4">Rural area</td><td colspan="4">Urban</td><td colspan="4">Semi-urban</td></tr>
<tr><td colspan="4"></td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td rowspan="2">4. Do you have experience in teaching science prior to enrolling for this course? (Please tick)</td><td colspan="6">YES</td><td colspan="6">NO</td></tr>
<tr><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td rowspan="2">5. If your answer 1.2 is YES, please indicate the location of the school where you taught.(Please tick)</td><td colspan="4">Rural</td><td colspan="4">Urban</td><td colspan="4">Semi-urban</td></tr>
<tr><td colspan="4"></td><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td rowspan="2">6. If your answer to 1.2 is yes, please indicate the type of school where you taught. (Please tick)</td><td colspan="6">Public school</td><td colspan="6">Private school</td></tr>
<tr><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td rowspan="2">7. Have you ever participated in any scientific research project? (Please tick)</td><td colspan="6">YES</td><td colspan="6">NO</td></tr>
<tr><td colspan="6"></td><td colspan="6"></td></tr>
<tr><td rowspan="2">8. How would you rate your level of confidence in teaching science?</td><td colspan="4">Low</td><td colspan="4">Average</td><td colspan="4">High</td></tr>
<tr><td colspan="4"></td><td colspan="4"></td><td colspan="4"></td></tr>
</table>

Section B

This section consists of ten classroom science-teaching vignettes similar to teaching practices found in today's classrooms. Please read each vignette carefully and decide whether each depicts an inquiry based lesson activity.

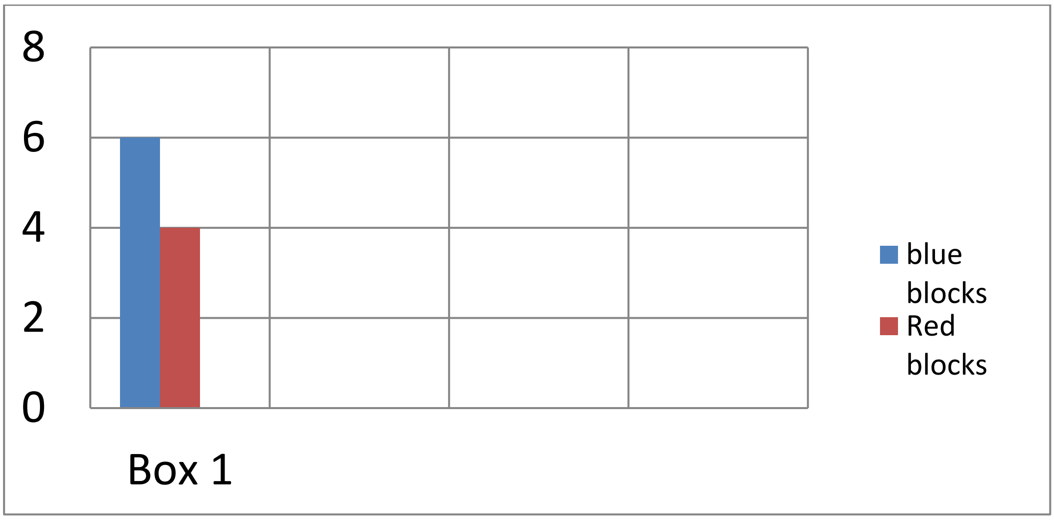
In each case, first state whether the activity is inquiry based or not and then provide a detailed explanation for your answer.

1. Miss Maseko is beginning a unit on magnetism with his first grade learners. She begins the unit, by giving each group a bar magnet and a tray that contains a paper clip, a coin, a nail, school scissors, a pencil, some keys, a marble a crayon, aluminium foil, some sand and students can include a few objects of their choice. She introduces the lesson by defining the term "magnetic attraction" and demonstrates how to test a couple of objects with a magnet. Student groups are then asked to sort the objects in their trays according to whether they are attracted by a magnet or not. [POSTT 2 #8]

2. Mrs. Mndluli, a grade 4 teacher wants her learners to learn about the different phases of the moon. After students have completed an exercise aimed at testing their prior knowledge of the moon phases, a student asks about the correct order of moon phases. The teacher responds to the student's question by challenging the class to determine the sequence of phases by observing the moon and recording their observations for one month (Bell, Smetana & Binns, 2005).

