INQUIRY OPPORTUNITIES PRESENTED BY PRACTICAL WORK IN SCHOOL PHYSICAL SCIENCES. A SOUTH AFRICAN CASE STUDY

Maria Tsakeni
School of Mathematics,
Natural Sciences and Technology Education
Qwaqwa campus
Saloshna Vandeyar
Department of Humanities
Faculty of Education
University of Pretoria
Marietjie Potgieter
Teaching and Learning
Faculty of Natural and Agricultural
University of Pretoria

Abstract

Inquiry underlies most science curriculums. There is a widespread belief that inquiry is a both 21st century skill and a vehicle to develop other 21st century skills in learners. Engaging learners in science process skills helps them to engage in inquiry through practical work. The result of integrating inquiry and practical work is a strategy called inquiry-based practical work. While this strategy is embodied in current science curriculums, it is often not easy to implement in science classrooms. This study explored inquiry opportunities presented to learners through practical work in the context of the Curriculum Assessment Policy Statement (CAPS) syllabus in South Africa. We regarded inquiry as a continuum with the levels of complexity defined according to learner autonomy over the science process skills, question formulation, experiment procedure design and solution finding. The variation in learner autonomy over the process skills results in four types of inquiry through practical work, which are confirmation, structured, guided and open-ended. A qualitative research approach in the form of phenomenon-based case study was used. Four research sites representing different school contexts were purposely selected. On each research site, one physical science teacher and one physical science class participated in the study. Data were generated by means of semi-structured interviews with teachers, focus-group interviews with learners and direct practical work activity observations. The study identified structured inquiry as the highest level of inquiry practised in the classrooms. However the structured inquiry was practised in four different ways depending on how learners were given autonomy over, the science process skills question posing, experiment procedure design and solution finding. The teachers ensured that the learners had autonomy over one or two but not all three of the process skills. The study recommends further studies to explore how the teachers can reduce the scaffolding for learners in order for them to engage in higher levels of inquiry such as the guided and open inquiry as part of the 21st century skills.

Keywords: *inquiry; inquiry-based practical work; physical sciences; practical work*

Introduction and background

Science practical work continues to capture the interest of researchers because of the many and evolving functions that it has for science teaching and learning. Reid and Shah (2007) assert that the original purpose for practical work in science was to prepare skilled technicians for industry and capable workers for research laboratories. However, according to Hofstein and Lunetta (2004), practical work is important in the science classrooms for (i) captivating the interest and motivation of learners (ii) understanding scientific concepts (iii) developing scientific practical skills and problem-solving abilities (iv) understanding the nature of science and (v) developing scientific habits. One of the scientific habits is the ability to conduct scientific inquiry. Inquiry and problem-solving are some of the fundamental 21st century skills that can be developed in science classrooms through practical work. Currently, there is not a single list of what constitutes 21st century skills. However, in one of the lists, the 21st century skills are clustered in five major themes or domains (National Research Council, 2008). The identified domains of 21st century skills are (i) adaptability, (ii) complex communication and social skills, (iii) non-routine problem solving, (iv) self-management and self-development, and (v) systems thinking. Bybee (2009) shows a relationship between a model of inquiry in science and the domains comprising the 21st century skills. Turman, Omar, Daud and Osman (2012) affirm that there is an intersection between science process skills such as those for inquiry-based practical work and the 21st century skills. Accordingly, practical work is a central feature of science. In addition, there are widespread beliefs that practical work is one of the vehicles of implementing inquiry-based science education (Ramnarian, 2014a; Dudu, 2014). In South Africa, experiments are some of the practical work activities contained in the Curriculum Assessment Policy Statements (CAPS) for physical sciences (Department of Basic Education, 2011). The inclusion of prescribed and recommended experiments for assessment in the science curriculum implies that learners have to be engaged in some forms of scientific inquiry in the science classrooms. Akuma and Callaghan (2019) observed that the use of inquiry-based practical work in South Africa is constrained due to material and non-materials challenges. Accordingly, this study explored inquiry opportunities for learners presented by practical work.

3. Conceptual framework: The construct of inquiry

The operational definition of inquiry used in this study assumes that inquiry is practised in varying degrees in school science (Herron, 1971; Ramnarain & Hobden, 2014). The inquiry-based activities practised in school science may range from teacher-directed and guided inquiry to learner-guided inquiry (Sadeh & Zion, 2009; Abd-el-Khalick *et al.*, 2004; Lunetta, Hofstein & Clough, 2007). School learners are not regarded as professional scientists (Kirschner, 1992). Lunetta *et al.* (2007) agree that inquiry practised by novices such as school learners differs significantly from inquiry practised by expert scientists. While the expert scientist engages in a search for new discoveries in the field of science, learners engage in activities to learn the subject matter (Kirschner, 1992). In addition, learners may also learn some process skills mentioned in the next paragraph.

