Teachers' implementation of laboratory practicals in the South African physical sciences curriculum

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The Curriculum and Assessment Policy Statement (CAPS) reforms in the South African school system came with an increased emphasis on laboratory practicals for the physical sciences. While reform implementation is known to be fraught with a myriad of challenges, for science teachers such significant changes in the practical components magnified the complex nature of the process. This article reports on physical sciences teachers' perceptions and experiences regarding the prescribed laboratory practicals. We use complex theory to unpack teachers' perceptions and their planning (or not) for the implementation of these prescribed practical components. In this qualitative study, we conducted document analyses on curriculum documents and the laboratory instruction activities, and semi-structured interviews with three teachers from different schools. All participants perceived the prescription of the laboratory experiments positively. The prescription of the experimental practical activities is on two levels: firstly, a list of experiments for each grade provided by the national Department of Basic Education (DBE), and secondly, authorities at the provincial level provided detailed write-ups that serve as lesson plans for the practicals. The provided practical laboratory write-ups offered limited opportunities for good laboratory instruction such as inquiry-based learning.

Introduction

Curriculum reforms for science teachers are routinely accompanied by changes in the practical laboratory components or practical skills that students must learn (Fitzgerald, Danaia & McKinnon, 2017). Justifying practical work in science education, Jenkins (1999) pointed out that it is only through practical laboratory work that learners get real experience about the natural world. While consensus may be easily reached on the rationale for laboratory work, the actual implementation is replete with unclear goals, multiple and often confusing types of approaches to achieve these objectives, and disappointments at the often-low achievements of outcomes when juxtaposed against the investment of time and laboratory resources. Despite all these challenges, research on the implementation of innovations in the science practical components often plays a secondary role, with most studies focusing on the implementation of content topics.

Teachers, being the implementing agents, often confront a wide range of obstacles in effectively organising laboratory activities (Fitzgerald et al., 2017; Mizzi, 2013; Yalcin-Celik et al., 2017). Besides their teaching duties, science teachers are tasked with preparing equipment, solutions, and reagents for practical science lessons, including materials and equipment procurements (Mizzi, 2013; Yalcin-Celik et al., 2017). The strain on these teachers is likely magnified during times of curriculum reforms when new topics and laboratory experiment requirements are introduced.

In the South African school system, reform efforts to improve teaching and learning in subjects such as physical sciences have been plagued by challenges at the implementation stages (DBE, 2011). More recently, CAPS was introduced after it had been observed that the implementation of the previous National Curriculum Statement (NCS) had been confronted with challenges (DBE, 2011; Grussendorff, Booyse & Burroughs, 2014). Adjustments in the practical components for physical science mark some of the most profound changes in the current curriculum cycle. The present reforms provide lists of prescribed practical activities for formal assessment as well as recommended practical activities for informal assessment in grades 10, 11 and 12. Umalusi, the board tasked with quality control in the South African schooling system, lamented that the prescribed practicals require specialised equipment that most schools do not have. Most of the schools in the country (95%) may not be able to implement these prescribed practical components of CAPS due to inadequate laboratory facilities (Grussendorff et al, 2014).

Recent studies on reforms in the practical components of science curricula have been mostly characterised by more emphasis on inquiry-based learning (Tsakeni, 2018; Ramnarain & Hlatswayo, 2018). Elsewhere, there has been a shift from inquiry-based learning to teaching for scientific practices (Crujeiras-Perez & Jimenez-Aleixandre, 2017; Ford, 2015; Osborne, 2014) and teaching for scientific competences (OECD, 2012). We sought to probe from a curriculum perspective how teachers were implementing the current prescribed practicals, through the lens of complex theory. In this study, we purposively focus on the grade 11 components. This study responds to the questions below:

1. What are teachers' perceptions of the prescribed and recommended practical components in physical sciences?
2. What opportunities and challenges do physical sciences teachers face in the implementation of the CAPS practical components?

Our study differs from some of the most recent studies on laboratory practices by physical sciences teachers in South Africa in two ways. Firstly, this study uses complexity theory as a theoretical lens, and secondly, while the most recent studies have focused on inquiry-based learning, this study focuses more on how teachers implemented the practical components, with regard to the resources at their disposal, including the curriculum documents and the context in which they worked.

