Inquiry-based practical work in physical sciences: Equitable access and social justice issues

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Physical sciences education comes with high expectations for learners to be successfully placed in tertiary institutions in related fields, and developing countries' aspirations to develop advanced and specialised skills to drive economies. However, some of the prevailing instructional strategies in science classrooms work to marginalise learners. This study explored access to effective inquiry-based practical work for physical sciences learners in two South African schools, through social cognitive and social justice lenses. Purposive sampling techniques were used to select an under-resourced high school and a well-resourced high school. Semi-structured interviews with two physical sciences teachers and open-ended observations were used to collect data in each of the schools for analysis through content analysis techniques. It came to light that the absence of practical examinations from the system of assessment resulted in an undervaluing of inquiry-based practical work in physical sciences classrooms. Additionally, instructional leadership practices did not support using this instructional strategy. The undervaluing of inquiry-based practical work marginalised learners, and the circumstances of limited access translated into a social justice agenda stemming from the high expectations associated with studying high school physical sciences. Recommendations are made to support inquiry-based practicals through the processes of assessment and tools for instructional leadership.

Introduction

Science curriculum content is characterised by a history of change often triggered by concerns in society, such as the need to enhance intellectual rigour and military, economic and social justice agendas. Jenkins (2013) noted the efforts made by scientists in the late 19th century to improve the intellectual rigour of learners by placing them in authentic environments, which put them in touch with the natural world. These efforts established practical work as an instructional strategy. Emphasis was placed on discovery learning through identifying generalisations or patterns, which was assumed to be inherent in all scientific investigations (Aubusson, 2011). The instructional approaches that were adopted further enhanced the role of practical work in the teaching and learning of science.

Amidst widespread beliefs that advanced skills and specialised knowledge in science, technology, engineering and mathematics (STEM) fields have the potential to shape the global economy (Clothey, Mills & Baumgarten, 2010), UNESCO (2004) pronounced a goal for the developing world to grow a scientifically literate and capable human capital base (De Boer, 2014; Aubusson, 2011). In response, most school science curriculums include scientific literacy as one of the goals of science education to ensure an adequate supply of the human capital entering the STEM fields (Aubusson, 2011). However, following a notable lack of interest by learners to study science, current curriculums aim to improve learner-engagement (Aubusson, 2011). Consequently, inquiry is a major philosophical theme contained in most national science curriculums (Barrow, 2006). Practical work provides authentic environments for learner inquiry in science (Allchin, 2014). Science as a secondary school subject is notably distinctive because it involves the teaching and learning of the substantive body of scientific knowledge and the various ways of investigating the natural world. The latter implies that inquiry-based practical work is an indispensable component of science classroom instructional strategies. Accordingly, the South African Curriculum and Assessment Policy Statement for physical sciences, which was first implemented in 2012, contains prescribed and recommended practical work activities (Department of Education, 2011). Additionally, the syllabus is contained in the *National Curriculum Statement Grades R-12*, which drew on social justice agendas that include equal access to education for all (Department of Education, 2011). The inclusion of prescribed and recommended practical work activities in secondary school physical sciences is a way of ensuring equal access to practical work experiences for all learners from different school contexts.

The drives to develop a scientifically literate and capable human capital are set in a context of 'education for all' initiatives by governments and significant funding has been channelled to that end (Fensham, 2013). Education for all is a social justice agenda among others aimed at preparing learners to compete equally for opportunities after finishing school. The use of public funds necessitates accountability practices that include centralised assessments (Allchin, 2014; Fensham, 2013). A direct result of centralising assessments is the creation of high stakes testing environments not only for accountability but also for promotion, certification, placement and selection of learners based on student achievement. Hence, most efforts by schools are directed at ensuring that learners sail through the assessments (Assaf, 2008). Regrettably, as Fensham (2013) pointed out, most of the centralised assessments are simplistic, cheap and do not focus comprehensibly on students' learning (Allchin, 2014).

The nature of assessments has indirectly influenced instructional practices in science classrooms. Taking assessment practices that rely on pen and paper examinations into perspective makes it difficult to justify the importance of practical work. Explicit teaching has been reported to be effective in ensuring student achievement in pen and paper examinations (Anderson, 2002; Reid & Shah, 2007). Nonetheless, science curriculums still maintain a policy impetus for inquiry as a central theme of science teaching and learning. The teaching and learning of physical sciences in South Africa is not alien to the tensions between curriculum stipulations and the actual enactments in the classrooms. Research findings indicate that the classrooms in Southern Africa have been dominated largely by explicit instructional practices (Ottevanger, van den Akker & de Feiter, 2007; Ramnarain & Schuster 2014). Explicit teaching strategies rely heavily on teacher explanations and demonstrations and focus mainly on covering the content in time for inevitable assessments (Lunetta, Hofstein & Clough, 2007).

