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Lessons from Learners Evaluations of Their Science Fair Project Experience: A Case Study of a Regional Science Fair in South Africa
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KEYWORDS Expo for Young Scientists, science fair, principles of scientific inquiry, practical work, scientific investigations, creativity.

ABSTRACT The purpose of this study was to compare students' evaluations of their experiences of scientific inquiry in their science fair projects with the evaluations of their experiences of scientific inquiry in scientific investigations in the classroom. A mixed-methods approach was used involving a questionnaire survey and structured interviews. The survey design was used in which a convenient sample of 334 (105 males and 229) grades 7-12 learners from 34 Stellenbosch Region schools in South Africa responded to an adapted two-part Principles of Scientific Investigation (PSI-S) questionnaire designed and validated by Campbell et al. The questionnaire sought to determine the extent to which learners experienced science fair projects and classroom based scientific investigations to be conforming to scientific inquiry principles. The interviews sought to establish the main sources of science fair project assistance. Findings suggest that the science fair project experience was evaluated as offering significantly greater opportunities for learners to experience more authentic scientific inquiry than classroom scientific investigations. However, neither the science fair nor the classroom offered perfect scientific inquiry. The Internet, professional parents and public facilities such as libraries and science centres seemed to be the main sources of out-of-school support solicited by students. The implications are that science fair activities should be decentralised to afford mass participation. The state should expand school IT infrastructures to democratise Internet access

and narrow the gap between the haves and the have not's. Teacher education and development should be resourced to support teachers in entrenching authentic scientific inquiry in their classrooms.

INTRODUCTION

There has been a worldwide dissatisfaction with the quantity and quality of practical work in school science education despite the wide acceptance of practical work as an important bridge between theoretical science and empirical evidence (Ling & Towndrow, 2006). Quantitatively there has been a noticeable decline in the number of experimental activities carried out in school science (Dillion 2008) with teachers focusing mainly on what works for assessment. Qualitatively, Dillion (2008) adds that in the 1980s and 1990s there had been a loss of much of the inquiry and process emphases of the 1960s and 1970s. By the end of the 20th century, it is argued, practical work had largely diminished to a recipe-following ritual designed to reach particular, 'ready-made' or 'proven science' outcomes, with little intellectual input from the learners (Haigh 2007; Hodson & Benze 1998; Ling & Towndrow 2006). Some researchers (e.g. Hodson 1990; Roth 2002) have consequently described school laboratory activities less sympathetically as 'ill-conceived, confused and unproductive' (Ling & Towndrow 2006:1).

In the South African context the situation has fared no better in that more emphasis has been placed on routine science problems in a system where 50% of the teachers are not even qualified to teach science (Hobden 1998). If anything, efforts to offer learners high quality science education have been stymied by a democratisation of access to basic education unaccompanied by equal attention to addressing historical inequities in the provision of infrastructure, resources and qualified teachers to support the new edifice. Although Kahn (2011) reports that nationally the proportion of qualified primary school teachers subsequently rose from 63,2% in 1999 to 84,2% in 2005, while that of secondary schools rose from 73.1% to 87.1% in the same period as a consequence of a great attempt to improve teacher qualifications through the National Professional Diploma in Education (NPDE) (and later the Advanced Certificate in Education (ACE)), he concedes that post-apartheid efforts at teacher training have largely failed. Severe backlogs have been experienced more persistently in mathematics and science. This challenge is not peculiar to South Africa (e.g. see Ingersoll & Perda 2009) but universally experienced yet more endemic in developing countries bereft of resources. To complicate matters further, however, rapid changes in the curriculum, administrative overload, and the increasing emphasis on learner performance on high-stakes exams, have meant that enormous pressure has been brought to bear on South African science teachers to simultaneously cope with the seemingly extraneous demands of practical work. Madas (1999:74-75) warns against the dangers of using measurement as the engine, or primary motivating power of the educational process since measurement-driven instruction can lead to rote learning and constrain the creativity and spontaneity of educators and learners. The Expo for Young Scientists (Expo), a science fair organised annually in South Africa courtesy of sponsorship from ESKOM (an acronym for Electricity Supply Commission, South Africa's power utility), provides learners, with a reprieve to experience inquiry science first hand by preparing, entering and presenting their own scientific investigation projects for exhibition out of their own volition.

A defining objective of the Expo for Young Scientists is to stimulate, recognise, promote and reward learner initiated scientific investigations, projects or inventions, among other activities. Judging is based on criteria which include originality, proficient application of the scientific method, thoroughness of the research effort, clarity of the written research report, and oral communication of results. In tandem with scientific inquiry principles students are expected to draw conclusions and results from evidence and analytical tools to derive a scientific claim (Olson & Loucks-Horsley 2000). In its Curriculum and Assessment Policy Statements (CAPS) for science, the DBE (2011:122) distinguishes between an experiment which is conducted to verify a known theory and an investigation which is an experiment to test a hypothesis the outcome of which is not known beforehand. The emphasis on scientific investigations, therefore, admits to a commitment to provide students with opportunities to experience inquiry in science classrooms (Lunetta et al. 2007). Asay and Orgill (2009) contend that an inquiry approach provides an environment in which meaningful science learning can occur, where students can develop the ability to critically evaluate scientific data, develop scientific ways of thinking and begin to understand the nature of science, what it means to do science and to participate in a scientific community. Students who use inquiry to learn science engage in many of the same activities and thinking processes as scientists who are seeking to expand knowledge of the natural world (National Research Council 1996). The Expo thus provides learners with an early engagement and apprenticeship into the ways of doing and thinking about science. In the process mathematics forms an integral part of scientific analysis and some have viewed it as the new microscope of science.

