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FINAL-YEAR PRE-SERVICE PRIMARY SCHOOL TEACHERS' UNDERSTANDING OF INQUIRY-BASED-SCIENCE TEACHING

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Abstract. *Teachers' accurate understanding of Inquiry-Based Science Teaching (IBST) is crucial for the proper enactment of this pedagogical approach. In this research, a qualitative case study design was used to explore and interpret pre-service teachers' understanding of IBST at the conclusion of their three-year primary diploma at a university in Swaziland. Data were collected using a semi-structured teaching scenario-based questionnaire in conjunction with individual semi-structured interviews. Thirty-four participants completed the questionnaire and eight of them were subsequently interviewed. The data were analyzed using a conceptual framework of IBST that outlines two dimensions of IBST; namely the cognitive and guidance dimensions. The results show that in the cognitive dimension, participants focused mainly on the procedural domain. With regard to the guidance dimension, they associated the pedagogical approach more with teacher-directed than learner-directed learning activities. This paper recommends that in training pre-service primary school teachers, teacher educators must broaden their focus from procedural aspects of IBST to include all its aspects; thereby developing their pre-service teachers' holistic and deep experiences of IBST.*
Keywords: *inquiry-based science teaching, primary school, pre-service teachers, scenario-based questionnaire, IBST understanding.*

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Introduction

This research was based on a conviction that Inquiry-Based Science Teaching (IBST) is a viable approach for achieving the different goals for teaching science; it presents a suitable context for fostering learners' understanding of science as a set of inquiry procedures, their deep conceptual understanding, their science process and thinking skills, and scientific attitudes. Several research by science educators provided evidence pointing towards the utility of this pedagogical approach in promoting learners' academic achievement (Abdi, 2014; Aktamis et al., 2016; Kock et al., 2015). In addition, research done by Bybee (2009) and Hu et al. (2008) have indicated that IBST can facilitate the development of general thinking skills among learners. However, currently, there is limited research in Swaziland on the potential of teacher education programmes in developing teachers' inquiry-based science teaching competencies. Even though a number of worldwide research have investigated teachers' understanding of IBST, very few of those conducted in developing countries have focused on pre-service primary teachers. Therefore, this research explored pre-service primary teachers' understanding of IBST at the conclusion of a 3-year experience in a science teacher education programme.

Research Problem

Within the IBST literature, findings based on a variety of studies indicate that teachers hold inadequate but varying understandings of IBST (Capps et al., 2016; Chabalengula & Mumba, 2012; Kang et al., 2008; Mugabo, 2015). Capps et al. (2016), by means of a survey design, found the majority of the participant science teachers from the United States could not describe IBST in terms of any of the essential features, as given by National Research Council [NRC] (2000). Chabalengula and Mumba (2012) employed a scenario-based questionnaire and found that, while most of the participant Zambian high school teachers regarded the teacher's role in IBST as that of a facilitator, they merely associated this pedagogy with learners' hands-on activities. A research report by Ssempala and Masingila (2019) however, indicated that an explicit reflective teaching about inquiry and the Nature of Science can

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enhance teachers' understanding of IBST; the participant Ugandan teachers' understanding of IBST improved from initially associating IBST with a question-answer pedagogy and hands-on activities, to later characterizing it in terms of its eight science practices as defined by NRC (2012). Oliveira (2009) reported that by using scholarly descriptions of IBST, teacher educators can promote teachers' understanding of the social roles of teachers and learners in inquiry-based science learning.