Notwithstanding the important goals that should be achieved through high stakes testing, science education comes with other learning goals that are inextricably connected to effective inquiry teaching. These outcomes of inquiry and practical work, according to Blosser (1990) and Anderson (2002), include the development of manipulative, inquiry, investigative, organisational and communicative skills, conceptual understanding and the development of cognitive abilities such as critical thinking, problem solving, application, analysis and synthesis. Other outcomes include understanding science processes and the nature of scientific enterprise, the development of correct attitudes towards science such as curiosity, interest, collaboration and consensus, risk taking and responsibility, objectivity, precision, confidence and satisfaction and achieving scientific literacy.

The goals of science education through effective inquiry teaching bring into perspective the scarcity of skills that are associated predominantly with the natural sciences in which secondary school education plays a crucial role as a preparation and initiation phase into the fields (Department of Higher Education and Training, 2014). Shortages of critical skills in the fields of science and engineering are common in most developing countries, including South Africa. Education is one of the drivers of the economy through the accomplishment of all the goals pronounced by the national curriculums (Nyoka, DuPlooy & Henkeman, 2014). It can be implied that participation in high quality science learning improves and widens access opportunities to participate and benefit meaningfully in a country's economy. For a country with a history of apartheid in the recent past, South Africa has a mammoth task of addressing issues of redress and equitable access to education (Nyoka, DuPlooy & Henkeman, 2014).

Given the potential of science education to make opportunities for promotion, certification, placement and selection available to learners and the potential to transform the economic and social conditions of communities positively, the *Curriculum and Assessment Policy Statements* (CAPS) for physical sciences is one such tool (Department of Basic Education 2011). For the purposes of providing equitable access to science education in post-apartheid South Africa, CAPS for physical sciences has a complex dual mandate of making learning opportunities available to learners from all walks of life and bringing about redress to formerly disadvantaged groups of learners. Internationally, governments have used science curriculums and 'education for all' initiatives in similar ways to cater for disadvantaged groups such as the people who crossed borders to settle in their countries (Aubusson, 2011).

Based on the discussion above, the crux of the problem in this paper is the state of compromise between the teachers' actual instructional practices and inquiry-based instruction through practical work as espoused by the national curriculum. The compromised instructional practices do not address the full spectrum of the science education goals. The compromised instructional practices are an adaptation of the curriculum in response to contextual factors such as scarcity of resources, lack of sufficient time, teacher professional identities, language of instruction, inquiry material demands, increased workloads, learner concerns, management issues and the high stakes testing environment mentioned earlier, among other factors (Cheung 2007; Webb 2009; Ottevanger, van den Akker & de Feiter, 2007; Stoffels, 2006). The compromised instructional practices in the science classrooms work to compound the challenges experienced in efforts to bring about redress and equitable access to science learning, as stipulated by the national curriculum. Leithwood and Jantzi (2006) confirmed that a significant mismatch exists between the 'changed' instructional practices and practices that lead to effective learning in the classrooms. Inquiry-based instruction comes as part of curriculum reforms aligned with learner-centred teaching and learning. This study explored how teachers implemented inquiry-based practical work activities in an environment where practical work in science was made to be compulsory. The CAPS syllabus as an educational reform prescribes practical work activities.

Equity and access challenges: Opportunities for inquiry-based practical work instruction

The improvement of intellectual rigour has always been a concern for researchers and scientists (Fensham, 2013). Accordingly, inquiry-based practical work instructional strategies aimed at improving learner engagement and learner-centredness. Inquiry-based practical work involves investigations conducted by learners in contextualised and relevant experiences (Aubusson, 2011). Learners are given opportunities to conduct investigations in ways that are scaffolded to meet the levels of their skills and knowledge (Allchin, 2014). In inquiry-based practical work, learners demonstrate understanding of the laws and theories of science and procedural knowledge instead of merely using worksheets with explicit instructions (Toplis, 2012). As mentioned in the introduction section, the inclusion of inquiry-based practical work in science is partly in response to political decisions to develop national science capabilities (Aubusson, 2011; Clothey et al., 2010). However, this strand of science as a human endeavour is reportedly difficult to measure and not genuinely reflected in assessments (Allchin, 2014; Fensham, 2013).