In this study, we conducted document analyses on curriculum documents provided by departmental authorities (from the federal government and the provincial authorities) and teachers' files, through which we sought to understand the changes in the CAPS pertaining to the practical components of physical sciences, and secondly teachers' planning (if any) for the practical components. Through semi-structured interviews with three teachers we sought to gain insights into their perceptions about the reforms and to probe their experiences in the implementation of the components, including opportunities and challenges for the successful implementation of this part of the curriculum. Interview recordings were transcribed into MS *Word* after listening to them multiple times. Content analysis reduced the data into codes and categories.

Science laboratory practical activities in reform implementation

Worldwide, science curriculum reforms are often accompanied by large-scale changes in the practical components, including the way students conduct experimental work. For example, recently in the United States, this quest is represented by the *Next Generation Science Standards* (Fitzgerald et al., 2017; Ford, 2015; NGSS, 2013), while in the Australian schooling system the national *Australian Curriculum: Science* (ACARA 2014), launched in 2014, has as one of its three strands, a focus on science inquiry skills (Fitzgerald et al., 2017). The *National Curriculum* in England urges teachers to promote learners to 'work scientifically' across all scientific disciplines that involve experimental skills and strategies (DfE, 2014).

Various approaches to science laboratory instruction are found in the literature: inquiry-based learning, teaching for scientific practices, teaching for scientific competencies and expository approaches, among others. Literature reveals blurred lines between inquiry-based practical experience, scientific practice approaches, or scientific competences approaches. We concluded that inquiry-based approaches, scientific literacy and teaching for scientific competencies are often used interchangeably, or just grouped under one umbrella term: inquiry-based learning. To us, a clear distinction is drawn between these three approaches which are learner-centred, against expository, teacher-centred approaches. Below we discuss the inquiry related approach first, before discussing the expository approaches.

Most of the recent science curriculum reforms have emphasised inquiry approaches, although in the literature challenges in persist over what inquiry is. Schwab (1962) and Herron (1971, as cited by Fitzgerald et al., 2017:2), discussed four levels of inquiry that are very relevant to the present discourse:

1. Confirmation inquiry: learners are provided with the question and procedure while the results are known in advance.
2. Structured inquiry: learners are provided with the question and procedure but from the collected evidence, they must generate an explanation.
3. Guided inquiry: learners are provided with the research question and they design the procedure to test their question and generate explanations.
4. Open inquiry: students formulate questions, design and conduct investigations and communicate their findings. The level of this inquiry is defined by the absence of a predetermined result.

Inquiry-based learning approaches are not undisputed in science practical and laboratory activities. More recently, there has been a shift from inquiry-based learning to teaching science as practice, which may involve developing students' understanding of the epistemic and discursive, practices in addition to scientific process skills (Crujeiras-Perez & Jimenez-Aleixandre, 2017; Ford, 2014; Osborne, 2014). The *Next Generation Science Standards* (NGSS (2013) and the *Framework for K-12 Science Education* (National Research Council, 2012) epitomised the shift from inquiry-based approaches to scientific practices approaches. Some of the activities required in scientific practices include, among others, 'asking questions, defining problems, developing and using models planning and carrying out investigations, analysing and interpreting data, using mathematical and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence obtaining, evaluating and communicating information' (Osborne, 2014:179). Scientific practices focus on applying knowledge and understanding of how humans learn (Donovan & Bransford, 2005) and a deep understanding of the nature of the discipline (Crujeiras-Perez & Jimenez-Aleixandre, 2017; Osborne, 2014). On the other hand, the scientific competencies approach is advocated by the Organisation for Economic Cooperation and Development (OECD) and seeks to develop key skills linked to scientific literacy: explain phenomenon scientifically, evaluate and design scientific inquiry and interpret data and evidence scientifically (OECD, 2012).

