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South African High School Students' Experiences of Inquiry During Investigations: A Case Study

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ABSTRACT This paper investigated Physical Science students' experiences of the nature of classroom inquiry during investigations. The paper followed a mixed method research design. One hundred and sixty-seven Grade 11 students were surveyed. The students were sampled from five schools in one of South Africa's 9 educational provinces. Students' experiences of the nature of inquiry in Chemistry practical investigations were assessed through a 20-item Likert-type questionnaire. Semi-structured interviews were conducted with five students from each Grade 11 class at each of the 5 schools. The interviewed students (25) were selected following the stratified random sampling technique. As a group, the majority of the surveyed students (82%) were found to experience generally moderate levels of inquiry in their Grade 11 Chemistry practical investigation. The nature of student experiences of laboratory experiences was found to be associated with gender. Implications for both the theory and practice of science education are raised.

INTRODUCTION

Anecdotal accounts from science educators suggest that few teachers are teaching science as inquiry. However, there is little empirical evidence to support this claim (Capps and Crawford 2014). For many teachers and for many students the notion of inquiry has been conflated with the idea that inquiry requires students to handle, investigate and ask questions of the material world (Osborne 2014). Hence any activity that is of a 'hands-on' nature can be considered to fulfill the basic requirement of this pedagogic approach. According to Osborne (2014), the goals of engaging in inquiry have been conflated with the goals of laboratory work such that, in the eyes of many teachers, the primary goal of engaging in inquiry is not to develop a deeper understanding of the whole process of inquiry but to provide a means of supporting their rhetorical task of persuading their students of the validity of the account of nature that they offer. At its worst, the alternative of inquiry is cookbook laboratory exercises where students simply follow a series of instructions to replicate the phenomenon (Veal and Allan 2013).

For the past six decades, science education curriculum reform efforts around the world emphasize the importance of developing students' abilities to do inquiry (Bell et al. 2005). Advocacy for this is based on the premise that inquiry is at the core of scientific literacy (Wong and Hodson 2008). Scientific literacy is commonly portrayed as the ability to make informed decisions on science and technology-based issues and is linked to deep understanding of scientific concepts and the processes of scientific inquiry (Bell et al. 2003). Scientific inquiry, as practised by professional scientists, refers to the various ways of studying the natural world, asking questions, proposing ideas, collecting evidence to justify assertions and explanations and communicating results (Hofstein and Lunetta 2004).

School science inquiry is seen as similar to the inquiry done by professional scientists as students also investigate the world, propose ideas and justify explanations based on collected evidence (Chinn and Malhorta 2002). Although the real world of science is not typically represented in the classroom (Ryder et al. 1999), school science aims to give future citizens (some of whom will become scientists) a good sense and an understanding of what science is and

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how it is done. If there is an alternative focus, it tends to be on the performance of the skills required to do inquiry—and then predominantly on the manipulative skills for successful experimentation (knowing how)—rather than the analysis and interpretation of the data or an understanding about inquiry and its role in science (knowing that or knowing why) (Osborne 2014).

There is an underlying conviction that engaging students in authentic investigative activities can lead to their developing abilities to perform inquiry (Vhurumuku 2011). This is especially so if the development of students' scientific inquiry experiences are made an explicit instructional goal during investigations (Campbell et al. 2010). Scientific investigations are activities in which students take the initiative in finding answers to problems (Jones et al. 1992). Given the centrality of investigations in school science learning and the importance of investigations in nurturing students' experiences of inquiry in science classrooms, it is critical to understand such student experiences and perspectives during investigations. Such an understanding is essential for the development and refining of pre-service and in-service science strategies for investigations that are responsive to classroom challenges such as the existing culture of transmission of knowledge in the science classroom (Lemke 1990; Sandoval and Reiser 2004). Moreover, an understanding of student experiences of inquiry when performing investigations can be useful in the crafting of constructivist-oriented pedagogies aimed at establishing a learning setting in which students can take ownership of the questions they pursue and can design (Linn et al. 1994). In turn, the students are equipped with skills to implement an investigation so as to pursue their questions, and interpret and communicate their results to others.