South Africa has emerged from an apartheid legacy that was characterised by inequitable access to education opportunities (Selod & Zenou, 2003; Gaigher, Lederman & Lederman, 2014). As much as the new policies work to bring equal access and redress, a new educational terrain of different school contextual settings according to access to resources has emerged (Selod & Zenou, 2003). According to Ocampo (2004), the cultural backgrounds of the school communities continue to influence the quality of education. The funds provided by the government have not been able to bring about the desired transformation in the given timeframes for the communities that are too poor to help the schools by paying the school fees that can make a difference. The result is an education landscape marked by enduring, inequitable access to science education. The situation is compounded by the fact that science practical work is often associated with the costs of building the laboratories, running and maintenance costs and staff time (Reid & Shah, 2007). Internationally, Fensham (2013) noted that promoting full participation in school science education for all learners is one way of dismantling conditions in stratified societies where a small minority is able to proceed to professional careers in science. Ideally, according to Raab and Terway (2010), an education system should give learners an equitable platform to compete fairly amongst one another upon graduation if education is to be a tool that will decrease poverty and increase economic growth.

The social justice model and the social cognitive theory as a conceptual framework

A social justice model is used in this paper as a lens to investigate the access to effective, inquiry-based practical work in high school physical sciences. The social justice model underscores the importance of ensuring that every individual has an equal opportunity to access the goods of life (Ratts et al. 2010; Yanicki et al., 2015). The model recognises that that there are constraining and enabling conditions to access the basics of life such as education, health services, employment opportunities and democratic processes among other services in the society (Yanicki et al., 2015). Inclusion and empowerment are crucial for the material, social and political well-being of individuals in a society (Yanicki et al., 2015). STEM fields are reported to be accessed by certain minorities in stratified societies (Fensham, 2013). The limited access to effective instructional strategies in school physical sciences defies the 'education for all' initiatives and the principles of social justice. The social cognitive theory principle of reciprocal determinism was used to explain the teachers' choice of instructional strategies for practical work. The theory posits that the behaviour of individuals, their intrinsic attributes and the environmental conditions are intricately connected and each of them can be explained on the basis of the other components (Bandura, 1977). It is in this view that this paper examines how classroom practices may further disadvantage learners who might have gained access to school physical sciences.

Method

In this phenomenological case study, two schools were selected as study sites using purposive sampling techniques. The schools had to be similar in size according to student enrolment; in this case both schools had enrolments of about 1500. One of the schools had to be a well-resourced school and the other one had to be under-resourced in order to enhance trustworthiness of the data. In phenomenological research, rigour is enabled by discussing the contextual factors that may influence how the study is conducted and the findings obtained in that study (Armour, Rivaux & Bell, 2009). The well-resourced school in the Tshwane South District in Pretoria of South Africa had 6 physical sciences laboratories and the under-resourced school had one physical sciences laboratory. The under-resourced school was a township school in the Tshwane West District in Pretoria. The well-resourced school had 90 teachers while the under-resourced school had 43 teachers. Data were collected through semi-structured interviews and field notes compiled through unstructured observations and two physical sciences teachers from each of the schools were the study participants. In the well-resourced school Molly, a teacher with 23 years of teaching physical sciences and Peter with eight years of experience were interviewed. Julius and Matt who had 17 and 15 years of teaching physical sciences respectively were interviewed in the under-resourced school (names are pseudonyms).

The interviews were conducted with physical sciences teachers because they would be able to give first-hand information on how they incorporated inquiry-based science through practical work activities. The practical work activities were in the context of the CAPS for physical sciences, which was implemented in 2012 in South Africa (Department of Education, 2011). The interviews were based on the following themes. The first theme was based on the teachers' views of the societal expectations of physical sciences education. These expectations have also been pointed out in the preceding discussions. The second theme was based on how the teachers implemented the practical work component of physical sciences. The third theme explored some contextual factors that influenced how the teachers implemented the practical work component of physical sciences. Finally, the subthemes and categories that emerged were used to understand how the implementation practices of the practical work component for inquiry-based science worked to improve the learners' chances to accomplish expectations for studying physical sciences or marginalise them. Accordingly, the content analysis methods were partly directed and partly inductive. The analysis was directed because the general themes were determined *a priori*. However, the categories emerged because they only applied to the context of the case study and might come out differently in other contexts. Being a qualitative case study that sought to explore a phenomenon using a few participants in their school settings, the findings will not be generalised. However, the findings will contribute to the body of knowledge by illuminating some ways in which learners are denied equitable access to inquiry-based practical work in physical sciences.

Findings

On comparing the science laboratory facilities for the two schools, one of the schools could be categorised as well-resourced and the other under-resourced. Julius from the under-resourced school revealed the material constraints associated with facilitating laboratory work in the school in the interview excerpt below.