Among the many interpretations of inquiry is the view that inquiry is a set of learners' skills (Barrow, 2006). The list of skills as reported in literature can be quite lengthy. However, some of the skills include identifying problems, formulating questions, designing and conducting investigations and formulating, communicating and defending hypotheses, models and explanations (Abd-el-Khalick *et al.*, 2004). In school science, it is not always possible for learners to practise all these inquiry actions in one practical activity. Practising all these actions in one practical activity would mean engaging learners in open inquiry (Kirschner, 1992; Lunetta *et al*., 2007). Cheung (2007) posits that not all school science practical work has to be open inquiry. The realisation that not all inquiry should be open-ended in the science classrooms takes into account that inquiry is not only used as an instructional strategy but that it is also regarded as part of the content. Learners need time to learn all the necessary skills that constitute inquiry gradually. Accordingly, a practical activity may be structured in such a way that learners practise and develop particular inquiry skills. Furthermore, as an instructional strategy, inquiry is used to serve different purposes for the achievement of the various science educational goals (Cheung, 2007).

Over the decades, attempts have been made to develop rubrics and tools to describe the inquiry continuum. One such rubric by Schwab (1962) and Herron (1971) has stood the test of time. The rubric utilises the extent of learner/teacher control over question posing, experiment procedure design and solution finding as criteria to determine the complexity of inquiry. The rubric was chosen as conceptual framework for this study. This rubric has four levels of inquiry, which are confirmation, structured, guided and open inquiry (Herron, 1971; Ndlovu, 2013; Chueng, 2007; Kellow, 2016, Akuma & Callaghan, 2019). For confirmation inquiry, learners are provided with the question, the experiment procedure and the solution. In structured inquiry, learners are either provided with the question and the procedure. Both confirmation and structured inquiry may be used in practical activities meant for verification of previously learnt scientific concepts. However, for structured inquiry the solution may also be known in advance by the teacher and not necessarily by the learners (Chueng, 2007). In guided inquiry, the solution is unknown in advance and the learners are guided by being provided a question. In open inquiry, learners generate all three, the question, the procedure and the solution.

4. Methodology

The research adopted a qualitative approach and a multiple case study research design with a purpose to explore inquiry opportunities presented by practical work in school physical sciences. The case study was on the manifestation of a phenomenon using more than one individual (Creswell, 2007). The phenomenon was learner experiences of inquiry when conducting practical work in the context of the CAPS syllabus. Semi-structured interviews with teachers, focus-group interviews with learners and lesson observations were used to gather data. The interviews with the teachers were to elicit their views of inquiry and the manner in which they were facilitating inquiry for learners in the context of the CAPS syllabus. The interview protocol contained questions that directly focused on the practice of inquiry-based laboratory work to ensure internal validity. Whilst the interview questions were guided on the one hand, on the other hand the teachers were allowed to narrate the stories of their experiences freely so that they could include all the things they deemed relevant. Accordingly, narratives of their experiences were captured in their entirety. The focus-group interviews elicited the learners' experiences with inquiry-based practical work as the teachers facilitated it. Six learners from each school participated in the focus-group interviews. The learners were asked to volunteer to participate in the focus-group interviews. The elicited learners' accounts were compared with the teachers' claims on the practice of inquiry through practical work. A practical work activity of each teacher's choice in which inquiry-based activities were facilitated for learners was observed. Accordingly, researchers made meanings of what the participants understood of the world around them (Creswell, 2007). The research design allowed the use of a social-constructivism meta-theoretical framework (for meaning making). Research participants were given a voice and platform to contribute in the construction of meaning. The researchers used their interpretations of the phenomenon under study to construct meaning.

4.1 Sampling

Purposive sampling was used at two levels to select the physical sciences teachers. At the first level, data were collected from seven teachers from different schools contexts. After the initial analysis of the data, four data-rich cases were selected at the second level. Purposive sampling techniques aim at selecting relevant and data rich sources (Teddle & Yu, 2007). The most important requirement for selection was that the teachers had to be practising and facilitating some form of inquiry-based practical work for the learners. Below is a table with a summary of the participants, the school contexts, the grades taught and the class sizes.