In this paper, student's experiences of inquiry refer to the extent, to which students are engaged in processes undertaken by scientists in doing science and developing scientific knowledge (Campbell et al. 2010), that is, extent to which students experience inquiry during science lessons or the extent students practise *open-ended inquiry*. Globally, while research on learning and teaching of science through inquiry is abound, very few studies have specifically focused on determining the extent student experiences of inquiry are open-ended and in-line with national curriculum reforms (Flick 2000; Keys and Bryan 2001). This is particularly so for the African continent. There is also evidence that some groups of students may benefit more from the inquiry method than others (Casem 2006). While most studies have not disaggregated data by gender or by race, Njoroge et al.'s (2014) study of secondary school students Kenya found that the inquiry-based-teaching approach resulted into higher students' scores in achievement in Physics. However, the study was not conclusive in differentiating between girls' and boys' performance. On the other hand, a study of fourth and fifth grade students by Kahle and Damnjanovic (1994) found that, while all students expressed increased enjoyment in doing science after inquiry activities involving batteries and bulbs, the girls in the study showed a more dramatic increase in enjoyment. Since these studies are inconclusive, more studies with results disaggregated by gender are needed to determine whether the inquiry method is most appropriate for all students.

The South African Curriculum Context

It is important to briefly examine the South African Physical Science curriculum in order to fully understand the context in which this study was undertaken. In line with international fashions and trends, South Africa introduced a new Physical Science curriculum in 2006 (Department of Education 2005). The new curriculum back then was known as the National Curriculum Statement (NCS). Recently, The National Curriculum Statements (NCS) introduced together with the Outcomes-Based Education philosophy in 2005, have been revisited with a view to simplifying the original documents and the subsequent supporting documents (Subject and Learning Area Statements, Learning Programme Guidelines and Subject Assessment Guidelines) for all subjects. The aim was to produce national Curriculum and Assessment Policy Statements (CAPS) as a "refined and repackaged" version of the original documents, and not create new curricula. The refining and repackaging of both the General Education and Training (GET) phase, Grade 8-9 and Further Education and Training (FET) phase, Grade 10-12 science documents was completed, and CAPS was launched at FET starting at Grade 10 level in 2012. Both the current curriculum and its predecessor advocate for learning and teaching of science through inquiry. As part of the refinement, Prescribed Practical Activities (PPA) and Recommended Practical Activities (RPA) were introduced. The learning outcomes in the NCS were replaced by content standards in the CAPS curriculum. The new CAPS curriculum requires learners to be involved in practical investigations when they undertake prescribed and recommended practical activities which are assessed and form part of the Physical Science summative assessment for the Senior School Certificate, called Matriculation.

The content standards specifically focus on scientific inquiry and problem-solving, for example the curriculum states that "*Practical investigations* will require learners to go through the scientific process" (Department of Education 2011:7). For Grades 10 and 11, any one of the recommended projects can be done as a practical investigation. However, for Grade 12, students are required to do two assessed practical investigations, one in Physics and one in Chemistry. Changes of this magnitude in classroom practices demanded by such reform visions ultimately rely on teachers (Fullan and Miles 1992; Spillane 1999). It was the researcher's conviction basing on Fraser's (1998) definition of classroom practices that student classroom experiences of inquiry can be used as a reliable indicator to determine achievement of the new curriculum's demands regarding scientific inquiry.

The skills and abilities which students are expected to develop as a result of doing investigations are listed as follows; (1) plan investigations, (2) conduct investigations, (3) interpret data and draw conclusions, (4) solve problems, and (5) communicate and present information and scientific arguments (Department of Education 2005:10). It is noteworthy that these skills and abilities encompass frameworks of scientific inquiry as described by several authors (for example, Hegarty-Hazel 1986; Sandoval and Reiser 2004; Campbell et al. 2010). Campbell et al. (2010), for example, describe scientific inquiry as involving, asking/framing research questions; designing investigations; conducting investigations; collecting data; and drawing conclusions.