Interviewer:	How many science laboratories do you have in the school?
Julius:	For science we have two, a physical sciences and a life sciences one and they have just been refurbished but we are still waiting for the other orders from the department.
Interviewer:	So how are you doing the practical work?
Julius:	It is very difficult but we still have some materials left from last year and the previous year so we only do experiments that are relevant [for portfolio work].
Interviewer:	Do you do the experiments in the classroom or in the labs?
Julius:	If it is electricity we know we have one circuit [board], then we do it in the classroom. Where students mix chemicals like acids because it is very dangerous then we use the labs. It is not easy for us.

For the well-resourced school each science teacher was based in science laboratories which were not lacking in terms of materials and equipment. Molly confirmed that there were six physical sciences laboratories in the school, which was a sharp contrast from Julius's school.

Interviewer:	How many labs do you have?
Molly:	In total? Six for physical sciences and five for life sciences which is 11 in total.

The interviewer probed further on how the one laboratory is shared in the under-resourced school. It was revealed that access to the laboratory was limited as there was a booking system in place. The interview excerpt below explains how.

Interviewer:	So learners of all Grades are able to do hands-on activities?
Matt:	I have Grade 12, one Grade 11 and another Grade 10. We take turns in the lab. The lab is separate from the classes, one has to book it first when they want to use it; if there is a clash at times, we prioritise the matriculants [Grade 12s].
Interviewer:	Where do you make the bookings?
Matt:	There is a lady who teaches Grade 10 physical sciences, she keeps the keys for both the Physical Sciences and the Life Sciences labs. We make bookings with her.

Expectations for physical sciences learners

Different stakeholders have varying expectations for the learners who chose physical sciences as a subject to study in high school. One of the expectations is that these learners will be able to pursue careers in STEM fields when they complete their schooling. However this goal of science education is not always easily achieved. Peter articulated this expectation as follows,

> Many learners feel that they have to take science because it might take them somewhere once they reach University but they do not have the ability or the passion for it and those are usually the students that get less than average of 40 [%] for a test or an exam. Or the learners that the parents forced to take science, those are the biggest challenges.

The strategies for laboratory instruction

Teachers from the two schools conceded that when it comes to practical work they resorted to demonstrations more frequently. The teacher in the under-resourced school cited lack of sufficient resources whilst the teacher in the well-resourced school cited lack of sufficient time. Matt from the under-resourced one said,

> We are not doing enough basically. We don't have enough equipment, normally I just do a demonstration and learners come and hold there and there. We don't have a lab assistant to organise this and that for you [us]. You have to clean that and you have classes to attend, so one ends up misplacing things.

It was very interesting to note that while Matt cited lack of resources as the reason why learners are not frequently engaged in hands-on practical work, Peter from the well-resourced school cited other constraints that resulted in him conducting demonstrations for his learners for practical work. He said,

> I do more demonstrations than they actually do more hands-on, we do the set pieces for assessment and um, if time allows us then we let them do extra.

However, the teachers felt that they were complying with requirements stipulated by the curriculum policies. They did this by making sure that students conducted the prescribed practical work activities for continuous assessment and portfolio work. On probing further into what the teachers thought about making more use of demonstrations compared with hands-on activities, the interviewer said,

> So for science you know it's also a practical subject, are you doing enough to make sure that you are doing justice?

Molly said 'We do as much as the department wants us to do'. In addition, Molly, as a teacher with more experience was able to provide a comparison of physical sciences practical work policies in the past and present curriculums. The detailed comparison shed light on some other factors that influenced the teachers' choices of instructional strategies for practical work, besides the lack of resources and sufficient time cited by teachers. It could be surmised from the teacher narratives that the assessment and instructional leadership practices were instrumental in the choice of practical work instructional strategies.

The role played by instructional leadership practices

The teachers' comments on teacher supervision practices seemed to suggest that these played a major role in determining the nature of laboratory work practices in the physical sciences classrooms. The teachers' choices of instructional strategies for practical work seemed to be informed by the nature of supervision practices by the district officials. In the interview excerpt below, Molly compared two different forms of teacher supervision practices and provided insights on how they informed classroom practices. She said,

> They used to do practical exams, so you had to prepare thirty six experiments which we did in grade 11 and 12, and at the end of 12, like they are doing moderations for the portfolios now they will pick a school and then the inspector which is now the subject facilitator will come then they will take your list and six learners and the learners will go with him into your class where everything has been prepared. He would give out experiments to do for each learner, and he evaluated them according to what they know and how they do experiments and they had 36 and they had to be able to do, so they have to get the apparatus, they have to set up the experiments and they had to do it. And his aim was that he had to ask questions until they couldn't answer any more. According to that he checked that I gave learners the correct marks.

