TITLE: THE RELATIONSHIP BETWEEN GRADE 12 LEARNERS' UNDERSTANDINGS ABOUT SCIENTIFIC INQUIRY AND ACHIEVEMENT IN PHYSICAL SCIENCES.

Abstract

Inquiry Based Learning (IBL) has driven curriculum reforms in science education globally, with many educators teaching science as inquiry, in the hope of improving learners' understandings of scientific concepts and improving achievements in standardised tests. The curiosity of whether learners' engagements and understandings of the Nature of Scientific Inquiry (NOSI) is capable of improving achievement in standardised Physical Sciences tests is important in validating the global emphasis on Inquiry Based Science Education (IBSE). The main aim of this study was to assess grade twelve Physical Sciences learners' understandings about the NOSI using the Views About Scientific Inquiry (VASI) questionnaire and then compare VASI scores with achievement scores obtained from the National Senior Certificate (NSC) preparatory Physical Sciences examination, a standardised provincial test used in preparing matriculants for the final NSC grade twelve examinations. The study followed a cross-sectional survey design, and involved one hundred and seven (107) grade twelve learners from three Johannesburg high schools. Data were collected using the adopted VASI questionnaire. Responses from the VASI questionnaire were coded and scored with the aid of a rubric. VASI scores were compared against the NSC preparatory test scores using descriptive and inferential statistics. The results obtained from data analysis indicated a strong positive correlation between learners' cumulative VASI scores and NSC preparatory scores. Group comparisons revealed no significant differences in VASI and NSC scores for male and female grade twelve Physical Sciences learners. These findings indicate that learners' understandings about the NOSI have a positive influence on performance achievements in a standardised Physical Sciences test. The implications of these findings for practice and research are also discussed herein.

Keyword: Nature of Scientific Inquiry (NOSI), Inquiry-Based Learning (IBL), Standardised test, National Senior Certificate (NSC) examinations, VASI, Achievement.

Introduction

The South African Department of Basic Education (DBE) and its assessment regulator Umalusi have consistently reported poor performance in Mathematics and Physical Sciences for learners who write the National Senior Certificate (NSC) examinations and learners who participate in the Trends in International Mathematics and Science Study (TIMSS). TIMSS data from the period 2003-2015 has shown that South African learners have generally performed poorly in mathematics and science with South Africa falling in the ranks of the "five lowest performing countries including Saudi Arabia (396), Morocco (393), Botswana (392), Egypt (371) and South Africa (358)" (Reddy, Visser, Winnaar, Arends, Juan, & Prinsloo, 2016, p. 2).

The DBE formerly referred to as the Department of Education, has investigated some of the factors affecting performance in Mathematics and Physical Sciences both in national and international benchmarking assessments over the years. Some of the factors, implicated in these findings, have included the vast inequalities that were perpetuated within the education system in the previous political dispensation, lack of parental support for these subjects, poorly trained educators and the content-driven nature of the previous curricula (Lelloit, 2014; Reddy *et al.*, 2016)

In the attempt to address these factors, several curriculum reforms have transpired and the nation has aligned with the global science education imperatives to teach science as inquiry with the ultimate goal of developing learners who are scientifically literate, can think critically, ask scientific questions, solve problems and distinguish unfounded claims from scientific evidence (DBE, 2011). The anticipated outcomes of these numerous national reforms in science education (from content-driven science education to IBSE), has been to improve achievement in science, promote interest in science and also address skill shortages in Science, Technology, Engineering and Mathematics (STEM) careers in the republic (Dudu, 2014; Mokiwa, 2015). Despite increased enactment of IBSE in South African science classrooms, findings from recent studies have showed that learners have mostly mixed and naïve understandings about the NOSI (Gaigher, Lederman & Lederman, 2014; Ramnarain & Hlatshwayo, 2018).

It can be presupposed that when learners engage in scientific inquiry and have a corresponding understanding of the nature of scientific inquiry, such experiences will enhance their understanding of scientific concepts, leading to a higher performance in science. When engaging in inquiry, learners describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. In this way, learners actively develop their understanding of science by combining scientific knowledge with higher order reasoning and thinking skills (National Research Council (NRC), 1996). However, some international studies have questioned the affordances of inquiry practices and understandings about the NOSI on learner achievements in standardised test. In fact, Anderson (2002) found that, inquiry-teaching approaches had no effect on learners' achievements in standardised test. Gee and Wong (2012), also reported that upon analysis of Programme for International Student Assessment (PISA) 2006 results for eight countries, learners who engaged in discovery inquiry approaches, had lower achievement scores in science while those who engaged in model and application inquiry lessons tended to "have higher achievement" (Gee & Wong, 2012, p. 303).