The Stellenbosch Regional Expo is organised annually by the Institute for Mathematics and Science Teaching (IMSTUS) as a distinctive part of the University of Stellenbosch's community interaction programme in which the university, as a knowledge partner, aspires to be relevant to the knowledge needs of its community. Over the years a major challenge has been to stimulate and sustain quantitatively and qualitatively high levels of participation from learners in disadvantaged schools. The remainder of this report first examines the role that scientific investigations ought to play in the broader context of practical work in the school science curriculum. Secondly, research questions are framed, an outline of the research methodology given and the results discussed. Finally, implications are drawn for preservice and inservice science education support systems.

INVESTIGATIVE/INQUIRY WORK IN SCHOOL SCIENCE

A number of terms have been used to describe practical work including: 'practical and inquiry skills', 'practical and investigative activities', 'independent enquiry', 'experimental work', and 'learning experiences in which learners interact with material or with secondary sources of data to observe and understand the natural world' (Dillion 2008; Lunetta et al. 2007). Although scientific investigations offer students the opportunity to conduct complete scientific inquiries into authentic questions generated by themselves (National Research Council 1996), inquiry is often inadequately understood by teachers many of whom have had very little or no experience of it at both school and undergraduate level (Melville et al., 2008; Windschitl 2002). It is therefore important to distinguish among various forms of inquiry. Olson and Loucks-Horsley (2000) define inquiry as a multifaceted activity that involves making observations, posing questions, examining books and other sources of information to 'see' what is already known, planning investigations, reviewing what is already known in light of experimental evidence, using tools to gather, analyse and interpret data, proposing answers, explanations and predictions and ultimately communicating the results.

In their attempt to simplify inquiry instruction, Bell, Smetana, and Binns (2005) emphasize that not all inquiry activities are created equal nor are all worthwhile activities necessarily inquiry-based. They have built on Schwab's (1962) different levels of inquiry, Herron's (1971) model of three levels of inquiry, Rezba, Auldridge and Rhea's (1999) four levels of inquiry instruction as well as the NRC (2000) inquiry rubric, to arrive at a two-dimensional four-level framework of inquiry as shown in Table 1.

<Insert Table 1 about here>

The first dimension of the model deals with the degree of structuring or amount of information provided to the student (research question, method and/or solution), resulting in a continuum ranging from highly teacher-directed to highly student-directed activities. A Level 1 inquiry (Rezba et al. 1999) is referred to as *confirmation*. At this level students are provided with the question, follow a predetermined procedure and expected results are known in advance. A Level 2 investigation is *structured inquiry* in which students investigate a teacher-presented question through a prescribed procedure. A Level 3 investigation is *guided inquiry* where students investigate a teacher-presented question using student designed/selected procedures. A final or Level 4 investigation is *open inquiry* in which students investigate their own questions on a topic through student formulated procedures to obtain their own (unknown) results. Bell et al (2005) point out that science fair projects are perhaps the most common form of Level 4 inquiries in science classrooms in that students investigate student-formulated, topic related questions and use their own procedures to arrive at their own results. This dimension of the model 'allows the teacher to tailor inquiry lessons to the particular readiness levels of the class' (Bell et al. 2005:31) as part of scaffolding inquiry from one level to the next. For example a Level 1 activity can become a Level 2 activity if students complete it prior to learning the targeted concept and a Level 2 activity can be revised to Level 3 by removing the procedural prescriptions. In other words, as students gain knowledge and confidence the constraints of inquiry can be relaxed for increased student independence (Toth, Brem, & Erdos 2009).

The second dimension is that of complexity or the level of openness and the cognitive demands (Bell et al. 2005) which varies from low-level (confirmatory inquiry) to high-level (open inquiry) activities. Students cannot be expected to conduct high-level inquiry investigations if they have participated exclusively in low-level activities throughout the year (Bell et al. 2005). They will need practice in inquiry building up to increasingly open and complex levels. Students will reap as little benefit from being thrown unprepared into Level 4 inquiry activities as they will from being held at low-level activities (Bell et al. 2005).

BOURDIEU'S SOCIO-CULTURAL CAPITAL AS A LENS FOR INTERPRETING OUT-OF-SCHOOL ASSISTANCE RECEIVED BY LEARNERS

Bourdieu's concept of cultural capital has been used as a theoretical lens in more studies than in any of his other theoretical concepts (Lamont & Lareau 1988). Bourdieu (1986; 1987) refers to four different forms of capital which he terms fundamental social powers. They include economic capital consisting of financial resources (e.g. occupation as economic indicator), *cultural* capital consisting of informational resources (e.g. linguistic and scientific resources), *social* capital consisting of resources based on connections and group membership (e.g. occupation as indicator of position in social space), and *symbolic* capital consisting of the form the different types of capital take once they are perceived and recognised as legitimate. He argues that the relative value of the different species of capital is continually being debated (Bourdieu, 1987). Sullivan (2002; 2003) points out that Bourdieu's cultural capital can loosely refer to cultural traits that help people to gain educational success. She further adds that the possession of cultural capital varies with social class. In other words, the influence of cultural capital on educational participation cannot be discussed in isolation of social capital which, in turn is determined to a large extent by economic capital. By analysing students' responses regarding the kind of out-of-school support they received or actively sought, this study might shed insight on how students can differentially accumulate capital to participate in the science fair and hence potentially obtain a differentially richer experience of inquiry science.