Table 1: Summary of participants

Teacher	School context	Grade	Number of learners
Teacher 1	Independent	10	18
Teacher 2	African township	11	36
Teacher 3	Former Indian	11	24
Teacher 4	Private	12	36

4.2 Data analysis

Qualitative content analysis methods were used to analyse the data generated from semi-structured interviews with teachers, focus-group interviews with learners and video transcripts of lessons. The content analysis was conducted partly deductive and partly inductive. The use of the inquiry-based practical work conceptual framework to guide data collection worked for defining the themes apriori. However, in order to identify the opportunities for inquiry through practical work the themes emerged from the data (Elo & Kyngas, 2007). The interviews and the observations were partly open-ended in nature, therefore categories and themes were expected to also flow from the data. Three basic steps of qualitative content analysis described by Elo and Kyngas (2007) were followed. The first step is open coding where the researcher is immersed in the data. Notes are written in the texts while reading and main topics of content are written on the margins of the pages. The main topics of content are transferred to a coding sheet. The second step involves grouping the sub-categories from the coding sheet into higher order categories so that the number of categories is reduced. Ultimately, in the final step of abstraction the larger groupings represent emerging themes that are used to describe the research topic.

5. Findings of the study

The analysis of the collected data revealed four inquiry-facilitating strategies in which the teachers used to facilitate question-posing, development of the experiment procedure and solution finding. Teacher 1 provided learners with the investigative question and steps of the experiment procedure. The learners were encouraged to analyse, interpret the collected data, and draw conclusions. The solution was contained in the conclusions. Teacher 2 encouraged his learners to formulate the investigative question using the information provided. He however provided learners with the steps of the experiment procedure and ultimately learners provided the solution contained in the conclusions they drew after analysing the data. Teacher 3 provided her learners with the investigative question. She instructed them to design the steps of the experiment procedure and use the data collected to come up with the solutions. Teacher 4 provided his learners with the solution and encouraged his learners to use it to formulate the question and design the steps of the experiment procedure. Below we outline the study findings for each teacher.

5.1 Teacher 1

Learners take control of solution finding

Grade 10 learners were observed conducting experiments to test the conductivity of materials and substances. Learners were making use of a laboratory activity in their workbook for experiments. Each learner had his own workbook. The workbook contained instructions on how to conduct the experiment as well as questions that helped build learners' conceptual understanding. Learners were also provided with the question. Katlyn said,

I think pupils must be able to pose the question to say this is the question I want to ask but I think also maybe time is limited we often give them the question because to let them go and pose a question it takes too long.

Partly, Teacher 1 used the practical activities to develop and consolidate learners' understanding of concepts. Accordingly, learners were encouraged to analyse and interpret data collected so that they would be able to discover patterns and relationships from which they would draw conclusions. Teacher 1 further said,

We do practical work so that they can see where people get the information from to draw up their theories and to try and explain what is happening… I had taught them everything about what you need for things to conduct electricity and I had taught them about the ionic compounds, that there are ions and free electrons in metallic compounds and all that. That was not enough they were still confused about it… They get cross with me sometimes because I always say to them write a justified conclusion.

Accordingly, learners were provided with the question and steps of the experiment procedure and they were expected to draw conclusions that contained the solutions to the questions.

5.2 Teacher 2

Learners take control of question formulation and solution finding

Grade 11 learners were observed conducting an experiment to verify Boyle's law in the laboratory. There was no worksheet for the experiment. Learners depended on the guidance from the teacher on how to conduct the experiment. Teacher 2 encouraged the learners to formulate the investigative question from all the information and guidance provided. In the next extract from the interview transcript, he explained how he guided his learners in formulating questions,

For an investigation if ever you give learners a scenario from Grade 10 they know the structure of questioning when you are conducting a practical investigation. When you give them the scenario you ask them what you think will be the investigative question in this.

One of the learners made an elaborate attempt at explaining how they formulate the questions. She said,

I think it's also easy to come up with the investigative question when you have the law maybe Boyle's law. You know that volume is inversely proportional to pressure it is easy to come up with the question when you try to put yourself in Boyle's shoes maybe. You can maybe ask 'Why does volume become inversely proportional to pressure?' Then that way you are able to answer yourself because the temperature is kept constant and you are also able to go deeper into detail concerning the particles inside the enclosed gas and things like that.