Therefore, according to Molly, in the previous system the teacher supervisor from the district would randomly select students who would be engaged in a practical examination as a way of assessing the teachers' preparation of students in practical work. As Molly further explains below, the teachers would strive to ensure that the students would be able to conduct practical activities on their own and develop the practical work skills that would be assessed. She further said,

> I think the learners had better skills because in order for them to able to do the practicals, when we evaluated them, they had to set up the whole thing for example: if

> you think of a titration, they had to set up the burette and he will see it, do they know how to prepare a standard solution, he will give them the chemicals and say prepare this and I want the concentration on that. So they have to do the calculations and be able to work with the scales, they had to make a standard solution and they have to do the whole titration and reach the end point without extra help, so if you haven't done it before you can't really do it.

In the new system the instructional leaders from the district only take a sample of the learners' portfolios to moderate how the teachers' allocate continuous assessment marks to the learners. Learners do not sit for practical work examinations. However, Molly felt that the teachers still need to ensure that students go through practical experiences in order to be able to answer some of the questions in pen and paper examinations successfully. She said,

> If I think of last year's paper and June's paper that they asked, where they asked the skills of where do you have to take the reading of the volume that was mentioned. Then that comes to the learners naturally if they have done it. It's the same with electricity where you read ammeter and read the voltmeter, I can now give them a photo of an ammeter and say give me the reading, so they won't have a problem because they actually did it practically, they have worked with the apparatus, so it's a familiar feeling and then it's fine with them.

It was interesting to note that while Molly conceded that students need to be engaged hands-on in order to gain skills and knowledge related to inquiry-based practical work, demonstrations predominated. Besides perceiving that the teachers acted in accordance with the instructional leadership practices, there were strong indications that the teachers' actions were influenced by the assessment practices in place.

The assessment practices

In the interview excerpt below, Molly explained the nature of assessment for practical work. She reveals a practice in which teachers use rote and drill methods to make sure students get good marks for the three prescribed practical work activities per year.

> Now we doing it in groups all the time and then they do the write up, we have three experiments a year from grade ten up to twelve, that add up to nine experiments, as opposed to the 36 experiments that we used to do in two years, so that's a big difference. Now we are prescribed specific experiments by the department, so you can't even go and say this year let's do this and next year let's do that one because what happens right now and this is definitely a training that they have, there are specifically three experiments that they can do. It means that in the extra classes that they get out there they have worked them out so well. No matter what the students do or whether they understand or not, he/she does a write up that they could have memorised and he/she knows that's where he/she gets his/her marks. So it sort of defines the purpose of what you are trying to teach him/her, to get good marks or to teach skills to be able to do practical work.

According to the above narrative, in the past the learners sat for practical examinations in addition to the pen and paper forms of assessment in physical sciences. The teacher revealed that currently the learners sat for pen and paper examinations only and practical work for portfolio work is conducted in groups and the teacher marks the experiment report. The marks gathered in the portfolio are part of continuous assessment. When the subject facilitators from the district arrive at the school they moderate the portfolios instead of taking the learners to the physical sciences laboratory to test their skills during practical activities. This is one of the push factors for teachers leading to feel that they might be wasting time by frequently engaging learners in practical work and helps explain why practical work in physical sciences is dominated by teacher demonstrations.

Discussion

Having identified scientific literacy as one of the crucial conditions for sustainable economic development, governments and other stakeholders unanimously call for an increase in the number of students entering universities to study science (Aubusson, 2011; Clothey et al., 2010; Fensham, 2013). These calls have succeeded in influencing the content of national science curriculums. There are strong beliefs in the school science education literature that scientific literacy can be achieved through instructional strategies that enhance student engagement and intellectual rigour (Allchin, 2014; Hofstein & Lunetta, 2004; Jenkins, 2013). Inquiry-based practical work stimulates learners' interest in science, serves as an alternative instructional method to cater for diverse ways of learning, and establishes science as a human endeavour (De Boer, 2014; Toplis, 2012).

The lack of laboratory facilities, equipment and materials is one of the factors that the literature confirms as a crippling for the implementation of inquiry-based practical work (Chueng, 2007; Christie et al. 2007). This paper further confirms that lack of materials denies physical sciences students access to quality science education. In this study the learners in the under-resourced school did not have ready access to laboratory facilities to perform their hands-on activities. Hence, the unavailability of laboratory facilities, equipment and materials in the under-resourced high school sits on the social justice agenda. Students in secondary schools do not experience inquiry-based practical work in similar ways. However, they write the same examinations and compete for the same placement opportunities for employment and further education. Christie et al. (2007) confirmed that in the teaching and learning of science in some South African schools is without the practical component because of lack of facilities and materials.