RESEARCH QUESTIONS

The aim of this study was to investigate science fair students' evaluations of their involvement in scientific investigations in the science classrooms and in their Science fair projects. More specifically, the following research questions guided this study: How do participating learners evaluate their experience of scientific investigations in their science classrooms in relation to student directedness and teacher directness? How do the learners evaluate their Science fair project experience in relation to student directedness and teacher guidance? How do the two experiences differ from each other?

METHODOLOGY

Sample

In this study a total of 334 grade 7-12 out of 360 learners from 34 schools which participated in the 2012 Stellenbosch Regional Expo for Young Scientists volunteered to complete the questionnaire. This constituted a relatively high return rate of 93%. Traditionally, learners have been regarded as consumers of readymade scientific knowledge and not worth consulting; a neglect that Rudduck and Flutter (2000) contend sat increasingly uncomfortably alongside the market philosophy espoused in many societies today. Accommodating the learners' voice about the quality of their school science education involves seeing them less as part of the problem of raising standards in school science and more as a key element in its resolution (Jenkins 2006).

Questionnaire

The survey questionnaire method was chosen to cover as many participants as possible during the limited time of the science fair. Campbell et al.'s (2010) Principles of Scientific Investigation (PSI-S), a Likert-type questionnaire for students, was adapted and split into a two-part questionnaire. Both parts consisted of 20 questions apiece which sought to elicit learner evaluations of scientific investigations in the science classroom and in the science fair project respectively as well as open-ended questions which sought to solicit information about additional sources of help received or sought to conduct the scientific investigations in the classroom or the science fair project. Another modification was to change 'student' to 'learner' in keeping with the South African educational parlance. The 5-point semantic scale ranged from 'Almost Never-1' to 'Almost Always-5' (see appendix). The administration of two similar questionnaires simultaneously amounted to a retrospective pre-post design which has the advantage of counteracting response-shift or change in the internalised standard by which a subject rates himself (Pohl, 1982). The students could therefore compare their science fair project experience with their routine classroom experience of science

Questionnaire reliability

As already noted earlier, the first part of the questionnaire was a slight modification of Campbell et al.'s (2010) questionnaire to solicit student evaluations of inquiry experiences in science classrooms. The Cronbach alpha reliability obtained by Campbell et al. (2010) for this instrument was 0.82 for 130 high school science students which, according to conventional limits for reliability estimates (i.e. Nunnally & Bernstein 1994), equated to a high level of internal consistency. In this study involving 334 students the estimate obtained was 0.89 for classroom experience (Part 1) and also equated to a high level of internal consistency. Part 2 of the questionnaire had identical categories and the same number of items as the first part with the only difference being the changes in the wording to solicit self-reported learner evaluations of the science fair project. The estimate for the 334 students in this study was 0.89 which also equated to a high level of internal consistency.

RESULTS

Quantitative results

Learner evaluations of scientific inquiry in the science classroom

Figure 1 summarises responses to the first part of the questionnaire with questions grouped according to the five inquiry principles as outlined in Campbell et al. (2010), namely framing research questions (A1-A4), designing scientific investigations (B1-B4), conducting scientific investigations (C1-C4), collecting data (D1-D4) and drawing conclusions (E1-E4).

<Insert Figure 1 about here>

On average the learners' involvement in formulating research questions that can be answered by scientific investigations (A1) was rated closer to Often than Sometimes but the use of the research questions to determine the direction and focus of the laboratory activities (A2) was rated closer to Sometimes. Encouragement of learners to frame their own research questions (A3) was rated as occurring slightly more frequently than Often while time devoted to refining learner questions (A4) was rated slightly below Often. The reliability estimate for questions in this category was a moderately high 0.76. The rating on whether learners were given step-by-step instructions before they conducted investigations averaged above Often while learner opportunities to design their own procedures was rated marginally below Often showing greater presence of teacher direction than learner direction in methodological design. Engagement of learners in the critical assessment of procedures (B3) and justification of their appropriateness (B4) were both rated closer to Often than Sometimes. The reliability estimate for questions B1-B4 was a moderate 0.61. Learners nearly Often conducted their own procedures of an investigation (C1) but at the same time surprisingly rated teacher conduct of experiments/investigations in front of the class (C2) as occurring almost as frequently. Learners, however, actively participate in investigations as they are conducted (C3) a little above Often times even though individual learner's participation (C4) is less frequent. The reliability estimate of the questions in this category of conducting experiments was unsurprisingly a low of 0.41. Learner involvement in data collection (Category D) and drawing of conclusions (category E) were perceived as a occurring more than Often across the board. The respective reliability estimates for these categories were a moderately high 0.71 and a high 0.81. Applying a scale of Very Low ($1<x<2$), Low ($2<x<3$) Moderate ($3<x<4.$), High ($4.0<x<4.5$), Very High ($4.5<x<5$) it can be concluded that the formulation of research questions, design and conduct of investigations, and the gathering of data were moderately high in the classroom whereas the drawing of conclusions by learners was perceived to be occurring at a high level of frequency. This would make classroom experience of scientific investigations semi-structured partly student directed and partly teacher directed.