Another set of studies have explored inexperienced teachers' understanding of IBST. For example, Ozel and Luft (2013) examined beginning American science teachers' conceptualization of inquiry-based instructions and reported that the participant teachers understood IBST as consisting of only two of its characteristics: posing science questions and giving precedence to empirical evidence. Binns and Popp (2013) also explored seven American pre-service teachers' construction of IBST in the context of a Master of Arts teacher training programme. Data gathered using an open-ended questionnaire and interviews before and after teaching practice indicated a slight development in the participants' understanding of IBST. In Binns and Popp's research, they only associated IBST with learners answering questions based on empirical evidence similar to participants in the study by Ozel and Luft (2013). Other studies have explored pre-service teachers' understanding of essential features of inquiry-based science teaching using evidence-based reflection. For example, a study by Seung et al. (2014) with pre-service elementary teachers pointed that they lacked an understanding of three essential features of IBST; that is, learners' creating, evaluating, and communicating evidence-based explanations. They also demonstrated a more teacher-centred view of IBST and in their reflections, they focused more on their own attempts as teachers than on what learners executed. Aulls et al. (2016) reported that secondary pre-service teachers only associated IBST with posing questions, acquiring knowledge from different sources, and promoting learners' problems solving skills.

Evidence of developments in teachers' understanding of IBST through teacher education programme has also been reported. For example, Lee and Shea (2016) found that a group of 54 American pre-service teachers demonstrated more informed understandings of IBST after engaging in various forms of inquiry activities. Compared to their pre-test associations, more participants during post-test associated inquiry-based learning with engagement of learners in posing science questions, and in designing and conducting investigations. Qablan and DeBaz (2013) explored pre-service teachers' enactment of IBST and reported that their classroom strategies were useful in promoting pre-service teachers' understanding of IBST. Similarly, Ortlieb and Lu (2011) found that after learning about inquiry-based teaching strategies, pre-service teachers were able to identify work that needed to be revised and they provided a conducive learning environment for learners. Schwarz (2009) showed that a model-based inquiry unit, embedded within a 5E instructional model could improve pre-service teachers' understanding of IBST.

Most studies (Capps et al., 2016; Chabalengula & Mumba, 2012; Kang et al., 2008; Ozel & Luft, 2013) on teachers' understanding of the aspects of IBST have used the five essential features of IBST outlined by the National Science Education Standards (NRC, 2000). These features describe the activities scientists and learners employ when constructing knowledge (Kang et al., 2008. The latest American national curriculum framework (NRC, 2012) uses the term 'practices' to highlight that doing scientific inquiry demands not just skills, but also related understandings. Teachers need an understanding of the various knowledge domains related to the inquiry process and of how to enable learners acquire these competencies in order to enact IBST effectively, (Abd-El-Khalick, 2012; Harris & Rooks, 2010; van Uum et al., 2016). However, despite all the evidence mentioned in the literature about IBST, little is known about assessing pre-service science teachers' understanding using a conceptual framework that incorporates these features of IBST.

Research Focus

Essential Features of IBST. This research made use of the conceptual framework of IBST proposed by Furtak et al. (2012) to analyse the data collected relating to the participants' understanding of both the cognitive and guidance dimensions of IBST. For the **Cognitive Dimension**, Furtak et al. (2012) grouped learners' scientific inquiry activities into four essential domains of inquiry-based science teaching: procedural, epistemic, conceptual and social. The procedural domain describes the processes by which scientists and learners go about seeking evidence. It encompasses questioning, planning and conducting investigations (Furtak et al., 2012; National Research Council [NRC], 2000). The epistemic domain encompasses the processes by which learners use evidence to construct knowledge claims, as well as the use of inquiry activities as a context in which to reflect upon issues pertaining to how science works (Furtak et al., 2012; Harris & Rooks, 2010). The conceptual domain highlights that inquiry-based learning involves learners in constructing scientific knowledge based on their prior knowledge and ideas (Furtak et al., 2012; Harris & Rooks, 2010). The social domain highlights science as a collective activity involving collaboration, debates and sharing of ideas (Abd-El-Khalick, 2012; Kock et al., 2015).