3. Miss Mvulane begins her lesson by telling her learners that the earth's rotation causes day and night. She then asks learners: "how does the rotation of the earth causes day and night?" Following a brief class discussion of the question, she shines a light (the sun) on a rotating globe (the earth). She asks the students to pay attention to a bright red dot she has placed on the globe, and asks several questions about where the dot is in relation to the light. Miss Mvulane then asks learners to go into their groups and use their observations to explain the relationship between the earth's rotation and days and night. Miss Mvulane concludes her lesson by reinforcing student learning by explaining how days and night are related to the earth's rotation, while again demonstrating this with the light and globe. POSTT1# 3.

4. Teacher Futhi is teaching her Grade 1 class how to make a simple bar chart. She begins her lesson by handing out to sets of blocks to learners and asks them to draw pictures that show how many blocks of each they were. After a class discussing of their pictures, she then passes her own drawing of a bar chart to learners (Figure 1) and has students, in their groups; discuss how the picture might also represent how many block of each color they were. POSTT 2 #3



5. Miss Sihlongonyane's class has been learning about matter. She now wants her 4th grade learners to learn that gases (like those in air are also a form of matter. She starts by introducing her lesson by raising some questions with her students about whether air is matter. She then tells learners that air is indeed matter, and that although air is not very dense, there is something there that can be felt. She then asks them to use fans at their desks to see if they could find evidence that air is indeed matter. POSTT 1#5

6. Mr Zwane asks his learners whether plants need light to produce oxygen. Some students hypothesize that plants need light to produce oxygen, but others believe that plants produce oxygen both during the day and night. Mr Zwane provides his learners with sprouts of water plants and then lets each group of learners decide on how they can go about testing their ideas and the teacher helps them where necessary by asking questions. After, coaching the class on how they can present their findings, Mr Zwane requests each group to present and justify its conclusions to the class. At the conclusion of the lesson, the teacher guides learners in evaluating their conclusions and the methods that they used to test their ideas (Bertsch, Kapelari & Unterbruner, 2014).

7. Mrs Fakudze wants her Grade 3 learners to be able to recognize different types of earth materials, namely rock, mineral, clay, sand and soil samples, which he has available for use in the lesson. She starts her lesson by engaging students in sorting and describing the various earth materials displayed on their tables, according to their unique characteristics. She then guides a class discussion about different types of soil materials and how the activity they have been doing is similar or different from how science functions. At the end of a lesson, Mrs Fakudze, refers them to the article that they read in earlier lessons about how scientists work; and leads a class discussion about how the activity they have carried out is similar or different from the ways scientists do their work. [POSTT 2#4]

8. In the context of learning about plant growth, some learners interrupted their teacher. The students pointed at three trees growing side by side and asked why they were different. One has lost all its leaves; the middle one had mostly yellow leaves, while the third had flourishing green leaves. Since Miss Dlamini knew that her learners they had already learnt about how seeds grow, she responded by asking her learners to make a list of ideas that might explain what was happening to the trees. Students gave various ideas and Miss Dlamini wrote all of them on a chart. She then encouraged students to think about which of the ideas were explanations that could be investigated, and which were only descriptions of observations. In groups, learners were asked to plan and conduct a simple investigation to gather evidence needed to test their ideas. Students then used the collected data and information from a pamphlet about growing healthy plants given to them by the teacher to revise their explanation of what affected the three plants. Each group then reported and justified their explanations based on evidence to the class. (National Research Council, 2000).
9.
   (c) Mr. Mavundla, A Grade 3 class has been doing an investigation on earthworms. Besides teaching students about the basic needs of earthworms, she also wants them to develop skills of observing, investigating, recording and seeking patterns. After carrying out investigations on the earthworms in groups by following teachers' instructions over some time, she requests different groups to present their data to the whole class so they could search for patterns in their observations. [POSITT]
   (d) During the data analysis, one student points out that the data collected by one group seemed to contradict data collected by another group. The teacher asks students to suggest ways of addressing the issue, accepting any response that relied on evidence. For example, re-examining recorded data, or comparing data collecting procedures, or repeating or taking more observations (POSITT).
10. Mr. Hlophe is teaching his Grade 6 class about a unit about the human circulatory system. In one of his lessons, he engages his learners in a heart rate experiment. He gives his learners a step by step procedure that requires students to perform jumping jacks as the exercise in the investigation. He asks them to organize their results in tables and a line graph. Finally, he guides learners in formulating conclusions by giving them a series of questions. At the conclusion of the lesson, Mr. Hlophe prompts learners to examine their resources and evaluate their conclusions and explanations independently, in light of the information provided in those resources (Association for middle Level Education, 2011).