It was evident that the teacher encouraged his learners to formulate questions even for verification experiments conducted after covering the topics in previous lessons. However, the teacher provided learners with the steps of the experiment procedure. He set up the apparatus himself and made protracted efforts to show learners how to execute the steps of the procedure before they could conduct the experiment. Learners analysed the collected data and drew conclusions.

5.3 Teacher 3

Learners take control of designing the steps of the experiment procedure and solution finding

Grade 11 learners were observed conducting experiments to prepare copper (II) carbonate in the laboratory. The teacher provided the learners with the question on how to prepare a precipitate of copper (II) carbonate. There was no worksheet for the experiment but learners could refer to textbooks to get any information that could assist them. The topic of solubility had been covered in previous lessons through expository methods of teaching and other practical activities. The learners possibly had some ideas of how to prepare insoluble salts in the laboratory. The learners worked in groups to identify the materials they would need and designed the steps of the experiment procedure. After setting up the apparatus, they called the teacher to give them the green light to proceed. On the one hand, some of the learners showed anxiety at being allowed to control how they would conduct the experiments. One learner said,

The teacher should just help us along the way because sometimes we get confused. We don't know exactly how it should look like or what should be happening so she can at least just guide us in the beginning like this is going to happen or this is not supposed to happen or this is what might possibly happen, this is the precaution you must take and stuff like that.

On the other hand, the teacher expected her learners to be more involved in the inquiry processes. She said,

The learners can support me by being more involved I think and doing work in time, of which I think at the moment I don’t have much complaints I think they are wilfully involved. Some groups that are a bit slow, those who don’t read and prepare in advance. If they read and prepare in advance so that they are ready for whatever practical we want to do that would assist me in saving time and enable us to do more.

5.4 Teacher 4

Learners take control of question formulation and design of the experiment procedure

Grade 12 learners were observed conducting a laboratory activity in which they were tasked to design an experiment to investigate the effect of surface area on the rate of reaction. The topic had been covered in previous lessons through expository methods. Accordingly, the solution to the problem had already been made available to learners. Learners were encouraged to formulate the question from all the information available. They also worked in groups to design the steps of the experiment procedure. In the following excerpt from the interview, Teacher 4 explained how he encouraged his learners to come up with experiment procedures.

Before doing an experiment, well, it’s an issue of having covered the topic and finished it then move on with them and then you tell them we are going to do an experiment on this section so you need to know your theory because once you come in here you don’t have time to research you have time to do. So you really need to make sure they know what they are doing.

And the other thing I did was I wouldn't let them proceed to the next step … I would let them do the setup. Once I see that the setup is fine that's okay with me then the next step they tell me how they are going to use that kind of setup to get the results and also how they are going to help to verify what they are going to verify.

Teacher 4 was well aware that learners already knew the solution to the problem. He said, "For the solution from what I was checking when they were doing the experiment you could see they can easily tell basing on the theory but as well as looking at their results..."

The learners' accounts also confirmed that they had been left to devise the steps of the experiment procedures most of the time. This is reflected in the following excerpt from the transcript of the focus-group interview.

Researcher: And the method, the steps that you are supposed to follow. Who gives you that?
Learner 1: We design that on our own. He doesn't tell us what to do.
Learner 2: He just gives us this and he says go and research. And then we research and whatever it is that we find that's what we do.
Researcher: So what do you think can be done to improve the way in which experiments are conducted?
Learner 3: More guidance from the teacher.
Researcher: You need more guidance?
Learner 3: Honestly yes because he is never really… I have never… I have been… how to do an experiment I have learnt from getting it wrong all the time… that's how we learnt. He has never really shown us how to…

The table below summarises how the teachers facilitated question posing, experiment procedure design and solution finding for learners.

Table 2: Summary of learner autonomy of inquiry actions

Teachers	Question	Steps of procedure design	Solution
Teacher 1	Provided by teacher	Provided by teacher	Provided by learners
Teacher 2	Provided by learners	Provided by teacher	Provided by learners
Teacher 3	Provided by teacher	Provided by learners	Provided by learners
Teacher 4	Provided by learners	Provided by learners	Provided by teacher