Since there is a dearth of South African studies on the impact of inquiry-based learning on learners' performances in standardised science tests, we seized this opportunity to exploit the research gap by investigating the possible relationship between learners' understandings of the NOSI and achievement scores in standardised test. Accordingly, the study was guided by the following research questions:

What is the relationship between learners' understandings about the NOSI and achievement scores in standardised Physical Sciences test?

Is there a statistically significant difference in VASI and NCS scores for male and female learners?

Literature Review and conceptual framework

As defined by Meyer and Crawford (2015), scientific inquiry refers to learning activities that can equip learners with the skills to investigate the natural world, engage in critical and analytical thinking geared at solving problems in authentic scientific context. The NOSI is characterised by eight core aspects, which should be exploited explicitly within science instruction, in science classrooms. These eight aspects include,

> (1) scientific investigations all begin with a question and do not necessarily test a hypothesis; (2) there is no single set of steps followed in all investigations (i.e. there is no single scientific method); (3) inquiry procedures are guided by the question asked; (4) all scientists performing the same procedures may not get the same results; (5) inquiry

procedures can influence results; (6) research conclusions must be consistent with the data collected; (7) scientific data are not the same as scientific evidence; and that (8) explanations are developed from a combination of collected data and what is already known (Lederman, Lederman, Bartos, Bartels, Antink, & Schwartz, 2014, p. 68).

These eight NOSI aspects have their underpinnings in the five features of scientific inquiry (NRC, 2000), the eight practices outlined in the Next Generation Science Standards (NGSS Lead states, 2013) and contributions from the American Association for the Advancement of Science (AAAS, 1993). The aspects embody a complete representation of how scientists investigate the natural world and communicate their findings within specific communities of practice. The K-12 science education framework of the NRC (2011), adopted the broader term "scientific practices" in inquiry-based learning instead of the term "skills" to emphasize that "engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice" (p. 30). This therefore implies that, it is not enough for science learners to acquire a set of investigative skills without really understanding the "whys?" and "hows?" of using acquired skills. Learners ought to acquire an understanding about the nature of scientific inquiry including, understanding the diverse methods that scientific investigations can follow, the role of scientific questions, ways in which procedures and human factors influence scientific conclusions, the relevance of data in making scientific conclusions, the differences between data and evidence and the place of prior knowledge in making conclusions.

The Nature of Scientific Inquiry (NOSI)

The Nature of Scientific Inquiry (NOSI) simply refers to "what learners should understand about inquiry" (Leblebicioglu, Metin, Capkinoglu, Cetin, Eroglu Dogan, & Schwartz, 2017, p. 5). The NOSI derives its conceptual groundings from the "Knowledge about inquiry" notion within the populous National Science Education Standards (NSES) and the corresponding NRC (2000) document (Leblebicioglu *et al*, 2017). Several science education researchers globally and in South Africa, have referred to the term "inquiry" as a multifaceted construct (Crawford, 2014; Gaigher *et al*, 2014; Lederman et al, 2014; Ramnarain & Hlatshwayo, 2018; Senler, 2015). For the current study, we positioned the understandings about the NOSI, within the conceptual framework of the aforementioned eight core aspects about scientific inquiry proposed by Lederman et al (2014). In the section below, we provide a brief description of each of these core aspects.

Aspect 1: Scientific investigations all begin with a question and do not necessarily test a hypothesis, refers to the role of scientific questions as the starting point for every scientific investigation. What this means is learners need to understand that, stating a hypothesis is not the only drive for scientific investigations, rather posing a scientific question, should be the starting point of every scientific investigation. The scientific question is what propels the inquiry and guides the inquirer on the relevant procedures that should be followed in an investigation (Antink-Meyer, Bartos, Lederman & Lderman, 2016; Lederman *et al*, 2014).

Aspect 2: There is no single set of steps followed in all scientific investigations (i.e. there is no single scientific method), is an aspect which indicates that, the ideology of a scientific method described by a series of steps typically followed in the experimental approach is not the only way used in scientific investigations. Scientific investigations can follow numerous methods, including testing hypothesis, observational inquiry and non-experimental methods of inquiry (Yang *et al*, 2017).