B Semi-structured interview schedule

Section A

Name of interviewee: ………………………………………………………..

Section B

1) Inquiry Based Science Teaching (IBST) is an approach that is recommended in the curriculum you will be teaching in the school. What do you consider as key elements of a good inquiry lesson? Please explain why you consider these elements as important.
2) Students will be asked to clarify their understanding of inquiry on the basis of their responses to the conceptions of IBST questionnaire.
3) Can you describe any experiences or other factors that you feel influenced the understanding of IBST you have just shared? Please explain how each of these experiences influenced your understanding.

C Examples of Lesson Plans

1. *Anele: Lesson plan 1*

CLASS : GRADE 6 C

DATE : 01 · 07 · 2016

TIME : 0800 – 0900 HRS

CLASS SIZE : 41

AGE : 10^+

ABILITY : Mixed

SUBJECT : Science

LESSON TOPIC : Magnets

TEACHING / LEARNING METHODS : Guided inquiry

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

1. test if a given metal is attracted to a magnet or not.
2. conclude that not all metals are attracted to magnets.
3. Conclude that a magnet can act through a non-magnetic object / non-metal.

MATERIALS

1. ~~Pins~~ Pins
2. Staples
3. Magnets
4. Wood
5. Duster
6. Iron bars
7. Aluminium bars
8. Stainless steel

ENGAGEMENT

- Present the following materials to the learners: iron bars, aluminium bars, magnets, wood, stainless steel objects.
- Ask them to state if the wood can be attracted to magnets.

Expected answers:

1. No, because ~~a~~ it is a non-metal.

- Group the metals together and ask them if the aluminium bar can be attracted to magnets, they must also ~~state~~ explain why they are saying so. Expected responses:

1. Yes, because it is a metal.

- The question that arises from this phenomenon is, "Are all ~~ma~~ metals attracted to magnets?".

EXPLORATION

Designing an investigation

- Let the learners go to their groups and find ways to investigat and answer the above question. They will write their suggestions in their Science exercise books and share them with the whole class.

Suggestions

1. One group proposes that we take ~~an empty can~~ one type of metal and bring it closer to a magnet and see if it is attracted or not.
2. Another group suggests that we test all the available metals and see if they are attracted or not?

- Call two volunteers to come upfront to test if ~~t~~ all the metals are attracted to a magnet. They must test one by one and tell the whole class what is happening.
- Then ask them, in their groups, to describe what has happened and try to answer the presented questions.

2. ***Dumsani: Lesson plan 2***

Date	14 June 2016
Time	9:00-10:00
Class	Grade 6^A
Ability	Mixed
Subject	Science
Lesson	Magnets
Age	11^+

Teaching methods: Group work, Guided Inquiry

Teaching aids: Magnets, metals objects and non metals objects.

Lesson objectives: By the end of the lesson learners should be able to:

Classify materials according to magnetic and non magnetic objects.