Learners' evaluations of scientific investigation in the science fair project

Figure 2 summarises responses to the second part of the questionnaire with questions grouped into five categories as in the first part.

<Insert Figure 2 about here>

On balance the category of learner involvement in formulating research questions (Category A) was rated as having occurred very Often across the board with respect to the science fair project scientific investigation. The reliability estimate for questions in this category was a high of 0.81. The rating on whether learners were given step-by-step instructions before they conducted investigations averaged fractionally below Often while learner opportunities to design their own procedures (B2) engage in critical assessment of their procedures (B3) and justifying them (B4) were all rated to have occurred greater than Often. The reliability estimate for questions in the Category B was a moderate 0.57. Learners more Often than not conducted their own procedures of the science fair project investigation (C1), actively participated as the investigation was conducted (C3) and each had a role as the investigation got under way (C4). Learners unsurprisingly rated teacher involvement in the conduct of investigations (C2) as having occurred midway between Seldom and Sometimes. The reliability estimate of the questions in this category of conducting experiments was a very low of 0.04 owing to the strong negative correlation with C2. Learner involvement in data collection (Category D) and drawing of conclusions (Category E) were perceived as having occurred more frequently than Often across the board. The respective reliability estimates for these categories were highs 0.81 apiece. Applying the same scale of Very Low ($1<x<2$), Low ($2<x<3$) Moderate ($3<x<4.$), High ($4.0<x<4.5$), Very High ($4.5<x<5$) it can be concluded that the formulation of research questions, design of investigations, gathering of data were perceived to have occurred at a high level of learner autonomy in the science fair project whereas the conduct of investigations was perceived to have occurred at a moderately high level of independence. This would make classroom experience of science fair scientific investigations more student-directed and much less teacher-directed. This is more so considering the strong negative correlation of question C2 (teacher conduct of investigation). The level of the open-endedness can be tentatively rated as having been guided in that learners got assistance with refining their research questions and the design of the investigations and carried out the rest of the steps on their own.

Comparison of the science classroom experience with the science fair experience

Figure 3 shows individual question differences in the learner evaluations of their classroom and science fair experience of scientific investigations.

<Insert figure 3 about here>

It is evident that overall, learners perceived the science fair project as meeting the principles of scientific inquiry more than in their normal science classrooms. Figure 4 shows the chi-square values for each question and the corresponding *p*-values computed using an online QuickCalcs calculator (Available from: http://www.graphpad.com/quickcalcs/ttest2) The differences were extremely statistically significant for 19 of the questions at $p<0.0001$ suggesting a confidence level of 99.999%.

<Insert Figure 4 about here>

The *p* value of 0.0052 for question A3 meant the Chi-square value was very statistically significant suggesting a confidence level higher than of 99.99%. To all intents and purposes, therefore, the difference between the science classroom and the science fair experience was perceived to be extremely statistically significant.

<Insert Figure 5 about here>

The online QuickCalcs calculator was additionally used to perform a Student *t*-test. A *t* value of 9.7696 was obtained for dependent samples with 333 degrees of freedom and a standard error of difference of 0.030. The two-tailed *p* value obtained was less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant. Hence it can be reaffirmed with 99.999% confidence that the science fair scientific investigation project was perceived differently from the science classroom experience.

Qualitative Results

Good research practice obligates the researcher to triangulate in order to enhance the validity of research findings (Mathison, 1988). In the spirit of that obligation, the open-ended sections of the questionnaire were analysed to gain insight into what the learners perceived to be major sources of additional support for their scientific investigation experiences. Only a total of 60 learners completed the open-ended sections. The responses were coded and Wordle

(Available from: http://www.wordle.net) an open source word cloud analysis tool, was used to analyse the patterns of support experienced by learners. Figure 6 shows the word cloud for the science classroom experience. The following were some of the learner remarks: ‘There are labs, but the teacher is doing experiments for us’, ‘The only support comes from parents or the ‘science centre’, ‘We went to an internet café to collect information’; our microscope was provided by the school’, ‘The equipment used is of a poor quality’, The internet is an excellent source of information, but school children should be made aware of plagiarism offenses’. The use of the internet as an additional support predominated while some evidence of teacher directed confirmatory investigations also featured. Some learners indicated lack of laboratory facilities or time for laboratory work at school.

<Insert Figure 6 about here>

Figure 7, on the other hand, shows the pattern of sources of support in the implementation of the science fair project. Although the internet again featured strongly the home environment per se appeared to be the dominant source of support for the science fair suggesting more teacher independent learner engagement with science. Examples of comments given included: apparatus as school are limited, all research was done at home’, ‘My mom and dad help me with my studies’, ‘I used internet and books at home’, ‘I received support and guidance from my engineer father as well as my expo advisor Mrs X’, ‘My grandfather helped, guided me to set up and conduct my experiment as it involves working with chemicals’. There was also greater support received from out-of-school sources other than home as shown by such comments as: ‘The product designer helped me with the dilution of the concentrate’, ‘We used Mr X’s cryogenic equipment for the science fair project’, ‘I went to see optometrists’, ‘I used doctors, physicists, etc. to help and check my hypothesis and conclusion’, and ‘We joined the West Coast Science Centre and received extra help for the science fair’.