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For the **Guidance Dimension**, Furtak et al. (2012) regarded guidance as another significant dimension of IBST. In line with other scholars (Harris & Rooks, 2010; Kock et al., 2015), Furtak et al. (2012) assert that learners receive guidance from their teacher as they "actively participate in constructing their own understanding" (p. 306). In accordance with the American *Science Education Standards* (NRC, 2000, p. 29), Furtak et al. (2012) regard the nature of IBST as varying according to the amount of teacher direction or what is left to learners to define. A number of researchers (Chabalengula & Mumba, 2012; Kang et al., 2008) have found this guidance dimension of IBST useful in ascertaining the amount of teacher guidance or learner responsibility teachers associate with IBST.

The research questions were addressed:

1. What are pre-service teachers' understanding of Inquiry-Based Science Teaching (IBST) with regard to its Cognitive Dimension?
2. What do pre-service teachers regard as learners' responsibilities in Inquiry-Based Science Teaching (IBST) with regard to its Guidance Dimension?

Research Methodology

General Background

The research was conducted in the context of a science teacher education programme in one university in Swaziland. The diploma programme equipped primary teachers for teaching all the primary school subjects. The major goals of the science teacher programme were to develop the pre-service teachers' knowledge and pedagogical skills as needed to teach science in ways that promote both learners' process and general thinking skills and also their knowledge of the conceptual and epistemic aspects of science. The science education programme was made up of science content and science teaching method modules. Pre-service teachers were also exposed to explicit reflective learning about the Nature of Science (NOS) in the context of their content courses. Two of the main goals of the final level science methods module were to promote the pre-service teachers' understanding and confidence in enacting IBST that integrates relevant NOS aspects.

To achieve this goal, pre-service teachers were firstly introduced to the five essential elements of IBST (NRC, 2000) and the 5E instructional model (see Table 1) (BSCS) (Bybee et al., 2006). This was followed by a discussion of a model lesson that includes the essential elements of IBST and an explicit-reflective discussion about NOS as indicated in Table 1. In groups of three, participants then planned and presented inquiry-based lessons in class; and each group received feedback. After revising their lesson plans, they implemented them during their microteaching sessions and subsequently, they reflected on the success or failure of their lessons.

Table 1
The BSCS 5E instructional model

Phase	Summary Learners Activities:
Engagement	Learners are engaged in activities that elicit their ideas and ends with a science question/s.
Exploration	Learners investigate questions.
Explanation	Learners create, communicate and justify explanations and learn new terms for new concepts; reflect on NOS issues.
Elaboration	Learners apply conceptual understanding and skills to new learning situations.
Evaluation	Learners assess their own conceptual and epistemic understanding and teacher also checks for the achievement of the objectives.

The research was interpretive in nature (Strauss & Corbin, 1990) and employed a case study design to understand how the group of pre-service teachers construct meaning of IBST within their specific context (Yin, 2003).

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Sample

The purposive sample for the research consisted of 34 pre-service teachers who volunteered for the research. All were science specialists at the end of the second semester of their final year of study enrolled in a Primary Teachers' Diploma. The research took place in the context of their final science methods module. Table 2 provides a summary of the participants' demographic data.

Table 2
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	Yes No	0 34
Self-professed level of confidence in teaching science	Low Average High No response	0 29 3 2

The data in Table 2 indicates that the sample consisted of slightly more female than male pre-service teachers. 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 achieved a formal qualification in teaching prior to enrolling in the programme. This seems to link with the significant proportion who reported only an average level of confidence in teaching science. Notably, none of the participants had previously participated in an independent scientific inquiry project.

A letter seeking permission to conduct the research was written to the university where the research was to be conducted. After permission to conduct the research and ethical clearance was granted by the Southern Africa Nazarene University (SANU) and the University of KwaZulu-Natal respectively, invitation letters were sent to all pre-service teachers in the cohort. The letters specified the research purpose, process and confidentiality of information. Any information that could reveal the identity of participants was avoided. Moreover, the letters clearly stated that participation was strictly voluntary and that they could withdraw from the research at any time.