The practical implementation of these approaches has not been as successful as policymakers may have envisaged (Fitzgerald et al., 2017). Some of the challenges identified by academics include the absence of models for teachers on what inquiry-based practical classes should be like, inadequate professional development that equips teachers on how to teach with inquiry approaches whilst under time constraints (Ramnarain & Hlatswayo, 2018; Tsakeni, 2018; Yalcin-Celik et al., 2017). In the South African schooling system, Tsakeni (2018) used a social cognitive and social justice lens to investigate South African teachers' implementation of inquiry-based learning. The study concluded that inadequate instructional leadership support to learning through practical experiments in science marginalised learners from good science instruction. Using a mixed-methods approach, Ramnarain and Hlatswayo (2018) investigated grade 10 rural teachers' beliefs and practice of inquiry-based learning. The study observes that while teachers held positive beliefs about inquiry-based learning, teachers were less prone to enact it in their classroom because of several factors. They cited poor resource provision, poor teaching materials, limited time for curriculum coverage, and large classes as militating against the enactment of inquiry-based learning in physical sciences classrooms. The shortcoming of these studies, in our view, is the tendency to overlook the curriculum as a major element in impacting the contextual setting for teachers' practices, for better or for worse.

Some academics have questioned the effectiveness of IBL (Kirschner, Sweller & Clark, 2006; Settlage, 2007). For Settlage (2007), implementing IBL in high school science is not practical and is not realistic. Furthermore, Settlage (2007) argues that IBL does not provide learners with the required scaffolding for learning specific concepts, nor can it adequately enhance the process of science learning. These researchers have tended to advocate for teacher-centred expository instruction in high school science, especially for practical experiments (Kirschner et al., 2006). Others have questioned the applicability of learner-centred approaches such as IBL specifically to African contexts, suggesting that in some cases where there is an emphasis on high stake examinations, the expository approach may be more effective (Schweisfurth, 2011). The expository approach is where the instructor exerts a high degree of control, and learners are given 'cookbook procedures' and often, outcomes (Josephsen, & Hvidt, 2015). Learners follow recipe-like procedures to achieve particular goals. Given the range of objectives that policymakers may want to achieve in learners, the onus rests on policymakers to be consistent on their message to teachers through curriculum documents. For us, the past four decades have provided clear evidence that expository methods provide limited opportunities for learners to develop high cognitive skills. The dichotomy between expository and learner-centred approaches offers interesting debate and discourse in regards to content topics. However, for science practicals, we concur with researchers who argue that IBL approaches offer the best opportunities for students to understand science, especially those aspects about its nature.

Complexity theory frames the present study. With its original application in the natural sciences, complexity theory has permeated into the social sciences through economics-related research (Mason, 2008). The theory applies to environments, organisations or systems that are complex, in that many elements or agents are connected to and interacting in multiple ways (Mason, 2008, p. 33). Complexity theory may be critical in understanding education reform implementation, as during reforms new properties and behaviours emerge, not only from the elements that constitute the original system, but also from the myriad connections among them. The addition of new elements or agents to a system exponentially multiplies the number of connections or potential interactions among those elements or agents, and hence the number of possible outcomes (Mason, 2008, p. 48). The linear addition of new elements multiplies exponentially the number of connections among the constituent elements. The increased emphasis on practicals in CAPS should be understood as an additional element that results in increased connections among the existent elements in an already complex curriculum implementation process. Pitfalls for researchers may relate to being over simplistic about causes and effects in the new system by looking at factors in isolation. Through a complexity theory lens, researchers avoid being reductionists in terms of cause and effect relationships during educational change. To meet the challenges of Ramnarain & Hlatswayo (2018) about '…stimulating and socially responsible learning experiences appropriate for the 21st century…' (Yusuf, Taylor & Damanhuri, 2017, p. 168), research should take cognisant of the increased complexity of the environment in which curriculum development and implementation occur.

Method: Data collection and data analysis

For this qualitative interpretive case study, the relevant authorities at the University of the Free State granted ethical clearance. Letters were sent to the principals of the three schools requesting permission to research in the schools. We sought consent from each of the participants, and we assured them of confidentiality. Three physical sciences (Grade 11) teachers from different high schools in a district in the Free State Province of South Africa were invited. We sought to have representatives of the types of schools in South Africa: School A (school from the locations or townships) school B (former Model C, formerly reserved for whites only and located in the suburbs) and school C (a rural school). Once the schools had been selected, we purposively selected participants who were teaching grade 11 at each school. In all the cases there was only one grade 11 teacher and they consented to be part of the study. Table 1 summarises some biographical details of the participants (assigned pseudonyms).