<Insert Figure 7 about here>

The increased autonomy of the learner in the science fair investigation was epitomised by learner remarks such as: ‘I had minimal help as I believe it is not the prize or acknowledgments you get, but what I have learnt as an individual’, ‘I made use of internet facilities at the school, home and library’. On the whole the results appeared to corroborate differences between science classroom and science fair experience with respect to learner and teacher directedness of scientific investigations.

DISCUSSION OF RESULTS

Campbell et al. (2010) point out that initial examination of the scree plot and eigenvalues related to the PSI-S scores in their study suggested a two-factor solution which accounted for 37.34% of the variance in respondent scores after an oblique rotation. In this study, with a larger group of learners, the two factors (analysed using Version 20 of SPSS) accounted for 41.86% of the variance in the science classroom experience and 48.97 % of the variance in the science fair project experience. Factor 1, accounting for 33.67 % of the variance in science classroom experience and 42.01% of the variance in the science fair project experience in this study, aligns with 'those aspects of scientific inquiry that have traditionally been overlooked in science instruction, student framing of research questions and student designing investigation' (Campbell et al 2010:23). The 10 questions loading to this factor were A1-A4, B2-B4, D1-D2 and D4. The Cronbach's alpha estimates of internal consistency for Factor 1 were 0.83 for science classroom experience and 0.89 for the science fair experience representing a high degree of internal consistency between the items. Factor 2, accounting for 8.19% of the variance in science classroom experience and 6.96 of the variance in the science fair experience in this study aligns with those aspects of traditional methods of instruction that teachers are more comfortable employing, students conducting investigations and drawing conclusions (Campbell et al 2010:23). The 10 questions loading to this factor were B1, C1-C4, D3, and E1-E4. The Chronbach alpha estimates of internal consistency for Factor 2 were 0.76 for the science classroom experience and 0.71 for the science fair experience representing a moderately high degree of internal consistency. Table 2 shows a proposed revision of Bell et al's (2005) categorisation from a continuum of four levels to that of six levels to account for the five categories or principles of scientific inquiry highlighted in this study.

<Insert Table 2 about here>

A comparison of learners' experience of scientific investigations in the classroom and the science fair project based on the identified categories and levels should sensitize teachers and teacher educators to ways in which teachers can be encouraged to adopt an inquiry approach in their professional practice. Increased learner participation in the science fairs could in turn widen opportunities for authentic inquiry and authentic experience of the nature of science (NOS). The NOS involves an understanding of the epistemic values, methods, and institutional practices of science, an experience of the inner workings of science-in-the-making, the thrill of discovering or creating new knowledge and an emancipation from the authoritarian view of knowledge as unquestioned wisdom (Osborne et al. 2003; Latour 1985; Claxton 1991).

Windschitl's (2002:113) raises concern about the vast majority of preservice science teachers entering initial preparation programmes without having conducted a single inquiry in which they have developed a question of interest and designed the investigation to answer that question. There should therefore be a deliberate effort to encourage teachers more aggressively to move away from the traditional comfort zone and embrace the principles of scientific inquiry. It is unreasonable, for example, to assume that such teachers will spontaneously embrace the idea of using open inquiry or scientific investigations with their own students (Windschitl 2002). In a sense, intervention strategies can be instituted to provide opportunities for both preservice and inservice teachers to conduct their own open inquiries and for them to obtain first-hand experience of the NOS which they can eventually relate to and radiate in their own classroom practice. Additionally, teachers can play critical roles in the inquiry process of their learners by appropriately scaffolding ideas and investigative activities, asking questions to help them verbalise their ideas about concepts, and by comparing and contrasting students' ideas with those of scientists (Lunetta, Hofstein, & Clough 2007) in each of the identified categories of scientific inquiry.

One implication for policy makers and resource allocators is the democratisation of Internet access in schools given that it was recently recognised as 'an indispensable tool for realising a range of human rights, combating inequality, and accelerating development and human progress' (United Nations 2011:22). The differential learner access to the Internet and such basic ICT gadgets as noted by Taylor (2011) implies unequal opportunities for success not just for science fair project presentation purposes, but also for mathematics and science education generally.

CONCLUDING REMARKS

This study set out to investigate the differences in which learners perceived their experience of scientific investigations in the science classroom and the science fair project. The findings were that the experience of scientific inquiry principles was extremely statistically different virtually in all questions and principles of inquiry suggesting that the normal classroom deprives learners of the authentic experience of the NOS. Practical work should not be diminished to a recipe following confirmatory ritual but rather should be conducted and experienced in a manner that extends the intellectual input of learners, lessens confusion and results in more productive science learning. Practicing teachers, particularly those from disadvantaged schools, need to be supported through university-school partnerships to overcome the challenges of inadequate experiences with learner-centred, scientific inquiry discourses. The unequal resourcing of school infrastructure in the form of laboratories, libraries, ICT facilities and internet connectivity can constrain and lead to unequal opportunities for effective participation in the science fair and prevent schools from teaching science and mathematics effectively - the gateway subjects to high exchange careers in today's knowledge economy. This study, therefore, affirms Taylor's (2011) finding that the science fair may not be the best vehicle for encouraging learners from historically disadvantaged schools to participate in science as not many home environments of such learners can be supportive enough. Internet access appears to be a resource with great potential to lighten the teacher's burden but whose availability to disadvantaged learners, teachers and communities is scarce.