Instruments and Procedures

Two data collection strategies were used for data collection. The questionnaire employed in the first step of the research was answered by the 34 pre-service teachers. The 34 participants were also invited to take part in the second step of the research where interviews were used to get deeper insights into the groups' understanding of IBST. Eight of them volunteered and so formed the sample for the second step of the research. The next two sections describe the two data collection instruments:

The questionnaire consisted of two sections: Section A elicited participants' biographic data, and Section

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B consisted of ten lesson scenarios aimed at generating data regarding the group's understanding of essential elements of IBST.

The ten chosen teaching scenario-based items were largely developed from the 'Pedagogy of Science Teaching Tests' (POSTT) (Cobern et al., 2014). The objective items that comprise the POSTT are not simply general statements about inquiry or science teaching, but instead are based on specific teaching scenarios related to IBST. They had been piloted among various groups of pre-service teachers and also assessed by a number of science education professors from different universities (Cobern et al., 2014).

For this research some adjustments needed to be made to the POSTT. Although it had been extensively validated for its intended purpose, its purpose was to assess teachers' understanding of pedagogical approaches for teaching science and so it was mainly focused on teaching for "understanding of science concepts" (Cobern et al., 2013, p. 3), rather than evaluating teachers' understanding of IBST. To suit the purpose and qualitative nature of the current research, the researcher adapted the questions. Firstly, instead of requiring participants to select a response from among a given list of options covering what they might do in a given situation, they were asked to explain in their own words whether each teaching scenario represented an inquiry-based lesson or not. Secondly, making meaning of teachers' understanding of IBST necessitated the inclusion of items that sought their understanding of what they regarded as essential dimensions of this pedagogy. Consequently, some of the items were changed so that they would reflect particular essential categories (features) of the different dimensions of IBST, as portrayed by Furtak et al. (2012).

To ensure content validity, the questionnaire was checked by two pre-service teachers, two teacher educators in the faculty where the research took place, and two experienced researchers. Based on feedback from these assessors, some items were rephrased for clarity. Furthermore, the questionnaire was piloted with ten pre-service teachers. The pilot research participants were asked to state any difficulties they had experienced in attempting to complete the questionnaire. As a result of their responses, one item was split into two in order to allow participants to consider a greater number of features when deciding whether a lesson scenario was inquiry-based or not. In addition, the pilot research participants indicated that an hour would be enough to respond to the questionnaire. The questionnaire was administered during the final 2-hour long lecture in the module, under the supervision of one of the researchers to ensure that data generated represented each individual's own construction of IBST. The pre-service teachers took around an hour to complete the questionnaire.

Administration of the questionnaire was followed up with individual semi-structured interviews with eight teachers for the purpose of data triangulation. Besides providing another source of data through the interviews, the researcher could gain deeper insights into the pre-service teachers' understanding of IBST as is appropriate for a case study. The interviews were carried out during their teaching practice in schools, before classroom observations. During the interviews, participants described what they regarded as essential elements of IBST and clarified their questionnaire responses. A digital audio tape was used to record all interviews.

Data Analysis

All interviews were transcribed verbatim. The first phase of the analysis employed a directed approach to content analysis (Hsieh & Shannon, 2005). For categories of description the four domains identified by Furtak et al. (2012) were used according to participants' questionnaire responses and the interview transcripts. The number of participants who mentioned each category of description (Kang et al., 2008;Ozel & Luft, 2013) and the total number of times each feature was mentioned in participants' responses was counted. To make sense of the group's understanding of the cognitive dimension of IBST, the group's representation of the different domains was computed by dividing the total number of times the group referred to a domain by the number of categories of description. Similarly to Kang et al. (2008), the second phase, a generic qualitative approach was used to further analyse the remaining data related to further activities that participants mentioned, which fell outside the four domains postulated by Furtak et al. (2012). The identified features were put into groups in accordance with grounded theory analysis (Strauss & Corbin, 1990).

The third phase of the analysis aimed at generating evidence relating to the group's understanding of learners' roles in IBST. An inductive coding method was used: the data for what pre-service teachers in their description of IBST identified as being carried out by learners themselves was searched for. Similar codes for identified features were combined to generate themes representing the main ways in which participants understood learners' role in IBST. The number of participants who mentioned each category and the frequency of each category were then established.