Engagement (5 minutes)

The teacher will tell the pupils a story on how he lost his steel pin on a grassy area, and will ask the pupils which is the best way or object he could use to search for his pin. Expected answer ' the teacher can use a magnet. The teacher will then show the pupils different kinds of materials for example wood, rubber, iron, nail, zinc, the teacher would then ask the pupils to predict which materials would be attracted by a magnet. The teacher will the pose a question for the investigation: "Are all metals attracted by magnets"?

Exploration (10 minutes)

The teacher will then group the pupils into groups of five and will provide each group with different materials, this will be including magnetic materials and non magnetic materials, also a magnet. Each group will be testing each and every material given to them by the teacher, whether it is magnetic or not. The teacher will then tell each group to group the materials according to magnetic material and non-magnetic materials.

Explaining (10minutes)

The teacher will then ask the pupils whether all metals were attracted by a magnet or not. The teacher will then explain to the pupils that metals that were attracted are those that are made out of Iron, steel and nickel. The teacher will then emphasize on the point that not all metals are magnetic objelts.

Elaboration (10minutes)

The teacher will then provide each group with another magnet such that each group has two magnet, Each group is expected to find out what might happen if two magnets are brought close together.

Self Evaluation (10minutes)

The teacher will tell each learner to write in two sentences what they have learnt about to corrert their misconceptins or to add from what they knew.

Evaluation (15 minutes)

The teacher will then tell the pupils to do an excercise ~~on page~~ that will be writen by the teacher on the Chalkboard.

3. ***Fanelo: Lesson plan 2***

Lesson Plan

Class	Grade 5
Roll	54
Time	1115 – 1215
Date	26 May 2016
Subject	Science

Topic: Changing forms of Matter

Teaching aids: water, a mirror, a kettle, saucer and some ice cubes.

Teaching methods: discussion, demonstration and guided discovery

Objectives: By the end of the lesson, learners should be able to;
1. describe how matter changes its state when heated or cooled
2. describe the processes of melting, freezing, evaporation and condensation

Rationale: Recognise that matter changes its state through different processes.

Lesson development

Steps	Teachers activities	Learners activities
step 1 Engagement (5 minutes)	-Tell the learners that some substances can have more than one state	

Steps	Teacher's activities	Learner's activities
	- ask the learners to give examples of substances that they think can have more than one state	- they share their thoughts
✓	- ask the learners that what causes some of the substances mentioned to change their states?	- share their ideas
	Question ~~or the~~ be addressed	or ~~que~~ hypothesis to be tested? state the expected answers.
Step 2 Exploration (15 minutes) Involve learners in ~~deciding~~ planning and conducting the investigation You can provide some guidelines.	- put some ice cubes in a saucer and place the saucer on top of the Kettle with water. Heat the ice cubes. Then tell the pupils to look carefully at what happens to the ice cubes. Then discuss this with them.	- observe what is happening
	- take the water from the ice cubes and boil it. Ask pupils to look at what happens to the water.	
	- Focus their attention on the steam escaping from the Kettle and help them to understand that the water has now turned into a gas.	

Steps	Teachers activities	Learner activities
	to complete the sentences in their exercise books (Just write the number and answer) - After they have completed these sentences, explain the words "melting, freezing, evaporation and condensation" to them by writing them on the chalkboard	- complete the sentences using heated or cooled - pay attention to the teacher
Step 4 Elaboration (10 minutes)	- Allow learners to use the different words in answering given questions like; a) When a solid is heated and changes into a liquid it is called _Melting. b) When a liquid is cooled and changes into a solid, it is called _freezing c) When a liquid is heated and changes into a gas, it is called _evaporation d) When a gas is cooled and changes into a liquid, it is called _ Condensation - Give a topic on 'Mass' for the following lecture	- answer the questions - listen to the teacher
Step 5 Evaluation (12 minutes)	-Ask learners to write the work on page 36 individually.	- write the work in their exercise books.

Summary (3 minutes): The teacher will emphasize that matter can change its state when cooled or heated and some substances can exist as a solid, liquid and a gas like water. Also matter changes its state through the following processes; melting, freezing, evaporation and condensation.