Aspect 3: Inquiry procedures are guided by the question asked; refers to the idea that, the procedure selected for every scientific investigation should be carefully selected to ensure that it leads to obtaining answers to the scientific question, which was posed at the beginning of the inquiry (Yang *et al*, 2017)

Aspect 4: All scientists performing the same procedures may not get the same results; is a NOSI aspect, which refers to the human factors like creativity and imagination and how they influence the conclusions made by each individual scientist, at the end of an investigation (Gaigher *et al*, 2014).

Aspect 5; Inquiry procedures can influence results; describes the role of procedure in scientific investigations. It can be noted that if different procedures are followed to investigate the phenomena the likelihood is that the results from these different procedures will be different even if the inquirers asked the same scientific question (Lederman *et al*, 2014)

Aspect 6: Research conclusions must be consistent with the data collected; for every conclusion made by a scientist there needs to be backing evidence derived from collected data. This aspect also emphasises the need for learners and scientists alike to be able to differentiate between unfounded claims and scientific evidence derived from analysed data (Antink-Meyer *et al*, 2016; Lederman *et al*, 2014).

Aspect 7: Scientific data are not the same, as scientific evidence in that, the presence of data alone does not suffice as evidence in scientific investigations. The obtained data has to be analysed for the determination of patterns and relationships, which will be presented as evidence (Schwartz *et al*, 2008; Senler, 2015)

Aspect 8: Explanations are developed from a combination of collected data and what is already known is a NOSI aspect that describes the role of data and prior knowledge. Prior knowledge helps a scientist to be able to make interpretations on the data at hand in relation to what was already known (Lederman *et al*, 2014)

Factors that affect the understandings about the NOSI

Several factors have been considered to affect the ways in which learners gain understandings about the nature of scientific inquiry. These factors include the manner in which learners are taught science as inquiry (Crawford, 2014; Osborne, 2014; Lederman et al, 2014), the nature of the engagement they have with inquiry (Leblebicioglu *et al*, 2017) and how well the NOSI aspects are planned, scaffolded and assessed as part of science content knowledge and instruction (Bartos & Lederman, 2014). In a study by Antink-Meyer *et al*, (2016) and another by Leblebicioglu et al, (2017), both Taiwanesse and American learners reportedly registered more informed understandings about some NOSI aspects after engaging in explicit inquiry activities at a science camp. In both studies, the science camp was used as a platform to engage the learners in inquiry tasks and the associated reflective conversations, questions and answers, which describe the explicit instruction, associated with the intention of teaching the NOSI. Findings from these two studies are indicative of the fact, when teaching and learning activities are carefully planned to include tenets of the nature of scientific inquiry, there will be a positive impact on learners understandings about scientific inquiry. Several researchers also argue that if the understandings about the NOSI is not targeted, as part of inquiry instruction the likelihood is that learners will only develop knowledge of the science content (Leblebicioglu et al, 2017; Crawford, 2014; Osborne, 2014) and not the nature of inquiry. In addition, findings, from other studies have indicated that conceptions and understandings about the NOSI and the Nature of Science are bound to improve only when explicit approaches that treat these concepts as valuable subject matter are included in science instruction within the classroom (Antink-Meyer *et al*, 2016; Leblebicioglu *et al*, 2017; Lederman *et al*, 2014; Bartos & Lederman, 2014). It is therefore widely advocated that, teachers need not only engage learners in doing inquiry, but also purposefully include reflective questions and activities that will draw learners' attention to the NOSI aspects embedded in any given inquiry task (Galano, Zappia, Smaldone & Testa, 2016; Lederman & Lederman, 2014).

Research design and methodology

The study followed a cross-sectional survey design to investigate the relationship between grade twelve learners' understandings about the NOSI (assessed within the VASI) and achievement in a standardised test (NSC preparatory examination test scores). The survey design was most preferred because it was cost effective and facilitated the collection of large amounts of data at the same time.

Sampling

One hundred and seven (107) grade twelve physical sciences learners were randomly selected from a population of 203 learners from three Johannesburg high schools. We regarded these schools as representative of the socio-economic spectrum of schools in Gauteng. The sample was therefore comprised of learners at township, suburban and independent schools.