Research Questions

This study was guided by the following questions:

1. What are Grade 11 Physical science students' experiences of laboratory inquiry during investigations?
2. Is the nature of students' experiences of laboratory inquiry associated with gender?

Theoretical Framework

This study is guided by the literature on operationalization and categorization of the phrase constructivist descriptions of *laboratory inquiry* (Dudu and Vhurumuku 2012).

'Inquiry in school science' is the theoretical construct guiding student experiences of laboratory inquiry. According to Hofstein and Lunetta (2004), scientific inquiry (as practiced by professional scientists) refers to the various ways of studying the natural world, asking questions, proposing ideas, collecting evidence to justify assertions and explanations and communicating results. *School science* inquiry is seen as similar to the inquiry done by professional scientists as learners also investigate the world, propose ideas and justify explanations based on collected evidence. Chinn and Malhotra (2002), however, argue that school based inquiry is cognitively and epistemologically different from authentic scientific inquiry (research done by scientists). It is noteworthy that the cognitive tasks needed for authentic science are more demanding than what is required for school science. Authentic scientific inquiry is a complex activity employing expensive equipment, elaborate procedures and theories requiring highly specialized expertise for data analysis (Chinn and Malhorta 2002). Schools lack the expertise and both the resources and time to engage in authentic science. Epistemologically, school science is simple inquiry aimed at uncovering and verifying simple observable regularities whereas authentic science aims at uncovering new theoretical models and revising existing ones. Therefore, when examining inquiry in the context of *school science*, it should always be borne in mind that this inquiry is within the cognitive and epistemological boundaries of *school science*.

Within this realm, learners' classroom experiences can be examined through a lens of the nature, form and extent of inquiry woven through the learning and teaching activities. Dudu and Vhurumuku (2012) describe school science learning activities as belonging to a continuum ranging from *closed inquiry* oriented to *open ended* of inquiry. In closed inquiry laboratories, learners are given little or no opportunities to, propose problems for investigation, ask questions, formulate hypotheses, design procedures, process answers and explanations, predict and communicate results as well as identify assumptions, use logical and critical thinking and engage in argumentation (Dudu and Vhurumuku 2012). To the contrary is *open ended* inquiry, which is learner centred and associated with such activities as; learners formulating their own problems and questions for investigation, seldom following step-by-step instructions from the teacher or laboratory guide, investigating problems that come up in class, offering alternative explanations to phenomena, high levels of learner-learner and learner-teacher argumentation and outcomes of experiment being unknown prior to the experiment (Domin 1999). In general, the greater the latitude given to learners to practice these activities, the more *open-ended* the inquiry

RESEARCH METHODOLOGY

The Instrument

Principles of Scientific Inquiry-Student (PSI-S) Questionnaire

For this paper, the researcher adopted the Principles of Scientific Inquiry-Student (PSI-S) instrument (Campbell et al. 2010) (see Appendix). Essentially, the instrument measures student experiences of the extent to which they experience inquiry during science lessons. The Likert-type instrument consists of 20 items categorized into five components of scientific inquiry; with each component having four items (see Appendix). The five components are as follows; (1) asking questions/framing of research questions, (2) designing investigations, (3) conducting investigations, (4) collecting data, and (5) drawing conclusions. The response alternatives are on a five-point bipolar scale ranging from Never Occurred to Almost Always. Examples of items on the questionnaire are “I formulate questions which can be answered by investigations”; I design my own procedures for investigations; I conduct the procedures for my investigation; “I determine which data to collect”; and “I develop my own conclusions from investigations”.