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Appendix (Table 3): Principles of Scientific Inquiry Questionnaire for Students (PSI-S)

	PART 1: LEARNER EXPERIENCES IN SCIENCE CLASSROOMS	
A	**Asking questions/framing research questions: in the science classroom**	
1	Learners formulate questions which can be answered by investigations	
2	Learner research questions are used to determine the direction and focus of the lab	
3	Learners are encouraged to frame their own research questions	
4	Time is devoted to refining learner questions so that they can be answered by investigations	

B	**Designing investigations: in the science classroom**	
1	Learners are given step-by-step instructions before they conduct investigations	
2	Learners are given an opportunity to design their own procedures for investigations	
3	Learners engage in the critical assessment of the procedures that are employed when they conduct investigations	
4	Learners justify the appropriateness of the procedures that are employed when they conduct investigations	
C	**Conducting investigations: in the science classroom**	
1	Learners conduct their own procedures of an investigation	
2	The investigation is conducted by the teacher in front of the class	
3	Learners actively participate in investigations as they are conducted	
4	Each learner has a role as investigations are conducted	
D	**Collecting data: in the science classroom**	
1	Learners determine which data to collect	
2	Learners take detailed notes during each investigation along with the data they	
3	Learners understand why the data they are collecting is important	
4	Learners decide stage when data should be collected in an investigation	
E	**Drawing conclusions: in the science classroom**	
1	Learners develop their own conclusions from investigations	
2	Learners consider a variety of ways of interpreting evidence when making	
3	Learners connect conclusions to scientific knowledge	
4	Learners justify their conclusions	

		How much information is given to the student?		
	Level of Inquiry	**Question?**	**Methods?**	**Solution?**
Teacher-Directed	**1- Confirmation**	✓	✓	✓
↕	**2- Structured**	✓	✓	
	3- Guided	✓		
Student-Directed	**4- Open**			

Table 1: Four-Level Model of Inquiry (adapted from Bell, Smetana, & Binns 2005)

		How much information is given to the student?				
Teacher -	**Level of Inquiry**	**Framing research**	**Design of investigat**	**Conduct of**	**Data collection**	**Drawing conclusi**

Directed		questions ?	ion?	investigation?	?	ons?
	1–Confirmation	✓	✓	✓	✓	✓
	2–Structured	✓	✓	✓	✓	
	3–Semi-structured	✓	✓	✓		
Student-	4–Guided	✓	✓			
Directed	5–Partly-guided	✓				
	6–Open					

Table 2: Revised levels of inquiry for this study

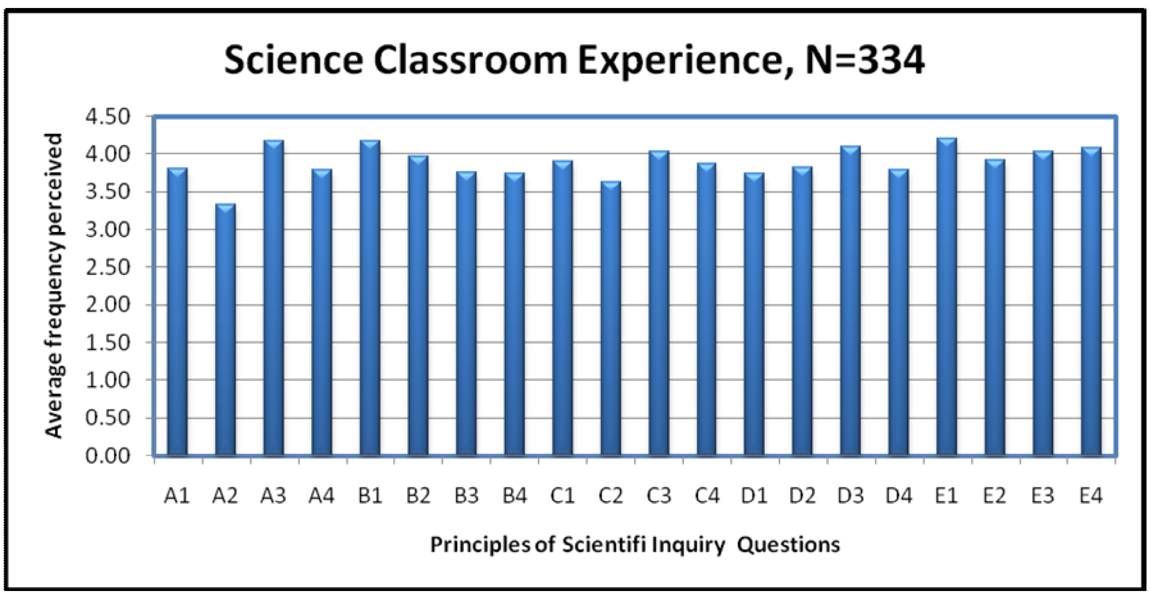

Figure 1: Learners' views about scientific investigations in the science classroom