Data Collection

This study adopted the Views About Scientific Inquiry (VASI) instrument to assess grade twelve learners' understandings about the NOSI. The questionnaire was developed and validated as reported by the authors in Lederman et al. (2014) to ensure exclusive assessment of the NOSI without conflating with the Nature of Science. The VASI questionnaire is an improved version of the Views of Nature of Scientific Inquiry (VOSI) questionnaire (Schwartz, Lederman & Lederman, 2008), which is targeted at assessing eight NOSI aspects instead of five aspects as was previously assessed in the VOSI. The instrument has been used extensively at different levels and in different context including the South African context to assess learners' views and understandings about the NOSI (Antink-Meyer, Bartos, Lederman, & Lederman, 2016; Gaigher, Lederman, & Lederman, 2014; Yang, Park, Shin, & Lim, 2017). VASI consists of seven open-ended items, some of which are divided into sub-sections, targeted at assessing understandings about the eight NOSI aspects already described above.

Data on grade 12 learners' performance in Physical Sciences was obtained as secondary data from participant schools. The NSC preliminary examination was written after the VASI had been administered. The NSC examinations are usually regulated for quality by Umalusi and comprises of two papers assessing physics and chemistry concepts scored at 150 marks each.

Data analysis

In order to ensure reliability in the coding of the responses to the VASI questionnaire, a random 10% sample of the completed VASI questionnaires were read and coded independently by three different coders, including two of the researchers from the current study and one other science education expert. An inter-coder agreement of more than 95% was reached for each VASI item. Learners' responses were either classified as naïve, mixed or informed. Naïve responses referred to responses, which were not consistent with the NOSI aspect or were contradictory, while mixed responses referred to responses, which were only partially consistent with a NOSI aspect or were correct but learners could not provide a satisfactory explanation for their reasoning. Informed understandings on the other hand, referred to responses, which were completely consistent with a NOSI aspect and learners, could provide satisfactory explanations for their reasoning (Lederman *et al*, 2014). After the inter-coder agreement was satisfactorily reached, all 107 questionnaires were coded by the first authors. The coding agenda/rubric used for coding the VASI items is illustrated in Table 1 below.

Table 1. *Coding agenda for the VASI item Responses (Adapted from Gaigher. et al, 2014)*

VASI item & NOSI Aspect	Naïve	Mixed	Informed
1a, b, and c: Scientific investigations may follow different methods.	1c: Only one Scientific method Or any two/more mistakes, e.g. 1b: yes, experimental and 1c: Similar or No Examples provided	No more than one of the following types of mistakes: 1b: Yes, it is an Experiment Or 1c: one general Method Or 1c: both examples are experimental Or 1c: both examples are non-experimental	All three answers must be appropriate 1a: Yes, the investigation is scientific as it aims to explain some aspect of the natural world 1b: No, it is not an experiment as there is no manipulation/control of variables/testing 1c: Yes, investigations can follow different methods: experimental/ practical/testing as opposed to nonintrusive/ non experimental/ research/ investigation/ observation/theoretical/ not-practical Two suitable examples required: one experimental and the other non-experimental
2. A scientific investigation should begin with a question not necessarily be testing a hypothesis	Investigation should start with a hypothesis; also questions are not essential	A question is useful, but is regarded as part of a formal structure, investigation may be undertaken first and questions formulated later	A scientific question is the main reason why an investigation is undertaken, a driving force to begin the investigation or inquiry.
3a. All scientists performing the same procedures may not get the same results	Similar procedures would always lead to the same results	Imperfect experimental conditions may lead to different results	The human factor may cause different interpretations of similar data, leading to different results
3b. Procedures followed in scientific investigations can influence results	Only one result is possible regardless of the procedure	Different results would be primarily caused by the different interpretations	Different procedures would yield different data-sets which would lead to different results
4. Data are not the same as scientific evidence	There is no difference between data and evidence	Evidence differs from data; unclear/wrong/no explanation	Evidence is generated from data, to support a claim/conclusion

5. Question drives the process of scientific investigations	Team B did better, illogical or no Explanation	Team A did better, no explanation/argues that the tire has a larger effect than road Or, B did better and argues that the different roads have different effects on tires.	Team A did the best experiment because they addressed the investigative question
6. Conclusions should be consistent with data collected	Option (a) is correct, with or without an explanation Alternatively, option (c) with no or illogical explanation.	Option (c) is correct, i.e. 'growth not related to sunlight' with an explanation Or, option (b) without explaining	Option (b) is correct, i.e. 'plants grow taller with less sunlight' because the data showed such a trend Speculations about the 'unusual' data are acceptable provided option (b) is chosen
7a & b. Explanations must be based on data and existing scientific knowledge	One or no relevant ideas.	Only two relevant ideas.	Three relevant ideas: Two reasons: function of ideas larger hind legs/ comparison with existing models of dinosaurs/fitting of joints One information type: existing knowledge of dinosaurs/skeletons/ joints