This paper highlights how access to placement opportunities related to further education in STEM related fields is further denied by prevalent instructional strategies for inquiry-based practical work. Based on the assumption that science education is one of the drivers of the economy and that education is a tool that can transform the socio-economic conditions of citizens, inequitable access to meaningful education can be considered as a social justice issue. Gaigher et al. (2014) pointed out that inquiry is one of the innovations contained in curriculums after democratisation and that rote and drill methods characterised curriculums before independence in South Africa. Cooper (2009) concurred that schooling can be a driver for social marginalisation. The resulting social injustices are more pronounced in the South African context where education is also used to bring redress to formerly disadvantaged populations. Anderson (2002) pointed out that over reliance on instructional strategies that depend on teacher explanation disregards the full sweep of science education goals. Accordingly, it is posited that limited access to inquiry-based practical work is on the social justice agenda due to the resultant limited access to opportunities related to STEM education and fields. The limited access to inquiry-based practical work is set on a backdrop in which science education in South Africa through the CAPS curriculum aims to provide science education for all including students from previously disadvantaged groups.

In spite of all the motivations that establish inquiry-based practical work as an essential component of physical sciences teaching and learning in secondary schools, some South African classrooms continue to be dominated by teacher-centred instructional practices that rely heavily on teacher explanations (Ramnarain, 2014; Webb, 2009). This is despite the CAPS syllabus for physical sciences emphasising the inclusion of practical work instruction by prescribing and recommending practical work activities. The prescribed and recommended practical work activities serve partly as a tool to make equal opportunities and similar experiences for instruction available to all learners who decide to study physical sciences. However, the fact that some may pass through secondary physical sciences without experiencing inquiry-based instruction through practical work creates a situation of inequitable access to physical sciences education. The teachers in this study confirmed that teacher demonstrations dominated physical sciences classrooms for practical work. The situation is partly created by assessment practices that do not sufficiently cover the aspects of inquiry. Seemingly, the assessment practices serve to meet the important needs for promotion, certification, placement and selection of learners. However, the major goals to develop sufficiently literate citizens to provide the required numbers to participate in the STEM fields are threatened. Accordingly, only a few learners continue to gain access to pursue careers in the STEM fields although the reasons are not the same from school to school and from time to time.

Inquiry through practical work responds to critical science education goals for skills and knowledge as well as understanding the methods of science. Ramnarain and Schuster (2014) mentioned that students get opportunities to learn the ways of the scientists through inquiry-based practical work instruction. This paper contends that instructional leadership should be able to negotiate the tensions between external pressures such as those created by a high-stakes testing environment and the purposes and values of education. In this study the teachers did not commit to engage students frequently in hands-on activities, because the instructional leadership tools and artefacts did not encourage them to do so. Bush (2007) asserted that school leadership which is not guided by educational purpose and values runs the risk of sliding into 'managerialism'. Based upon this assumption, school leadership practices should adopt a transformative character to look beyond the immediate goals of achieving high pass rates and think of the nature of the future citizen as informed by values that trigger curriculum innovations.

Teachers continue to use explicit explanations to teach physical sciences because they are effective for quick content coverage and pen and paper examinations (Anderson, 2002). Spillane et al. (2001) contended that this is how teachers have been conditioned to interpret the accountability tools, suggesting that leadership practices greatly influence instruction. Furthermore, instructional leadership should mobilise and activate resources to ensure implementation (Spillane et al. 2001; Sherer, 2008). The undervaluing and neglect of inquiry through practical work are an indication of the nature of instructional leadership practices in place. The performance of schools is a basis for judging the performance of other institutions such as districts, provinces, ministries and governments. High stakes testing environments become drivers of teaching and learning strategies that rely heavily on teacher explanations and demonstrations. Emphasis is placed on percentage pass rates through pen and paper examinations, though Ramnarain and Schuster (2014) argued that the question items in such examinations do not provide authentic conditions for the assessment of inquiry.

Conclusion

The undervaluing of inquiry-based instructional practices through practical work in some physical sciences classrooms, as conditioned by instructional leadership and assessment practices, is a social justice issue. Learners are denied access to the full sweep of physical sciences education goals and consequently have limited capabilities to participate meaningfully when competing with others in tertiary education and in a civil society. The re-establishment of practical work instructional strategies in physical sciences calls for instructional leadership and assessment practices that take cognisance of the physical sciences subject subculture and its potential to contribute to the socioeconomic transformation of societies.