6. Discussion

The study set out to explore the inquiry opportunities presented by practical work activities in the context of CAPS for physical sciences using a qualitative case study design. The practical work activities involved were experiments contained the syllabus. The conceptual framework delimited the concept of inquiry to the science process skills of question posing, experiment procedure design and solution finding. The extent of learner or teacher autonomy of one or more of the process skills mentioned determined different strategies of facilitating inquiry-based practical work for the learners. Four instructional strategies for facilitating inquiry-based practical work were identified in this case study. The instructional strategies were all classified as structured inquiry. First, the teacher had autonomy over question posing and experiment procedure design whilst the learners had autonomy over the solution to the question. This approach is typical of the Schwab (1962), Herron (1971) and Chueng (2007) classification of structured inquiry. In addition, the findings seemed to point to three more ways in which the teachers facilitated structured inquiry. In the second approach, the teacher facilitated that learners determine the question for inquiry by prompting the learners through scaffolding techniques. The scaffolding was in the form of presenting a problem or situation to the learners and ask learners to formulate a question for the scientific phenomenon to be investigated. Once learners provided the investigative question, the teacher provided the procedure of the experiment. The learners ultimately provided the solution to the investigative question in the form of a conclusion. In the third approach, the teacher provided the investigative question and the learners formulated the experiment procedure and provided the solution. In the fourth approach, learners were provided with the solution and they formulated the question and designed the steps of the experiment procedure.

Table 3: Expanded version of Schwab 1962 levels of inquiry

Form of inquiry	Question	Steps of procedure design	Solution
Confirmation (solution known to both teacher and learners)	Provided by teacher	Provided by teacher	Provided by teacher
Structured (solution known to the teacher and at times by learners)	Provided by learners	Provided by teacher	Provided by learners
	Provided by learners	Provided by teacher	Provided by learners
	Provided by teacher	Provided by learners	Provided by learners
	Provided by learners	Provided by learners	Provided by teacher
Guided (solution not known to both teacher and learners)	Provided by teacher	Provided by learners	Provided by learners
Open (solution not known to both teacher and learners)	Provided by learners	Provided by learners	Provided by teacher

We concluded that the four strategies used by the teachers were all structured inquiry since the solution to the question was known to the teacher and at times to the learners. These findings are significant in that they show that the classic structured inquiry from Schwab's rubric (teacher provides question and experiment procedure whilst learners provide the solution) has other variations as discussed above. The findings are all in line with the notion that learners are novice scientists and may not be able to practise open inquiry (Kirschner, 1992, Lunetta *et al.* 2007) - that is, teachers only allowed learners autonomy over one or two of the process skills involved in the type of scientific inquiry described. These variations of the structured inquiry enables learners to learn some targeted inquiry skills in a particular practical work activity. Chueng (2007) agrees that open inquiry is rarely used in the classrooms. However, the findings are also notable in that there was no evidence to suggest that guided-inquiry in which the teacher may provide scaffolding for inquiry activities in which the solution is not known by both the teacher and the learners was practised. The implication is that inquiry-based practical work was practised at the levels of confirmatory and structured levels through the experiments in CAPS for physical sciences syllabus. Akuma and Callaghan (2019) also agree that the use of inquiry-based practical work is limited in the South African context.

The two forms of inquiry (confirmation and structured) are important for achieving some of the functions of practical work such as (i) captivating the interest and motivation of learners and (ii) understanding scientific concepts. The lower level of inquiry practised may limit the achievement of other goals such as (i) developing scientific practical skills (investigations) and problem-solving abilities (ii) understanding the nature of science and (iii) developing scientific habits. We posit that the use of experiments only as a form of practical work may also have limited the use of higher levels of inquiry such as the guided and the open-ended. Some forms of practical work such as the investigations and projects by their nature may open up the opportunities for learners to engage in higher levels of inquiry. The limited levels of inquiry opportunities through practical work may also limit the development of 21st century skills in learners. First, the limitations pointed out on the level of inquiry practised is suggestive to the limitation of the development of inquiry as a 21st century skill. Bybee (2009) also observed that an inquiry model 5Es (engage, explore, explain, elaborate and evaluate) did not cover all the domains of the 21st century skills of adaptability, complex communication and social skills, non-routine problem solving, self-management and self-development, and systems thinking. Similarly, the use of structured inquiry may develop interest and motivation in learners due to the use of hands-on activities (Lunetta et al., 2007). The interest and motivation is aligned to self-management and self-development (Bybee, 2009). The systems thinking may also be developed since the practical work activities enhance the learners' conceptual understanding. However, there is little evidence that learners will develop the skills of adaptability, complex communication and non-routine problem solving when they engage in structured inquiry.