This questionnaire was administered before learner interviews were conducted. For each class, all learners who were taking Physical Science completed the PSI-S. School A had 35, school B had 32 (all girls), school C had 44, school D had 23 and school E had 33 students giving a total of 167 learners. In South Africa, only 30 per cent of students who complete school at the National Senior Certificate level sit for the Physical Science examination (South African Institute of Race Relations, 2012). Given this unpopularity, Physical Science class sizes vary from school to school. The researcher’s choice of this instrument was based on the conviction that experiences of their classroom experiences can be used as a reliable indicator of teacher practices and classroom inquiry (Fraser 1998). The instrument was judged to be suitable for quantitative characterization of the extent of openness of inquiry as experienced by students in South Africa’s science classrooms as its items cover and capture the investigative skills advocated for by the new curriculum’s Subject Statement for Physical Science (Department of Education 2011). The researcher’s confidence in the instrument was enhanced by the high reliability test score (Cronbach alpha = 0.85) and exploratory factor analysis results obtained from piloting the instrument with 90 Grade 11 students, at a school in Johannesburg (Dudu and Vhurumuku 2012).

Semi-structured Interviews

Learner interviews were conducted after administration of the PSI-S questionnaire. Five students from each Grade 11 class at each of the 5 schools were selected based on the representativeness of the categories in which their [students] answers were grouped. This follows the stratified random sampling technique (Gall et al. 2007). The students were interviewed individually. Selection was purposive in the sense that their responses to the questionnaire sought further probing and clarification regarding the category into which their responses fitted. However, the selection was also convenient since it was based on the researchers’ judgments of subjects’ convenient accessibility, willingness and proximity, since some of the interviews had to be done during lunch time and after school. Students were asked questions focusing on what actually happened during their laboratories when conducting investigations. They were also asked questions about their experiences in identifying the problem for investigation, role of individual students, planning and design, data collection and interpretation, drawing conclusions and communicating the findings. Probing was done in order to solicit additional insights and to crosscheck the researcher's initial interpretations and synthesize common understandings between the interviewer and the interviewee. This helped the researcher to revise interpretations and correct mistakes, informing the researcher's perspectives on the classroom events. All interviews were audiotaped and transcribed verbatim.

Sampling

All the 167 (108 females and 59 males) students who participated in this study were conveniently selected from Grade 11 Physical Science classes at five (5) high schools in Gauteng Province, Johannesburg, South Africa. One school was a single-sex school hence the number of female students is more than that of male students. The schools were selected from a possibility of ten schools that place emphasis on Mathematics, Science and Technology. The teachers for these sampled students are the ones who appeared to be cooperative and willing to participate in the study. Secondly, the teachers for these students also willingly agreed to teach investigations with Grade 11 classes during the period of the study. At each school, one Grade 11 class participated in the study. The class was randomly chosen by the teacher. All the 167 students completed PSI-S instrument.

Data Analysis

For quantitative analysis, SPSS for Windows (Version 16) was used to perform relevant non-parametric (inferential) statistics. For qualitative data, ATLAS.ti version 6.2 was used to analyse interview transcripts. The analysis for PSI-S was done as explicated below.

Principles of Scientific Inquiry-Student (PSI-S) Questionnaire

The response alternatives on the five-point bipolar Likert scale ranging from (1) never occurred (2) seldom, (3) sometimes, (4) often to (5) almost always were allocated scores from 1, 2, 3, 4 to 5, respectively. Scoring was done in reverse for statements representing non-inquiry or closed-inquiry laboratory. Reverse scoring was done for the following items: A1, A2, A3, A4, B2, B3, B4, C1, C3, C4, D1, D2, D3, D4, E1, E2, E3 and E4. Total scores were obtained for all the 20 items in the instrument and for each of the five sections. Open-ended inquiry is represented by high scores (maximum = 100) and laboratory work which is closed inquiry is reflected by low scores (minimum = 20). The rankings given to the statements by each class were used to categorize the type of laboratory they experienced from closed (low) inquiry to open-ended (high) inquiry along a continuum. As an example, students exposed to more open-ended laboratory work were expected to rank statement C3 'I actively participate in investigations as they are conducted' very highly, and those in low-inquiry laboratories to rank statement B1 'I am given step-by-step instructions as I conduct investigations' very highly.