References

Allchin, D. (2014). From science studies to scientific literacy: A view from the classroom. *Science & Education*, 23(9), 1911-1932. http://dx.doi.org/10.1007/s11191-013-9672-8

Anderson. R. D. (2002). Reforming science teaching: What research says about inquiry. *Journal of Science Teacher Education*, 13(1), 1-12. http://dx.doi.org/10.1023/A:1015171124982

Armour, M., Rivaux, S. L. & Bell, H. (2009). Using context to build rigor. Application to two hermeneutic phenomenological studies. *Qualitative Social Work*, 8(1), 101-122. http://dx.doi.org/10.1177/1473325008100424

Assaf, L. C. (2008). Professional identity of a reading teacher: Responding to high-stakes testing pressures. *Teachers and Teaching: Theory and Practice*, 14(3), 239-252. http://dx.doi.org/10.1080/13540600802006137

Aubusson, P. (2011). An Australian science curriculum: Competition, advances and retreats. *Australian Journal of Education,* 55(3), 229-244. https://doi.org/10.1177/000494411105500305

Barrow, L. H. (2006). A brief history of inquiry: From Dewey to standards. *Journal of Science Teacher Education*, 17(3), 265-278. http://dx.doi.org/10.1007/s10972-006-9008-5

Blosser, P. E. (1990). The role of the laboratory in science teaching. *Research Matters – to the Science Teacher*, No. 9001. https://www.narst.org/publications/research/labs.cfm

Bush, T. (2007). Educational leadership and management: Theory, policy and practice. *South African Journal of Education*, 27(3), 391-406. http://wrap.warwick.ac.uk/426/

Cheung, D. (2007). Facilitating chemistry teachers to implement inquiry-based laboratory work. *International Journal of Science and Mathematics Education,* 6(1)*,* 107-130. https://doi.org/10.1007/s10763-007-9102-y

Clothey, R., Mills, M. & Baumgarten, J. (2010). A closer look at the impact of globalization on science education. *Cultural Studies of Science Education,* 5, 305-313. http://dx.doi.org/10.1007/s11422-010-9258-6

Christie, P., Butler, D. & Potterman, M. (2007). Report to the Minister of Education Ministerial Committee on Schools that work. Pretoria: Sol Plaatjie House. http://www.education.uct.ac.za/sites/default/files/image_tool/images/104/schoolsthatwork.pdf

De Boer, G. (2014). The history of science curriculum reform in the United States. In N. G. Lederman & S. K. Abell (Eds), *Handbook of research on science education, volume II*. New York: Routledge. https://www.routledge.com/Handbook-of-Research-on-Science-Education-Volume-II/Lederman-Abell/p/book/9780415629553

Department of Basic Education (2011). *Curriculum and assessment policy statement. Grades 10-12. Physical Sciences*. Pretoria: Government Printing Works. http://www.education.gov.za/LinkClick.aspx?fileticket=uVcOcx728Y8%3D&tabid=466&mid=1332

Department of Higher Education and Training (2014). Call for comments on the national scarce skills list: Top 100 occupations in demand. *Government Gazette*. (No. 37678). http://www.dhet.gov.za/Research%20Coordination%20Monitoring%20and%20Evaluation/Call%20for%20comments%20on%20the%20national%20scarce%20Skills%20List%20Top%20100%20occupations%20in%20Demand.pdf

Fensham, P. J. (2013). The science curriculum: The decline of expertise and the rise of bureaucratise. *Journal of Curriculum Studies,* 45(2), 152-168. http://dx.doi.org/10.1080/00220272.2012.737862

Gaigher, E., Lederman, N. & Lederman, J. (2014). Knowledge about inquiry: A study in South African high schools. *International Journal of Science Education,* 36(18), 3125-3147. http://dx.doi.org/10.1080/09500693.2014.954156

Hofstein, A. & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, 88(1), 28-54. https://dx.doi.org/10.1002/sce.10106

Jenkins, E. W. (2013). The 'nature of science' in the school curriculum: The great survivor. *Journal of Curriculum Studies,* 45(2), 132-151. http://www.tandfonline.com/doi/abs/10.1080/00220272.2012.741264

Loucks-Horsley, S., Stiles, K., Mundry, S., Love, N. & Hewson, P. W. (2010). *Designing professional development for teachers of science and mathematics* (3rd ed). Thousand Oaks, CA: SAGE. http://dx.doi.org/10.4135/9781452219103