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Researcher and data triangulation were employed. Discussions among the three researchers helped to improve the interpretation of participants' responses. Results generated by analysing questionnaire data were also compared with those obtained from analysing the interview data.

Research Results

Participants' reasons for categorizing a lesson scenario in the questionnaire and their descriptions of IBST during follow up interviews were used to ascertain their understanding of essential elements of IBST.

*Pre-service teachers' Understanding of the Cognitive Dimension of IBST***.**

Tables 3 and 4 provide a distribution of the participants' understanding of the cognitive dimension of IBST, based on the questionnaire (34 respondents) and interview (8 participants) responses, respectively.

Table 3
Pre-service teachers' understanding of the cognitive dimension of IBST

Inquiry Domain	Essential feature of inquiry	Number of participants	Frequency (Total number of utterances)	Average representation of each domain
Conceptual	Builds on learners' prior knowledge	15	33	
	Eliciting learners' ideas	14	33	
	Provide conceptually oriented feedback	13	24	
				30
Procedural	Addressing science questions	33	133	
	Designing investigation procedures	27	60	
	Executing scientific procedures	34	191	
	Recording data	12	15	
	Making data representations	4	5	
	Hands-on	23	42	
				74
Epistemic	Formulating evidence-based conclusions	26	54	
	Generating explanations	22	32	
	Discussing the nature of science	0	0	
				29
Social	Discussing	17	30	
	Presentations	24	39	
	Debating scientific ideas	7	10	
	Working collaboratively	3	3	
				21

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Table 4
Interviewees' understanding of the cognitive dimension of IBST

Inquiry domain (Furtak et al., 2012)	Essential feature of inquiry	Interviewees who mentioned each feature	Number of participants
Conceptual	Builds on learners' prior knowledge	8, 5, 4	3
	Eliciting learners' content related ideas	8, 1, 3, 6	4
	Provide conceptual-oriented feedback	8, 5, 7, 2, 6	5
Procedural	Addressing science questions	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	------------	0
	Hands-on	8, 2, 4, 6, 3	5
Epistemic	Formulating evidence-based conclusions	8, 5, 7, 4	4
	Generating explanations	8, 5, 4	3
	Discussing the nature of science	--------	0
Social	Discussing	8, 4	2
	Presentations	8, 1, 4	3
	Debating scientific ideas	8	1
	Collaborating	8, 4	2

As is noticeable from Tables 3 and 4, the interview and questionnaire-based results mostly corroborated each other. In their characterization of IBST, participants used features that fall into the four domains of the cognitive dimension of IBST. However, they mainly cited features belonging to the procedural domain, with some features being less represented. For instance, with regard to the procedural domain, participants rarely mentioned learners' engagement in recording data and making data representations. Moreover, with the exception of the conceptual domain, whose features were somewhat equally represented, some features of the other domains were very poorly represented. The social features of arguing ideas and working collaboratively were also very poorly represented. None of the participants associated IBST with explicit reflection about the nature of science (NOS); an epistemic aspect of IBST. Compared to the questionnaire respondents, fewer interviewees referred to building on learners' prior knowledge and classroom discussions.

The following interview direct quotes are examples of what the participants said concerning each domain of IBST. The domains are presented in order of their popularity in the interview data.

Procedural Domain. The following interview extracts indicate that as a minimum, some interviewees associated IBST with an instructional strategy that engages learners in asking scientifically oriented questions, designing and carrying out scientific investigations, and recording data.

> 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. (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]

*Conceptual Domain***.** The following extracts illustrate that at least some participants were aware that IBST engages learners in constructing new conceptual knowledge and demonstrated an understanding that this process

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demands that learners should draw from what they already know, express and test their ideas, and also receive conceptually oriented feedback.