Interviews

A 'hybridization' of the processes of analytic induction and sequential analysis following the procedure used by Vhurumuku et al. (2006) was used to analyse transcripts from learners' interviews. For each class, transcribed student interviews were entered into ATLAS.ti version 6.2 and analysed as data sets. The analytic induction involved continued reading and rereading of transcriptions to unveil common patterns. For each data set, emerging patterns were then used to develop categories. Responses were then classified on the basis of the formed categories. Frequency counts were made for each category. The data were also looked at from the angle of sequential analysis, a slight variation to analytic induction (Harwell 2000). In this process, interpretations for each response to a question were written as memos and comments. Memos and comments are methods used to record one's ideas and observations about codes, quotations and the hermeneutic unit (HU). Formed comments and memos were reduced to clusters based on the responses. Cluster phrases emerged from the responses. For each of the processes, that is, analytic induction and sequential analysis, each researcher (including a colleague in the department who assisted with checking reliability of the analysis) independently did the analysis. This was followed by a process of discussion, negotiation and adjustment leading to consensual arrival at common clusters.

RESULTS

Students' Experiences of the Nature of Laboratory Inquiry

Results from students' responses to the PSI-S instrument are summarized as shown in Table 1. Each student's total score was mapped onto an inquiry continuum (see Table 1). Students' scores from the PSI-S instrument were categorized and mapped against a score range (see Table 1). Total number of students per score range was converted into a frequency percentage thereby revealing the nature of inquiry most of the students perceived they experienced.

A student's score below the theoretical midpoint of 60 (maximum =100, minimum = 20) was taken to mean that the student perceived his/her laboratory experiences as of low inquiry or very low inquiry (see Table 1). Scores above 60 were taken to mean experiences of laboratory inquiry as of medium or high inquiry. On the average, students can be said to experience the nature of inquiry as somewhere between low and medium inquiry (inquiry taken to exist along a continuum). From Table 1, it can be seen that as a group the learners perceived the level of inquiry in their laboratories to be generally medium. Slightly above four- fifths of the students (82%) scored within 61-80 score range. While some individual students within the sample (17 or 13 %) view the level of inquiry in their laboratories as high and a small fraction as very low (9 or 5 %) (see Table 1).

Students' total scores on the PSI-S differed statistically significantly with gender as determined by the Mann-Whitney U test ($Z = -2.89$, $p = 0.004$). It was also found that there was statistically significant difference in male and female PSI-S non-inquiry oriented item scores ($Z = -2.62$, $p = 009$). However, no statistically significant difference was found between male and female PSI-S inquiry oriented item scores ($Z = -1.08$, $p = 0.28$).

Interview Results

Students in all five classes were in agreement with how they went through the whole process of chemistry practical investigations. They were showering praises to their teachers about the latitude given to them to; ask or frame questions for investigation, design and conduct investigations, collect their own data, interpret results, and then draw their own conclusion was narrow and more closed. Most importantly is the guidance that they received from their teachers during the initial stages. The initial stages are important in that the students have to identify a question which will give meaning and direction to the whole practical investigation. Some of the students when asked "what are your experiences in identifying the problem for investigation?" said

...we are not given steps to follow by the teacher but he asks us questions which are critical and lead us to focus on what we want to find out. We have to think deep and this makes us frame investigative questions which are good (L3SCAInt6).

...our teacher told us that for an investigative question to be good, it must contain the variables which are investigated. As a result, we always check for the variables we are investigating and make sure that they are included in the investigative question (L21SCBInt5).