The second phase of data analysis was aimed at transforming the data by quantifying the responses with scores. As proposed by Scherp (2013), the transformation of qualitative to quantitative data has been used extensively in education research to "facilitate discoveries of patterns in the data" (Scherp, 2013, p. 67). Numerical values were allocated to coded questionnaire items, in order to generate a cumulative VASI scores. Where no response was provided to a VASI item, the item was scored a zero (0), naïve responses scored a one (1), mixed responses scored two (2) and informed responses scored three (3). After this process was completed, the data was treated as quantitative data. VASI scores for each questionnaire were allocated out of 24 . The scores for all 107 respondents were then captured on SPSS 25 and analysed for internal consistency and subsequently descriptive and inferential statistics against the preliminary NSC test scores. VASI scores obtained for the entire dataset were checked for inter-item internal consistency to ensure the reliability of the transformed data. Cronbach's alpha was calculated and an alpha coefficient of .61 was obtained indicating a moderate internal consistency between the VASI questionnaire items.

Research Question and Hypotheses

The inquiry was guided by the following research question.

- What is the relationship between learners' understandings about the NOSI and achievement in Physical Sciences?

- Is there a statistically significant difference in VASI and NCS scores for male and female learners?

The stated hypotheses included,

Null Hypothesis 1 ($H_0 1$): There is no relationship between NOSI understandings and achievement in a standardized test.

Alternative Hypothesis 1(Ha1): There is a relationship between NOSI understandings and achievement in standardized test.

Null Hypothesis 2 ($H_0 2$): There is no difference in VASI and NCS scores for male and female learners.

Alternative Hypothesis 2(Ha2): There a difference in the VASI scores for male and female learners.

Results

VASI and preliminary NSC tests scores were analysed using SPSS 25. Descriptive and inferential statistical tests were performed, to make meaning of the data. The section below reports on the findings from the descriptive statistics. Pearson's correlation coefficient, test for normality of data and independent sample t-test for gender group comparison.

Mean scores

Table 2 below shows the sample mean VASI and NSC scores obtained by participant grade twelve learners, with the mean VASI score M= 14.99, S.D =3.16 on a scale of 24 while the mean NSC examination score M= 55.25%, S.D = 18.01.

Table 2. *Mean scores*

		NCS SCORES	VASI SCORE
N	Valid	107	107
	Missing	0	0
Mean		55.25	14.99
Median		57.00	15.00
Std. Deviation		18.006	3.158
Skewness		-.198	.064
Std. Error of Skewness		.234	.234
Kurtosis		-.674	-.744
Std. Error of Kurtosis		.463	.463

Relationship between VASI scores and preliminary NSC scores

In answering the first research question, Pearson's correlation coefficient was used to assess the relationship between VASI scores and NSC Pre examination scores. Pearson's correlations are expressed as a coefficient between +1.00 to -1. A coefficient near +1 has a high size and a strong positive correlation, while coefficients closer to .00 show that variables are most likely unrelated (Pallant, 2010). The results of Pearson's are displayed on Table 3 below.

Table 3: *Pearson's correlation between VASI scores and preliminary NSC scores*

Descriptive Statistics			
	Mean	Std. Deviation	N
VASI SCORE	14.99	3.158	107
NCS Pre-Score	55.25	18.006	107
Correlations			
		VASI Score	NCS Pre-Scores
VASI Score	Pearson Correlation	1	.687**
	Sig.(2-tailed)		.000
	N	107	107
NCS Pre-Score	Pearson Correlation	.687**	1
	Sig.(2-tailed)	.000	
	N	107	107
** Correlation is significant at the 0.01 level (2-tailed).			

The results displayed on Table 3 show a strong positive correlation between VASI score and the NCS pre-score, with Pearson's $r(107) = .687$, $p < .01$. This observation alone does not indicate a causal relationship for the two variables, NCS score and VASI score. Therefore to establish the direct causal relationship, we calculated the coefficient of determination r^2 = square root Pearson's correlation coefficient. This determination coefficient describes the percentage to which a variable affects another. Our computation showed the value of $r^2 = (.687)^2 = .472$. The value of r^2(Coefficient of determination) in percentage indicates that 47.2% of the variation in the NCS pre-score can be explained by the variance in the VASI score while the remaining 52.8% of variance would be explained by other factors.