Observed 26-05-2016 [illegible]

Self evaluation: The lesson was successful as the intended out comes were achieved efficiently.

D. **Lesson interview schedule**

Pre-lesson Interview

Section A: Background information

Pre-service teachers' name……………………………………………….

Location of the school……………………………………………………..

Grade Level taught…………………………………………………………

Number of students in the class………………………………………….

Availability of teaching materials………………………………………..

What kind of support have you received from the class teacher or other teachers in the school with regards to teaching science?

Section B

1. Inquiry Based Science Teaching (IBST) is an approach that is suggested in the curriculum you will be teaching in the schools. Could you describe how you developed your lesson with inquiry in mind?
2. The teacher will then be asked to provide reasons behind:
   a) Any differences between intended and enacted learning activities.
   b) Any differences between the manner in which the activities were presented against what was planned prior to the lesson, e.g., the amount of direction/ assistance they eventually provided to learners.

c) How the teacher interacted with students. These will include teachers' handling of situations or scenarios in the classroom, such as the handling of learners' questions and learning difficulties and misconceptions.

d) Any other comments the teacher wants to make connected to the manner in which they delivered the lesson.

E. Observation Schedule

Doman of IBST	**Description**	**Comments on what the teacher does and what learners do**
Conceptual	Eliciting learners' ideas	
	Drawing on learners' prior knowledge	
	Providing conceptually oriented feedback	
	Any other	
Procedural	Asking scientifically oriented questions	
	Designing investigations	
	Carrying out scientific procedures	
	Recording data	
	Representing data	
	Any other	
Epistemic	Nature of science	
	Drawing evidence-based conclusions	
	Generating and revising scientific theories	
	Any other	
Social	Participating in class discussions	
	Debating ideas	
	Presentations	
	Working collaboratively	
	Any other	
Any other activities outside the four domains		
Guidance dimension		

F. Lesson recordings

Anele: Lesson 2

Cognitive dimension

Conceptual domain

The teacher elicited students' ideas about concepts by asking them to predict whether a magnet would attract different materials and asking them to justify their responses. As learners explained their prediction, it was apparent that a number of them harbour a misconception that the ability of a metal to be attracted by a magnet depends on its heaviness. The teacher used an iron pin and an aluminium block to clarify to learners that magnetic property does not depend on the heaviness of the metal but on the material making up the object regardless of its size.

Procedural domain

Learners were not engaged in asking their own scientifically oriented questions. They were however involved in designing and conducting the investigation aimed at answering a teacher presented question of whether a magnet could attract all metals. The planning of the investigation did not focus on how they could collect the data and not how they would analyse them to answer the question. Not all learners were however involved in carrying out the procedure necessary to collect the needed data due limited resources. Some learners only had to observe while only two of them were involved in testing the objects. He instructed learners to write down their observations. Even though this was a good opportunity for learners to learn or practice how to use a table to present their observation, the teacher did not instruct them to do so.

Epistemic domain:

He directed learners to analyse the data collected only to address the scientifically oriented question posed by the teacher, which is whether a magnet attracts all metals. He did not prompt learners to make any other conclusions based on the data, such as determining which of these metals a magnet attracts. This was the case even though learners had been given names of the different metals and the fact that some learners had pointed out that magnets attract objects made of iron. He also did not instruct learners to create explanations for why a magnet attracts only some of the metals rather than all of them. For example, even though he did not prompt learners to provide explanations,, they used their ideas and their observations to state that the ability of an object to be attracted depended on its heaviness. The teacher's concern was however more on correcting this misconception rather providing learners an opportunity to test their explanations and consequently revise them in light of available evidence.

Social domain

The teacher attempted to encourage interaction and collaboration among learners by engaging learners in discussion in their different groups on how to conduct the investigation and in formulating conclusions based evidence. Learners also presented their plans for the investigations as well as conclusions made based on evidence. They were however not involved in debating scientific ideas such as the idea of whether or not magnets attract heavy objects and only metals made or iron.