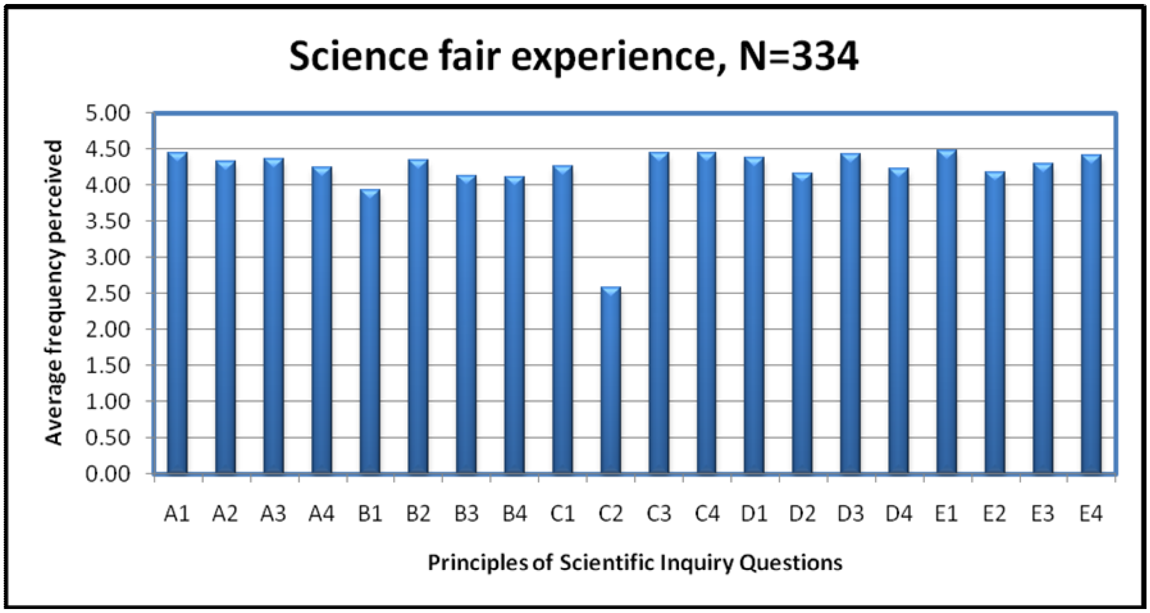

Figure 2: Learners' views about their science fair project experience

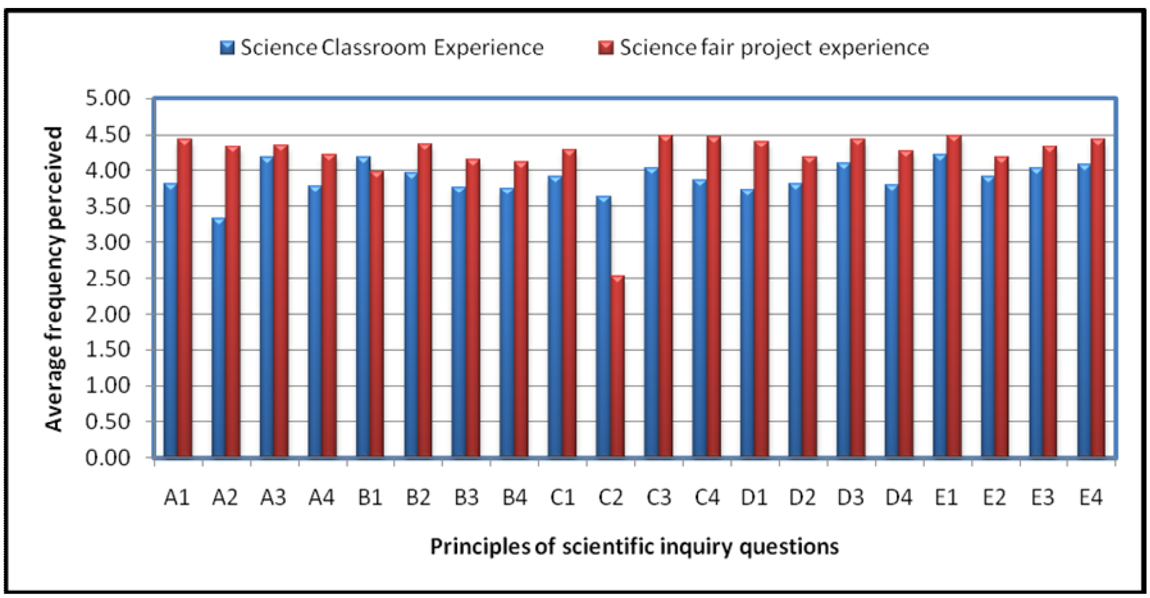

Figure 3: Differences in learner evaluations of science classrooms and the Expo project by individual questions