Table 1: Participant profiles

Participant	Gender	School	Education	Major	Experience (years)
Siyanda	F	School A (Township)	BEd	Physics and Chemistry	7
Andres	M	School B (Suburbs)	BEd	Physics	15
Thandie	F	School C (Rural)	BSc	Chemistry	6

Three participants (assigned pseudonyms), two female teachers and one male teacher, were interviewed for this study. The participants were selected from three schools offering physical sciences in a South African district.

Semi-structured interviews conducted at the schools with the three participants were approximately one hour each. The interview included some questions that were "… broad and general so that the participants can construct the meaning of a situation, a meaning typically forged in discussions or interactions with other persons…" (Cresswell & Poth, 2017, p. 21). Through the document analysis, we sought to probe how teachers plan for the practical activities, including their challenges and opportunities for the successful implementation of the curriculum components. We used teachers' files to analyse their planned experiments for grade 11. We analysed the written planned activities supplied to teachers by provincial departmental authorities for the laboratory activities. Interview questions were structured with guidance from Brinkmann and Kvale (2008), with emphasis to directly probe interviewees' perceptions around the formulated themes. In most cases, further questioning followed these up. During the interviews, we also had opportunities to ask questions on some queries we had from our document analysis. During the recording of the interviews, participants were allowed space to narrate what they considered important concerning their implementation of the practical components, including what their perceptions were on the changes themselves.

The interviews were listened to multiple times and transcribed into MS Word documents. The collected data were content analysed. The contents of each participants' narrative were compared to identify the emerging themes on how each participant made sense of the implementation. The data from document analysis and interviews were integrated and triangulated to ensure trustworthiness. The transcripts were decoded, and themes and categories were identified. Cross-analysis of the interview data was conducted to capture physical sciences teachers' perceptions of their implementation of the practical components and their general perceptions with regards to the changes. As we conducted the content analysis on the data, we could distinguish common themes, codes, and categories in their stories and recognise patterns and emerging relations. In the end, we integrated these messages from the three voices with the findings from the document analysis into a coherent structure that shed some light on the implementation of the practical components in the physical sciences.

Results

In this section, we present the findings from the document analysis followed by those from the semi-structured interviews.

Document analysis: Findings

Through the document analysis we sought to respond to the following question:

> What opportunities and challenges do physical sciences teachers face in the implementation of the CAPS practical components?

The teachers' files and the analysis of the documents found therein revealed that the prescription or recommendation of practicals is at two levels. From the National (or Federal) Department of Basic Education (DBE), the physical sciences CAPS recommend a list of experiments. At the provincial levels, the list is slightly modified and complete write-ups of the experiments to the minutest detail are provided to teachers. Teachers did not write their own lesson plans for the experimental practicals. Work schedules provided to teachers indicated what they needed to cover each week, including content and practical experiments. All teachers had to adhere to strict timelines as 'common tests' that learners have to sit for periodically are conducted at the same time all over the province. Therefore, teachers must ensure they complete the coverage of specified sections of the syllabus before each common test.

This overly prescription on what teachers should do has already been reported from studies of the written curriculum (Grussendorff et al, 2014) and from studies on the implemented curriculum (Ramatlapana & Makonye, 2013). The challenges revolve around how teachers would contextualise to the needs of their students, especially considering the wide disparity between the poor and the rich communities in South Africa, which extends to schools. Furthermore, teacher autonomy has been linked to enhancing learner autonomy and improving the teaching and learning process (Rogat, Witham & Chinn, 2014). The list in Table 2 shows the practical experiments that were to be covered in each term.

The above list from the curriculum documents consists of experiments that offer possibilities for developing higher order skills in learners, such as those enshrined in enquiry-based learning, science competencies or scientific practices approaches. Five experiments are prescribed in the first term, another five in the second term and four should be conducted in the third term. Learners are not expected to conduct any experiements in the fourth term and the focus shifts to end of year examinations. For example, on the experiment of the verification of *G*, instead of providing recipe-like procedures to learners, learners could be given tasks that lead them to designing the experiments or practicals. In this province, physical sciences teachers did not have to write their own plans for the experiments. This is because the provincial department provided a booklet with complete write-ups including the minutest details: aim of experiment, apparatus, procedures, etc. Teachers' remaining challenges were in terms of setting up the experimental apparatus as they did not have laboratory assistants.