Guidance dimension of inquiry

Learners did not address their own questions or their own ideas about the phenomenon under investigation. The teacher mostly adopted a guiding position as learners were engaged in designing the investigation and formulating answers to the scientifically oriented question based on data. However, in addressing secondary questions, the teacher adopted an active direct approach. The teacher however struggled in asking good questions aimed at guiding learners in designing investigations.

2. Bandile: Lesson 2

Cognitive dimension

The conceptual aspect

Prior to informing the learners of the lesson topic, Bandile provided learners some magnets and involved learners in a discussion about magnets. He began the discussion by first finding out if they could identify the objects provided: paper, wood, iron fillings and magnets. He then asked them to name different types of magnets they know and displayed each type as they mentioned it. The teacher then engaged learners with some preliminary concepts such as making them establish which materials a magnet could attract. He then informed them that magnets have an attraction force that is concentrated at the poles. After that deliberation, he attempted to elicit learners' ideas regarding the subject they were to explore by asking them to predict how the thickness of a non-magnetic material can affect the ability of a magnet to act through it. Similarly to his first lesson, he did not however address the crucial preceding concept of whether or not a magnet' force can pass through a non-magnetic material. Without this background knowledge and in addition to that the question itself was not clearly presented, it made it difficult for learners to understand what material's thickness was to be investigated such that some learners' responses indicated that they supposed the teacher was referring to the thickness of the magnet. As a result, the teacher could not obtain any learners' responses relevant to the subject of the investigation.

In addition, due to the teacher's erroneous use of words, learners were confused and could not finally develop the desired concept. The teacher tried to clarify the concept by using an analogy. He brought two learners, one thinner than the other and asked if they were to swallow some iron fillings and attempted to use a magnet to flush them, who would spew the most iron fillings. The learners were able to give a reasonable supposition, implying that learners understood the concept, but were only confused by the teacher's incorrect use of the word thicker. He however, did not allow learners to explain their prediction.

Procedural domain

During the engagement phase of the lesson, learners tested whether or not a magnet can attract objects made of paper, wood and metal. They also carried out teacher-directed procedures intended at finding out the effect of thickness of a non-magnetic material on the ability of a magnet to act through it. However, he did not instruct learners to record and make data representations. The teacher planned that learners would develop a plan of how the can use provided items: a test tube and beaker to find out the effect of the thickness of magnetic material on the ability of a magnet to act through it. The teacher also intended that in groups, learners will carry one plan that they would have agreed on as a class and record their observations. However, due to teacher's failure to address key preliminary concepts and his lack of fluency in English language, the teacher experienced a lot of difficulty in presenting the question clearly, eliciting and probing their ideas and consequently, he could not successfully guide them through the process of planning their investigations.

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Epistemic domain

The participant also attempted to guide learners through the process of formulating evidence based conclusions regarding how the thickness of a non-magnetic material affects a magnet's ability to act through it by asking them questions. He started by asking them to state from which object the magnet was able to pull more iron fillings; "is it the one that is thicker or less thick?" Learners responded by stating that it is the one that is less thick, which is the test tube. However, due to the teacher's confusion of the words more thick for thinner, he corrected the learners and stated that the test tube is more thick and repeated the statement in their mother tongue, which actually translates as " it is thinner" not thicker as the teacher had put it. Because of this confusion, when he asked learners whether the thickness of the non-magnetic material has an effect on the ability of a magnet to pass through it, the learners could not provide an answer. The teacher eventually told learners that the thickness of the material affects the attraction force of the magnet, when he actually meant the ability of the magnet to act through it. The thicker (meaning thinner) the object the stronger would be the attraction. On noting learners' puzzlement, he tried to clarify the point by bringing two learners, a fat and a thinner one. He asked them that assuming they had both swallowed the same amount of iron fillings, and they used a magnet to pull them up to the mouth, which of the learners would spew more iron fillings. Learners gave two different responses because of their different understanding of the meaning of the word less thick. The teacher accepted only the answer he wanted.