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 education, volume II*. New York: Routledge. https://www.routledge.com/Handbook-of-Research-on-Science-Education-Volume-II/Lederman-Abell/p/book/9780415629553

Magee, D. & Meier, A. J. (2011). Science education and culture: Inquiry-based learning. *Journal of Intercultural Communication*, issue 27, November 2011. https://www.immi.se/intercultural/nr27/magee.htm

Nyoka, A., DuPlooy, E. & Henkeman, S. (2014). Reconciliation for South Africa's education system. *Elm Magazine*, Issue 2/2014. http://www.elmmagazine.eu/articles/reconciliation-for-south-africa-s-education-system/

Ocampo, M. L. (2004). A brief history of educational inequality from apartheid to present. Global perspectives on human language: The South African context. [viewed 14 August 2015] http://web.stanford.edu/~jbaugh/saw/Lizet_Education_Inequity.html

Ottevanger, W., van den Akker, J. & de Feiter, L. (2007). *Developing science, mathematics and ICT education in Sub-Saharan Africa: Patterns and promising practices.* World Bank Working Paper, 101. http://siteresources.worldbank.org/INTAFRREGTOPSEIA/Resources/No.7SMICT.pdf

Raab, E. & Terway, A. (2010). School fees in South Africa: Increasing quality or decreasing equality. Washington DC: USAID/EQUIP 2. http://www.equip123.net/docs/e2_School_Fees_in_South_Africa-CS.pdf

Ramnarain, U. & Schuster, D. (2014). The pedagogical orientations of South African physical sciences teachers towards inquiry or direct instructional approaches. *Research in Science Education,* 44(4), 627-650. http://dx.doi.org/10.1007/s11165-013-9395-5

Ratts, M. J., Anthony, L. & Santos, K. N. T. (2010). The dimensions of social model: Transforming traditional group work into a socially just framework. *The Journal for Specialists in Group Work,* 35(2), 160-168. http://dx.doi.org/10.1080/01933921003705974

Reid, N. & Shah, I. (2007). The role of laboratory work in university chemistry. *Chemistry Education Research and Practice,* 8(2), 172-185. https://dx.doi.org/10.1039/B5RP90026C

Rout, S. & Behera, S. K. (2014). Constructivist approach in teacher professional development: An overview. *American Journal of Educational Research,* 2(12A), 8-12. http://dx.doi.org/10.12691/education-2-12A-2

Selod, H. & Zenou, Y. (2003). Private versus public schools in post-apartheid South African cities: Theory and policy implications. *Journal of Development Economics,* 71(2), 351-394. http://dx.doi.org/10.1016/S0304-3878(03)00033-6

Spillane, J. P., Diamond, J. B., Walker, L. J., Halverson, R. & Jita, L. (2001). Urban school leadership for elementary science instruction: Identifying and activating resources in an undervalued school subject. *Journal of Research in Science Teaching,* 38(8), 918-940. https://pdfs.semanticscholar.org/4021/b49b3cdb104484ddfd64839fa39ffb014082.pdf

Stoffels, N. T. (2005). 'Sir on what page is the answer?' Exploring teacher decision-making during complex curriculum change, with specific reference to the use of learner support materials. *International Journal of Educational Development,* 25(5), 531-546. http://dx.doi.org/10.1016/j.ijedudev.2005.02.004

Sun, M., Penuel, W. R., Frank, K. A., Gallager, H. A. & Youngs, P. (2013). Shaping professional development to promote the diffusion of instructional expertise among teachers. *Educational Evaluation and Policy Analysis,* 35(3), 344-369. http://dx.doi.org/10.3102/0162373713482763

Toplis, R. (2012). Students' views about secondary school science lessons: The role of practical work. *Research in Science Education, 42*, 531-549. http://dx.doi.org/10.1007/s11165-011-9209-6

United Nations Educational, Scientific and Cultural Organization (UNESCO) (2004). *Education for all: The quality imperative.* Paris, France: UNESCO. http://unesdoc.unesco.org/images/0013/001373/137333e.pdf

Webb, P. (2009). Towards an integrated learning strategies approach to promoting scientific literacy in the South African context. *International Journal of Environmental and Science Education,* 4(3), 313-334. http://www.acarindex.com/dosyalar/makale/acarindex-1423903862.pdf

Yanicki, S. M., Kushner, K. E. & Reutter, L. (2015). Social inclusion/exclusion as matters of social (in)justice: A call for nursing action. *Nursing Inquiry,* 22(2), 121-133. http://dx.doi.org/10.1111/nin.12076

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