> 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]

> The teacher should elicit learners' ideas and prior knowledge because this 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. (Pre-service teacher 8, interview) [Eliciting learners' ideas; drawing from learners' prior knowledge]

> 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]

*Epistemic Domain***.** The following quotes indicate that these interviewees regarded IBST as involving the interpretation of data in order to derive evidence-based conclusions or explanations.

> 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]

*Social Domain***.** The next sets of direct quotes indicate that some of the participants understood collaboration and interaction among learners as being aspects of IBST.

> 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]

Other Characteristics of IBST identified by participants not in the Cognitive Dimension identified by Furtak et al. IBST Model. In addition to the above-mentioned four domains of inquiry postulated by Furtak et al. (2012), analysis of both questionnaire and interview data indicated that participants also associated IBST with engagement of learners in activities that demand higher order thinking skills. The following direct quotations support this claim.

> The lesson is inquiry because 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)

> It is also inquiry because it is all about being creative. For the learners to draw the bar chart, firstly they have to think about how they can classify the objects (Participant 7, interview).

Pre-service Teachers' Understanding of Learners' Responsibilities with regard to the Guidance Dimension of IBST

Table 5 provides results from analysing the questionnaire data for features that the participants indicated that learners should carry out themselves, or at the least be involved in their execution.

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Table 5
Questionnaire responses pre-service teachers' understanding of learners' responsibilities with regard to the Guidance Dimension of IBST

Codes	Themes	Number of participants who mentioned this feature	Frequency of each aspect in participants' responses
Learners must pose own questions Learners must test their own ideas	Learners must investigate their own questions or ideas	12	20
Learners must be involved in designing the whole investigation themselves 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	Learners must plan at least some aspect of an investigation	12	35
Learners must perform scientific procedures themselves Learners must make their own observations	Learners must carry out scientific activities themselves or at the least, make their own observations.	13	30
Learners must answer science questions themselves Learners must form evidence-based conclusions/ explanations themselves	Learners should construct understandings themselves	17	55
Learners should evaluate their findings independently by consulting other resources.	Learners should evaluate their findings themselves	7	7

As is evident in Table 5, participants understood the pedagogical approach of IBST mostly in terms of allowing learners to formulate evidence-based knowledge claims themselves. The second and the third most popular activities that questionnaire respondents considered to be learners' responsibility in IBST were the design and execution of at least some aspect of an investigation. The eight interviewees also associated IBST with similar aspects of learner activities. However, unlike the questionnaire respondents, none of the participants associated IBST with learners evaluating their findings; rather they asserted that the teacher should help learners evaluate their conclusions.

The following direct interviewee quotations indicate participants' understanding of different aspects of learners' roles in IBST.

> 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)

> Learners must conclude for themselves according to the evidence they have collected. (Pre-service teacher 8, interview)

The above quotations illustrate participants' association of IBST with engagement of learners in constructing conclusions themselves, based on evidence. The next set of extracts demonstrates how some of the participants connected IBST with learners engaging in designing investigations themselves.

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> 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 shows that some participants also linked IBST with learners being actively involved in conducting investigations themselves.

> 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 generally mention learners posing their own science questions; some of them however pointed out that learners should investigate their ideas, as shown in the following extracts:

> Investigating on their own means they should be given the chance to 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).

Discussion

The first result of the research was that participants were mostly aware of only the prominent characteristics of the cognitive dimension of IBST; in particular those of the procedural domain. Their understanding of the other domains was minimal. Almost all participants referred to learners' engagement with science questions and executing scientific procedures, but rarely mentioned other facets such as the procedural aspects of recording data and making data representations; and the social aspects of working collaboratively and arguing their ideas. Even though the Swazi curriculum prescribes that learners must learn how scientific knowledge is developed, participants did not refer to explicit discussions about NOS.