...The investigative question is like a foundation for a house. A good question ensures that the investigation is focused. The design and conduct are from the question. Our teach-

Table 1: Categorization of students' experiences of laboratory inquiry (n = 167)

Score range	*Number of learners per school per category*					*Total*	*Frequency as percentage*	*Nature of inquiry*
	School A	*School B*	*School C*	*School D*	*School E*			
20-40	0	0	0	0	0	0	0	Very low inquiry
41-60	2	2	1	0	4	9	5	Low inquiry
61-80	24	24	42	19	28	137	82	Medium inquiry
81-100	9	6	1	4	1	21	13	Very high Inquiry
Total	35	32	44	23	23	167	100	-

er has taught us to think critically when framing investigative questions. She guides us well and now we can frame good investigative questions which are measurable and achievable as she always hints (L6SCDInt2).

At this juncture, experiences of instruction as asking or framing questions for investigation and designing and conducting investigations appear to be open-ended on the inquiry continuum basing on the responses given by some of the students.

Another interesting finding is that all interviewed learners managed to link use of group practical activities to the idea that science is a co-operative activity. They said this helped them share ideas and help peer review and replicate each other's work in the process. In responding to the question, "how do you do the actual investigation?" one student from school C commented,

...we do it as groups and observe what actually happens during the course of the practical investigation. Doing it as individuals, we would not do the same thing as we would when we are in groups because we share ideas; like they say two heads are better than one. It is so helpful doing it in groups (L2SCInt11).

Another student from school B said

...when we do practical investigations, we are in groups. This has helped us at times to argue meaningfully. Our teacher at one time told us to go and think about how we would determine the relationship between volume and temperature of a gas when pressure is constant, that is, Charles' law I suppose, given balloons, measuring cylinders and some weights. We argued vehemently from the design, to procedures, data interpretation etc. That helped us think critically and argue [...eh...eh...eh] let me say argue scientifically (L17SBInt18)

The students raised the fact that science is not a solitary pursuit and as such scientists work in a community of practice and validate each other's work. It could also be said that students are aware of different and relevant pedagogy in the school context. If students are aware of advantages of co-operative grouping strategies, it might make them interpret laboratory activities not as similar (regarding level of practice) to what scientists do but simply as 'school science' as Chinn and Malhotra (2002) contend. This is because in school science learners are both cognitively and epistemologically limited as highlighted by Chinn and Malhotra unlike in authentic scientific inquiry. Some of the students' responses were suggestive of student awareness of the cognitive and epistemological limitations of school science. One student from school E during interviewing had this to say

...you see here at school, we lack the expertise and both resources and time to engage in real science. Most of the time, we perform confirmatory experiments to verify certain laws and theories and mostly we do these in groups so that we can help each other (L5SEInt14).

The students believed scientists in authentic scientific inquiry, are not limited compared to their own practice. One student from school D noted

...the way we do our investigations is completely different from that of scientists. As we do our practical investigations, we are more concerned with the confirmation of scientific laws, for example, Boyle's law. However, when a scientist like Boyle invented his apparatus, he had no yardstick. He tried his ideas several times until he came up with the Boyle's apparatus. That is the difference between our investigations and those of scientists. The focus of scientists is to solve real life persistent problems and ours is to confirm laws and theories (L3SDInt8).

Students' experiences of the scientific value of practical activities organized by the teacher appear to be impaired and distracted by the nature of the curriculum requirement in the sense that the two practical investigations they do are assessed and sent to the District for moderation and become part of the school-based assessment (SBA). The practical investigations contribute 40% to the Continuous Assessment (CASS) mark, which is school-based, meaning that this component has a huge weighting on the overall assessment. When asked 'at what stage do you stop working as a group?' two students expressed the sentiments of many by saying

...after collecting the results, each one of us will be on his own since we will start working on our investigation reports which are marked. Our teacher says the results can be the same but everything else has to be different (L1SCInt10).

...the teacher emphasizes always that group work is up to the data collection stage, thereafter, everyone is on his/her own. The teacher also says since the reports are going to be tak-

en to the District for moderation, they must not look the same though we are using the same results. At times it is confusing… (L2SDInt7)

This impairment and distraction could mean that the nature of instruction itself is a possible factor responsible for students not practising open-ended inquiry during investigations.