Conclusion

The practical work activities such as experiments from the CAPS syllabus for physical sciences allowed learners to engage in inquiry activities up to the level of structured inquiry. Accordingly, learners were given an opportunity to practise one or two of the following, question posing, experiment procedure design and solution finding. Four ways of engaging learners in structured inquiry were deciphered from the teachers' practices. The realisation that there are varied ways of facilitating structured inquiry deepens our understanding of the classic rubric that classifies inquiry into confirmation, structured, guided and open-ended. Teachers play an important role in determining the inquiry opportunities that learners experience in physical science classrooms. The limited opportunities for inquiry skills development also limits the development of 21st century skills in learners through inquiry-based practical work based on the intersection between the two sets of skills (Turman *et al.*, 2012).

References

Abd-el-Khalick, F., Boujaoude, S., Duschil, R., Lederman, N.G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust, D. & Tuan, H.L. (2004). Inquiry in science education: International perspectives. *Science Education*, 88, 397-419.

Akuma, F.V. & Calaghan, R. (2019). Teaching practices linked to the implementation of inquiry-based practical work in certain science classrooms. *Journal of Research in Science Teaching*, 56, 64-90.

Barrow, L.H. (2006). A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education*, 17, 265-278.

Bybee, R.W. (2009). The BSCS 5E instructional model and 21st century skills. National Academies Board on Science Education. Retrieved from http://itsisu.concord.org/share/Bybee_21st_century_Paper.pdf

Creswell, J.W. (2007). *Qualitative inquiry and research design: Choosing among five approaches*, 2nd edition. Thousand Oaks, CA: Sage.

Cheung, D. (2007). Facilitating chemistry teachers to implement inquiry-based laboratory work. *International Journal of Science and Mathematics Education*, 6, 107-130.

Department of Basic Education (DBE). (2011). *Curriculum and assessment policy statement. grades 10-12. Physical sciences.* Pretoria: Government Printing Works.

Dudu, W.T. (2014). South African high school students' experiences of inquiry during investigations: A case study. *International Journal of Educational Science*, 7(2), 241-251.

Elo, S. & Kyngas, H. (2007). The quantitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107-115.

Herron, M.D. (1971). The nature of scientific enquiry. *School Review*, 79(2), 171-212.

Hofstein, A. & Mamlok-Naaman, R.M. (2007). The laboratory in science education: The state of the art. *Chemistry Education Research and Practice*, 8(2), 105-107.

Kellow, J. (2016). *Herron's model*. Available at http://www.inquiringmind.co.nz/Herron_Model.htm [Accessed 16 February 2016].

Kirschner, P.A. (1992). Epistemology, practical work and academic skills in science education. *Science and Education*, 1, 273-299.

Lunetta, V.N., Hofstein, A., & Clough, M.P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory and practice. In S.K. Abell & N.G. Lederman (Eds.). *Handbook of research on science*, pp 393-441. New York: Routledge.

Millar, R. (2004). *The role of practical work in the teaching and learning of science. High school science laboratories: Role and vision*. Washington, DC: National Academy of Sciences.

National Research Council, (2008). *Research and future skill demands. A workshop summary.* Washington, DC: National Academy of Sciences.

Ndlovu, M. (2013). Science fair learners' evaluation of their experience of scientific investigations in the classroom and during their project work. *Proceedings of the International Conference of Education, Research and Innovation (ICERI)*. Seville, Spain, 18-20 November 2013.

Ramnarain, U.D. (2014a). Teachers' perceptions of inquiry-based learning urban, suburban, township and rural high schools: The context-specificity of science curriculum implementation in South Africa. *Teaching and Teacher Education*, 38, 65-75.

Ramnarain, U.D. (2014b). Questioning the validity of inquiry assessment in a high stakes physical sciences examination. *Perspectives in Education*, 32(1), 179-191.

Ramnarian, U. & Hobden, P. (2014). Shifting South African learners towards greater autonomy in scientific investigations. *Journal of Curriculum Studies*, 47(1), 94-121.

Sadeh, I. & Zion, M. (2009). The development of dynamic inquiry performances within an open inquiry setting: A comparison to guided inquiry setting. *Journal of Research in Science Teaching*, 46(10), 1137-1160.

Schwab, J.J. (1962). The teaching of science as an inquiry. In J.J. Schwab & P.F. Brandwein (Eds.). *The teaching of science*. Cambridge, MA: Harvard University Press. pp. 3-103.

Teddle, C. & Yu, F. (2007). Mixed methods sampling: A typology with examples. *Journal of Mixed Methods Research*, 1(1), 77-100.

Turiman, P., Omar, J., Daud, A.M. & Osman, K. (2012). Fostering the 21st century through scientific literacy and scientific process skills. *Procedia- Social and Behavioural Sciences*, 59, 110-116.