In line with several previous research (Binns & Popp, 2013; Mugabo, 2015;Ozel & Luft, 2013), this research found that the Swaziland pre-service teachers also hold an inadequate understanding of the cognitive dimension of IBST. The current research has, however, found that a comparatively large proportion of the participants were aware of the conceptual domain of IBST. In contrast with results from previous research (Kang et al., 2008; Ozel & Luft, 2013; Wallace & Kang, 2004), this research therefore indicates that teachers can associate IBST with learning of science concepts. For example, while in the research by Kang et al. (2008), less than 2% of respondents talked about the evaluation of learners' explanations in the light of scientific knowledge, in the current research an average of 38% (13 out of 34) participants cited conceptual elements.

Participants' high understanding of the conceptual domain of IBST could be related to the 5E instructional model employed in this teacher education programme at the Swaziland University. The 5E instructional model emphasizes that science lessons should permit eliciting and discussion of learners' prior knowledge and ideas, investigation of their ideas, communicating and sharing of their conclusions and their receiving conceptually oriented feedback (Duran & Duran, 2004) and thus, it incorporates all aspects of the conceptual domain. Nevertheless, even though the teacher education programme also incorporates an explicit reflection about NOS and discussion about essential features of inquiry, the research results indicated that these efforts had not helped the pre-service teachers develop a comprehensive understanding of IBST.

The second result from this research was that participants held different conceptions with regard to learners' tasks, which connects to the guidance dimension of IBST (Table 5), but as found in previous studies (e.g., Chaba-

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lengula & Mumba, 2012; Kang et al., 2008; Ozel & Luft, 2013), they demonstrated a more teacher-directed view. They associated IBST primarily with learners forming knowledge claims themselves based on evidence, and only a few linked IBST with learners posing their own questions.

Participants' poor association of IBST with some aspects of the cognitive dimension of science, and with more learner-centred activities indicates a poor understanding of the processes involved in generating knowledge in science and their limited view of the nature of science; most probably linked to their lack of experience in more open forms of inquiry. A number of studies (e.g., Aulls et al., 2016; Windschitl & Thompson, 2006) show that pre-service teachers' school experiences influence their teaching orientations or ability to learn about IBST. In line with a view of science as a body of knowledge, participants associated IBST mainly with promoting learners' conceptual understanding, as demonstrated in the following interview extract:

> 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 will be able to guide them in a way that their *misconceptions will be changed into accepted scientific conceptions*. (Participant 8, post-questionnaire interview)

The data generated by means of the questionnaire and interview data corroborated each other in many ways, indicating that the scenario-based questionnaire could be a useful tool in assessing teachers' understanding of IBST. Kang et al. (2008) found that teachers referred to a science question more in their scenario-based questionnaire responses than in their own written descriptions of IBST. This study has found that participants generally mentioned more aspects of the different domains of IBST in their questionnaire responses than in interviews. This research has therefore established that a scenario-based questionnaire is more useful than narrative data approaches when one seeks a detailed account of participants' understanding of this pedagogy.

Conclusions and Implications

The research has shown that pre-service teachers generally have an inadequate understanding of both the cognitive and guidance dimension of IBST. In terms of the cognitive dimension, they understood it mainly as consisting of the procedural domain and gave little attention to the epistemic, conceptual, and social domains. Moreover, with the exception of the conceptual domain, they mainly mentioned only prominent features of the other three domains. The group also associated learner responsibility in the guidance dimension of IBST mainly with learners formulating conclusions themselves based on evidence; other aspects of learner-directed learning in IBST were minimal. The study has therefore established that at the end of their 3- year experience in science courses, pre-service teachers had an insufficient understanding of what it means to teach science by inquiry. This research also confirmed that while narrative data approaches are suitable when exploring teachers' understanding of main features of IBST, a scenario-based questionnaire is most suitable when seeking a broader account of IBST features.

Based on the research results, it is recommended that content modules within the science teacher education programmes should engage pre-service teachers in learning science by means of more open forms of IBST, coupled with discussions about science's epistemology in order to promote teachers' understanding of the nature of science. In addition, teacher educators should investigate the effect of an instructional model that explicitly integrates the four domains of IBST within the different phases of the 5E learning cycle. The research by van Uum et al. (2016) suggests that this instructional model can promote pre-service' understanding of more open forms of IBST.

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