Table 2: Recommended practicals for grade 11 physical sciences

Term	Practical code	Practical
1	P1	Determine the resultant of three non-linear force vectors
	P2	The effect of different surfaces on the maximum static frictional force
	P3	Newton's second law of motion
	P4	Verification of the value of *G*
	P5	Effect of intermolecular forces on evaporation, surface tension, solubility, boiling point and capillarity
2	P6	Critical angle of a rectangular glass block
	P7	Diffraction through a single slit
	P8	Verification of Boyle's law
	P9	Verification of Charles' law
	P10	Preparation of a standard solution
3	P11	Induced current in a coil by moving a magnet in and out of the coil (demonstration)
	P12	Ohm's law
	P13	Exothermic and endothermic reactions
	P14	Acid-base titration
4	No prescribed practicals for the fourth term	

The experimental practicals were mostly expository, involving learners following predetermined procedures. Only a few of these activities provided opportunities for learners to design experiments. In Table 3, we summarise our findings on the opportunities which the experimental write-ups provide for skills development.

Table 3: Evaluation of teachers' practical laboratory plans
in offering opportunities for developing skills in learners

Skills	P1	P2	P3	P4	P5	P6	P7
Follow instructions to perform an experiment using equipment correctly	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Formulate a hypothesis	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Interpret results	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Write a practical report	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Record measurements/collect data	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recognise and evaluate alternative explanations for the same set of observations	No	No	No	No	No	No	No
Design and build a working device	No	No	No	No	No	No	No
Design experiment/investigation including controls	No	No	No	No	No	No	No
Suggest suitable experimental techniques	No	No	No	No	No	No	No

Thus, from Table 3 it can be inferred that the analysed experimental write-ups were tailored to develop lower level skills than higher cognitive learning or inquiry-based learning. Teachers had little control over what cognitive levels to develop in learners as the write ups are done on their behalf. Their role had been reduced to being implementers of an instructional program devoid of flexibility or contextualisation. The types of skills that Crujeiras-Perez and Jimenez-Aleixandre (2017) used on ninth and tenth graders that involved planning investigations, designing experiments or suggesting experimental techniques, were missing in the write-ups provided.

Findings from interviews: Teachers perceptions

Through the semi-structured interviews, we sought to respond to the following question:

> What are teachers' perceptions on the prescribed and recommended practical components in physical sciences?

Teachers' perceptions were organised into themes that emerged from the literature review, such as their general reception of the practical components of CAPS, professional development pertaining to the reforms, resource provisions, work overload and their perceptions on the degree of inquiry-based laboratory practices. Some of these themes overlap when seen from the teachers' point of view. Below we present our findings under the major themes.

Teacher perceptions of the prescribed changes

The participants in this study perceived the prescriptions and recommendations in the practical components as positive. Siyanda responded to our question on her perception about the introduction of the recommended practicals:

> ... the positive about these changes are that the practical experiments are included. Before…the practicals were not that stressed but now they are included in grade 10, 11 and 12. And learners must have them, they must have those skills. They must have the demonstration skills, the handling of data… all those… identification of all those variables… independent and dependent variables. So, that is an added advantage. Ah… that's the main advantage…

These teachers cited that the prescription and recommendations gave them clarity and they knew exactly what practicals to conduct with the learners, unlike in the previous NCS curriculum. Andre felt there was clarity in the CAPS curriculum:

> … the practical recommendation brings clarity on what we should do. This is good because as teachers we do not have a lot of time… so now things are much clearer…. and we know the twelve skills that we have to develop in learners … for me everything is clear.

According to the teachers, some of the new prescribed experiments would benefit those learners who proceed to tertiary education. Thandie added that '…the titration experiments are very good… good for learners especially for their future at the university…'. Such observations were very interesting to us as they indicated that teachers were not always necessarily focused on their own interests during the implementation, but rather their interests extended to what was good for learners as well.