The social domain

Even though the teacher had already organized learners into groups, he did not use organization to promote communication and collaboration among learners. Learners were not given opportunities to discuss and reach communal decisions at an stage of the lesson, starting from when made predictions regarding whether or not the thickness of a non-magnetic object can affect a magnet's ability to act through it, in planning investigations or in explaining their observations. Moreover, though he provided learners opportunities to present their observations and conclusions, he did not provide learners an enough opportunity to discuss and debate their ideas. The teacher seemed to be more concerned with learners providing a correct answer as in all such occasions, similar to the previous lesson, learners were also not required to justify their responses. For example, after learners had conducted the practical aspect of the investigation, he asked learners to state the object from which the magnet was able to pull more iron fillings. Then he asked them what conclusions they could make based on these observations. Without waiting long enough for an answer, he asked them again "is it from the thicker or less thick object"? Most of them said the one that was less thick. The teacher first accepted the answer, but quickly changed and said the test tube is thicker (when he actually meant thinner), without allowing learners to defend their answer. It is most probably because of the lack of exchange of ideas between the teacher and the learners and among learners that the teacher could not notice reasons behind learner's difficulty in making the desired predictions and formulating conclusions based on their observations.

Guidance dimension

During the engagement phase of the lesson, Bandile directed learners as they tested some materials to verify that a magnet only attracts objects made of iron: a concept he provided them in advance. Later, at the exploration phase he attempted to lead learners in a discussion of how they can address a question, he had presented himself, however, due poor language proficiency, he eventually provided them the procedure himself. He also attempted, but, due to the same language challenge, she could not successfully guide learners in drawing conclusions themselves.

G. Ethical Clearance

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

29 January 2016

Mrs Khanysile Brenda Nhlengethwa 214584306
School of Education
Edgewood Campus

Dear Mrs. Nhlengethwa

Protocol reference number: HSS/1709/0150
Project title: Pre-service primary teachers' enactment of Inquiry Based Science Teaching (IBST): A case study of a university in Swaziland

Full Approval-Expedited Application

In response to your application received 23 November 2015, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted FULL APPROVAL.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment /modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

....

Dr Shenuka Singh (Chair)
Humanities & Social Sciences Research Ethics Committee

/pm

Cc Supervisor: Dr Nadaraj Govender & Dr Doris Sibanda
Cc Academic Leader Research: Professor P Morojele
Cc School Administrator: Ms T Khumalo

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H. **Editing Certificate**

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EDITING CERTIFICATE

NAME: Khanyisile Brenda Nhlengethwa

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Draft PhD thesis: *Pre-service Teachers' Understanding and Enactment of Inquiry-Based Science Teaching: A Case of a University in Eswatini*

I confirm that I have edited this draft thesis for grammar and appropriate use of academic language. I have also attempted to improve the flow of the student's writing and make it more succinct. Where the student's meaning was not clear I have made suggestions about how to reword the material. I needed to make very few suggestions about the structure of her argument. I reformatted a table as an example. I have made suggestions about formatting the remainder of the document. I highlighted errors in the list of references, but it was for the most part correctly formatted. There were exceptionally few instances where in-text citations did not correspond to the reference list; I have not cross-checked with the original publications.

As an independent educational consultant, one of my specialisations is editing academic documents. I am a native English speaker. I obtained a BSc at the University of Natal, with chemistry and applied mathematics majors. After graduation, I was a Research Officer in the Ministry of Roads and Road Traffic in, as was then, Rhodesia. My duties included writing reports and editing those for my colleagues. Some years later I entered the teaching profession and studied with UNISA for a postgraduate Higher Education Diploma, achieving a distinction for the English language module. After 20 years teaching at high school, I took up an academic position at the University of KwaZulu-Natal, where I completed an M.Sc. in chemistry education and wrote several research

SHalstead

articles. Since retirement about seven years ago, I have edited many academic papers, theses and dissertations, several of which were judged to be *cum laude*, and one of which required no alterations from the examiners.

Sheelagh Edith Halstead 29th April 2019

TURN IT IN REPORT