DISCUSSION

The goal of this paper is to add a new perspective on student experiences of inquiry-based laboratory investigations: particularly so from the African continent. As educators, we can appreciate the value of student experiences, and we can recognize their importance when designing and implementing curriculum reforms. The PSI-S survey instrument has proved to be a very useful tool for examining both the immediate and ongoing student reaction to their experiences of scientific inquiry. The high percentage of student participation in the survey supports the overall ease of use of this instrument and suggests that the cumulative results accurately reflect the opinions of a diversity of students.

From Table 1, it is clear that most students' (82%) experiences of laboratory inquiry were found to be generally moderate followed by very high inquiry as determined by the PSI-S instrument. These results would imply that students practised laboratory inquiry skewed more towards open-ended on the inquiry continuum. Dudu and Vhurumuku (2012) assert that the more closed the laboratory experiences the lower the level of inquiry, and the more open-ended the experiences the higher the level of inquiry. If students' experiences of their laboratory inquiry are taken as reliable indicators of the nature of instruction (Fraser 1998), it would mean that the laboratory instruction experienced by the students is largely student-centred. It could also mean that the existing culture in the students' science classrooms was associated with activities such as students connecting new knowledge to past experience, asking the questions for investigation, designing and planning investigations to solve problems, formulating hypotheses, deciding which observations to make and how to record the observations, independently interpreting data, engaging in discourse among themselves and with the teacher (openness of argumentation), seeking alternative explanations to problems, and applying information to solving novel problems (application of experimental findings). This finding corroborates the ideas of Osborne (2014), who suggested that the notion of inquiry has been conflated with the idea that inquiry requires students to handle, investigate and ask questions of the material world. However, this would contradict the findings of Vhurumuku (2011) who found Zimbabwean A-level Chemistry students experiences and perceptions of laboratory work to be generally low. Furthermore, anecdotal comments from semi-structured interviews given earlier provided additional insights on these findings.

Contrary to expectations, this study did find an overall significant difference between gender and student experiences of laboratory inquiry measured by the PSI-S total scores. The Mann-Whitney U test also showed that males and females differed in terms of their experiences of laboratory inquiry experiences measured by the PSI-S non-inquiry oriented item scores. This finding was unexpected and it is difficult to explain this result, but as Capps and Crawford (2014) suggest, it might be related to the possibility that participation in limited inquiry-based laboratory activities affect different groups of students in different ways and this warrants further investigation. However, the observed difference between gender and student experiences of laboratory inquiry measured by PSI-S inquiry oriented item scores was not significant. The absence of any significant difference between gender and student experiences of laboratory inquiry measured by PSI-S inquiry-oriented item scores is a positive result of the instructional design and educational value of practical investigations being conducted by students, suggesting that the format of these investigations is inclusive, and an important feature for retention of students in Physical science (Lotter et al. 2013). This latter finding is in agreement with Casem's (2006) findings which showed lack of a significant association between gender and the various aspects of the instructional design of undergraduate lower-division Biology core inquiry laboratories.

Student comments reveal enthusiasm for the opportunity to "perform open-ended investigations." However, frustrations with the curriculum and examination requirements are also expressed. It appears that curriculum and examination requirements limit learner autonomy .i.e. degrees of freedom or latitude given to learners to identify the materials to be used, plan and design their own procedures, identify the type of variables involved (control, independent, dependent), formulate a question or hypothesis, and determine how the variables can be manipulated, controlled, and measured (Chin 2003; Nivalainen et al. 2013). However, students were supported at the initial stages of framing or asking investigative questions. This initial phase is particularly important in that identifying a question plays an important role because it gives meaning and direction to what follows (Howes et al. 2009; Veal and Allan 2013). Classroom instruction encouraged group activities. Students were allowed to engage in the kind of laboratory interactions which can be described as promoting scientific argumentation, for example, arguing about the merits and demerits of procedures, hypotheses, data interpretations, and so forth. Classroom instruction encouraged the kind of classroom discourse described as characteristic of the practice of inquiry (Rogoff 1990, 2003).