Gender differences

In our quest to answer the second research question, and establish whether there are possible statistically significant differences between male and female learners' scores, we firstly determined the normality of the data, which is the primary assumption for parametric testing. Table 4 below shows the results of normality distribution table against gender for both the VASI and the preliminary NSC scores.

Table 4. *Test of normality for gender*

	Participant Gender	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
			df	Sig.		df	Sig.
NCS Preparatory examination PS scores	Female	.088	61	.200*	.975	61	.235
	Male	.099	46	.200*	.956	46	.079
VASI_SCORE	Female	.109	61	.068	.972	61	.180
	Male	.129	46	.052	.959	46	.105

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The table above shows the results for the Shapiro-Wilk test. If the significance (p) value of the Shapiro-Wilk Test is > 0.05, it indicates that the data is normal. If it is ≤ 0.05, the sample data significantly deviates from a normal distribution (Fields, 2009). In this case, the p value for both females (.235) and males (.079) exceeded .05, suggesting a normal distribution of scores for both datasets.

After the normality was established, the data was then subjected to an independent sample t-test to establish if there was any significant differences in the VASI and preliminary NSC scores for gender. The result of the t-tests are illustrated on Table 5 below.

Table 5. *Independent sample t-test*

	Participant Gender	N	Mean	Std. Deviation	Std. Error Mean	t	p
VASI Score	Female	61	14.48	3.102	.397	-1.97	.82
	Male	46	15.67	3.134	.462		
NCS Pre-Scores	Female	61	52.85	18.152	2.324	-1.59	.91
	Male	46	58.43	17.500	2.580		

As seen on the table above, the results of the t-test revealed that there is no statistically significant difference (at the 95% level of confidence) in the test scores between females and males learners for the VASI score (*t (*105) = -1.97, p = .82) and for the preliminary NSC score *t* (105) = -1.59, p =.91).

Discussion and conclusion

The reveal that there is a strong positive correlation between grade twelve learners' understandings about the nature of scientific inquiry as assessed by the VASI and Physical Sciences achievement scores as assessed in the preliminary NSC preliminary examination. These findings suggests that if learners acquire understandings about the nature of scientific inquiry, this understanding tends to increase conceptual understandings and may contribute positively to performance in physics and chemistry tests. Although this study did not directly investigate the effects of inquiry-based learning experiences on science achievement, the finding on the relationship between learners' understanding of scientific inquiry and achievement, are in harmony with other studies where the effects of inquiry-based learning were investigated directly. For example, research by Maxwell, Lambeth and Cox (2015) with 5th grade learners showed that learners in the inquiry-based learning group scored higher than learners in the traditional group on the academic achievement post-test. Similarly, studies by Han, Capraro and Capraro (2015), Gee, and Wong (2012) revealed that inquiry related learning in science and STEM education has the ability to improve learners' achievement scores in science.

These findings provide motivation for why learners need to make deliberate efforts and ask the questions relevant for their understandings of the NOSI. The findings also suggest that, teachers who aspire higher achievements in standardised science test should nurture learners understanding about scientific inquiry through inquiry-based experiences as this could improve learner achievement in science. From the findings, we recommend that teachers explore inquiry-learning strategies, which will assist learners to reflect on aspects of the NOSI. The focus should not be to inform or tell learners what should be known, but rather to scaffold learners through open classroom conversations about the NOSI and how scientists investigate the natural world. As postulated by Hodson (1992), the mastery of science process skill alone will not suffice when a learner is expected to recall information, for instance when writing standardised tests. Over and above the acquisition of science process skills, learners should be aware of why they choose procedures, do experiments, collect data using specific procedures and how explanations are formulated. In South Africa, research findings have also indicated that, teachers also lack informed understandings about the nature of scientific inquiry (Dudu, 2014; Dudu & Vhurumuku, 2012) and this is an important consideration because according to Fraser (1998) learners' conceptual understandings are a direct reflection of teacher practice. We therefore recommend that teacher educators also lay emphasis on not only inquiry pedagogic strategies but also on the teachers' understandings of the NOSI.

For researchers we recommend larger scale research on learners and teachers' understandings about the NOSI inquiry and the implications for conceptual and procedural understandings in science education. Emanating from this study, we propose extensive research (larger sample sizes) aimed at explaining "why" and "how" understandings about the nature of scientific inquiry may contribute to achievement in science.

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