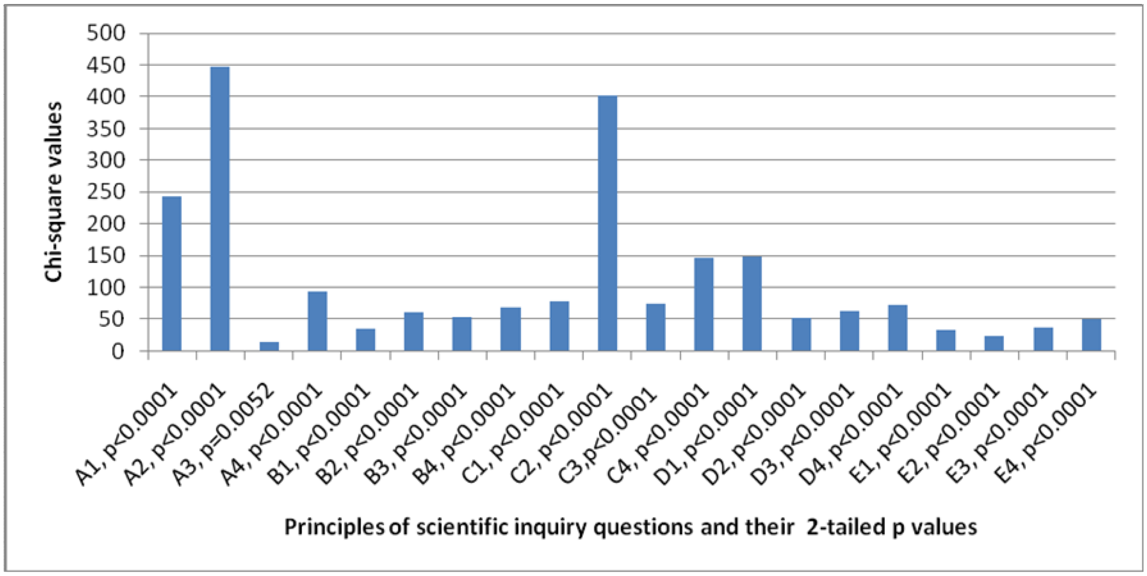

Figure 4: Chi-square values by question

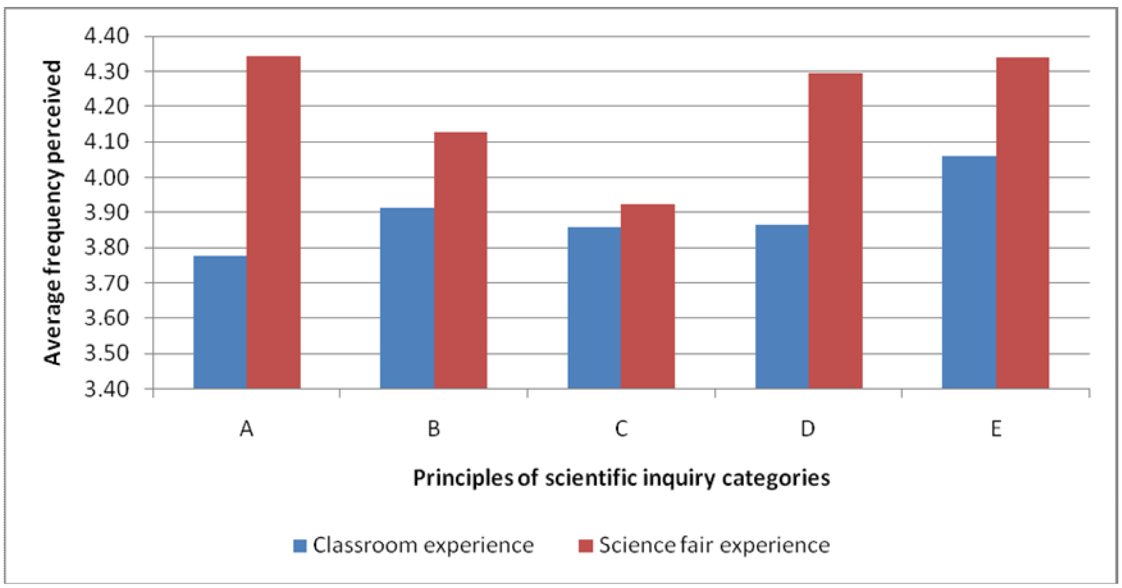

Figure 5: Differences in learner evaluations of science classrooms and the Expo project by PSI category

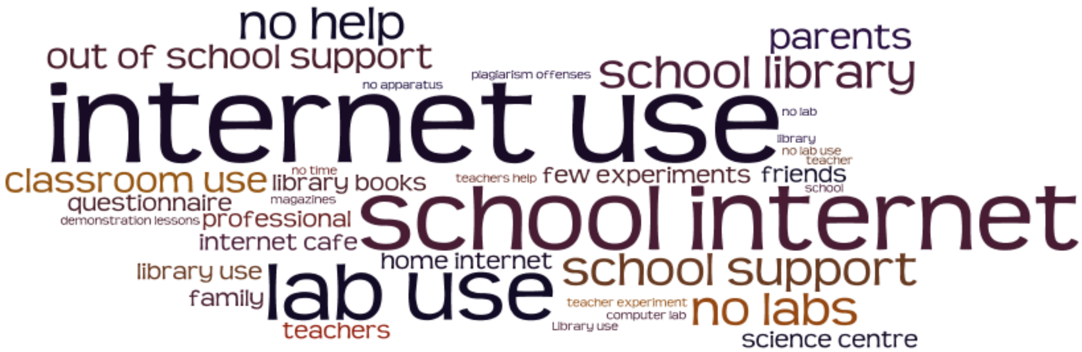

Figure 6: Science classroom experience

Figure 7: Science fair project experience