CONCLUSION

In conclusion, students' comments did provide some anecdotal evidence that were suggestive of their awareness of the cognitive and epistemological limitations of school science. Students also appeared to perceive the benefit of the inquiry format during investigations and express support for the opportunity to participate in laboratory activities that mirror the authentic process of scientific discovery Students were supported at the initial stages of investigations and were allowed to engage in the kind of laboratory interactions which can be described as promoting scientific argumentation. However, a key finding that emerges from these results is the negative comments that continue to be expressed regarding curriculum and examination requirements that limit student autonomy to perform open-ended inquiry. This becomes an important variable that influences student experiences of the format and educational value of the inquiry laboratory experience. Results from this study indicate that implementation of limited inquiry-based laboratory investigations on certain concepts in high school chemistry classes increases the difference between male and female experiences. Possible reasons for these observed differences include the validation or confirmation value of hands-on activities, and value associated with alternative ways of acquiring knowledge in science, particularly discovery or open-ended inquiry.

RECOMMENDATIONS

This study attests to the usefulness and niftiness of the Principles of Scientific Inquiry-Student (PSI-S) instrument in that it enabled student's experiences of their classroom inquiry (their practice of inquiry) to be elicited. Research to further develop the PSI-S's instrument for purposes of assessing students' experiences of the nature of inquiry in other science laboratories (Physics, Chemistry and Biology) is recommended. Student responses to the PSI-S survey instrument appear to reflect their most recent experiences. It may be necessary to use other means of assessment to identify students' experiences of laboratory inquiry during investigations in order to corroborate the PSI-S instrument's results. Moving instruction from a focus on school based assessment (SBA) to an inquiry-oriented one might be helpful in the implicit translation of learners' laboratory experiences into more desirable inquiry practices (conceptions). This might help more students to make connections between their own laboratory experiences and the real nature of professional science and narrow the gap between school science inquiry and professional science inquiry. Given that this paper's findings point in the direction of some groups of students benefitting more from the inquiry process than others, more studies with results disaggregated by gender are needed to determine whether the inquiry method is most appropriate for all students.

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APPENDIX

This questionnaire wants to find out what you think about what you experience during science lessons. Indicate how often you think each of the activities listed happens during your science lessons by ticking (") in the appropriate box.

Item		*Almost never*	*Seldom*	*Some-times*	*Often*	*Almost always*
A	*Learners Ask Questions/Framing Research Questions: In the Science Classroom*					
A1	I formulate questions which can be answered by investigations					
A2	My research questions are used to determine the direction and focus of the lab					
A3	Framing my own research questions are important					
A4	Time is devoted to refining my questions so that they can be answered by investigations					
B	*Designing Investigations: In the Science Classroom*					
B1	I am given step-by-step instructions before they conduct investigations					
B2	I design their own procedures for investigations					
B3	We engage in the critical assessment of the procedures that we employ when we conduct investigations					
B4	We justify the appropriateness of the procedures that are employed when we conduct investigations					
C	*Conducting Investigations: In the Science Classroom*					
C1	I conduct my own procedures of an investigation					
C2	The investigation is conducted by the teacher in front of the class					
C3	I actively participate in investigations as they are conducted					
C4	I have a role as investigations are conducted					
D	*Collecting Data: In the Science Classroom*					
D1	I determine which data to collect					
D2	I take detailed notes during each investigation along with other data I collect					
D3	I understand why the data I am collecting is important					
D4	I decide when data should be collected in an investigation					
E	*Drawing Conclusions: In the Science Classroom*					
E1	I develop my own conclusions for investigations					
E2	I consider a variety of ways of interpreting evidence when making conclusions					
E3	I connect conclusions to scientific knowledge					
E4	I justify their conclusions					