Professional development and capacity building on practical components

For Fullan (2001) change involves building ownership and capacity in others (teachers); hence, some of our questions were directed at eliciting participants' perceptions on capacity building just before the launch of CAPS and soon after the launch. Support programs during and after the launch of CAPS may have been developed and implemented without clear understanding of teachers' needs, resulting in limited effectiveness in assisting teachers for successful implementation (Gudyanga & Loyiso, 2018). Physical sciences teachers' frustrations concerning their everyday practice included insufficient training for practical experiments. Siyanda expressed herself:

> remember when CAPS was introduced, they told us there will be experiments but they did not tell us how to do the experiments, except for a few experiments… although we have done them at tertiary level, a lot of things have happened, some of us may have forgotten those experiments we learnt at university. So CAPS is a good idea but they did not do everything, they did not train us in other aspects like practical work…

While participants attended a series of workshops in the run up to the launch of CAPS, the consensus was that inquiry approaches were not a priority. The workshops prioritised how to manipulate science equipment and set up the recommended practicals. All participants testified that of the few workshops that were provided after the launch of the reforms, none were focused on assisting teachers to improve their laboratory skills.

Resource provision to support the reforms

The lack of laboratories, chemicals and apparatus in most South African schools has been cited previously as an obstacle in the implementation of C2005 and NCS science reforms (Ramatlapana & Makonye, 2013; Grussendorff et al, 2014). Participants confirmed that the departmental authorities had made provisions for the supply of mundane laboratory needs. Oftentimes, the challenges were related to teachers' insufficient expertise in using the equipment, chemicals and other apparatus for successful laboratory instruction.

Siyanda confirmed the challenges she faced in carrying out the practical experiments with learners. She confessed that resources might be available but sometimes she was unable to use them:

> In my school we have the Shanduka project… the Kagisho Shanduka project. So, we get resources from there. But at the same time, they need to unpack the resources, they need to bring the manuals and tell us how these things work, where they work, which experiments are for what, because the box will lie, it will not be opened, time goes and you ask somebody please come and explain how to use this, for which experiment...

All the three schools purposively selected had well-equipped laboratories. Grussendorff et al (2014) had asserted that only 5% of South African schools were sufficiently resourced for CAPS implementation. Our findings do not dispute these findings by Grussendorff et al (2014), as this study targeted schools that we knew had laboratories.

"I majored in chemistry, but I am also expected to have expertise in physics practicals."

In the South African schooling system, physical sciences are a composite of two subjects: chemistry and physics. In some schools two teachers may teach the same classes with one assigned to teach chemistry topics and the other to teach physics, oftentimes in alignment with their majors. Two of the participants taught both chemistry and physics topics and revealed challenges in their teaching of topics they had not majored in. The third teacher had majored in both chemistry and physics. Thandie, the chemistry graduate from the rural school, explained how new practical requirements impacted her as a physical sciences teacher who majored in chemistry only, yet was expected to assist learners in both chemistry and physics practicals. For her, it took less time and less effort to prepare a chemistry practical than it would take to prepare a physics practical.

> …I need to learn how to carry out those new experiments especially in physics because even… though there are new experiments in chemistry I can always improvise because… as I am from a chemistry background... I can jump into the storeroom without much preparation and get chemistry experimental apparatus and quickly set up a chemistry experiment with little difficulty, but physics! I struggle…

Andres, who majored in physics admitted that teaching chemistry topics was not as easy as teaching chemistry. He commented that "…we have got our own strengths so you'd prefer physics because you are more comfortable with the physics content while someone else would prefer chemistry…". These challenges pertaining to teachers teaching topics in a subject they had not majored in are magnified during curriculum reforms when new topics and new practical experiments are introduced.

Time constraints

All physical sciences teachers who took part in this study cited time as constraining against inquiry-based learning. These findings coincide with other studies (Ramnarain & Hlatswayo, 2018; Tsakeni, 2018). The participants confessed that their practicals with the learners were mostly demonstrations instead of individual experiments, and hence teacher-centred practices. Siyanda expressed herself:

> …there are time constraints, you cannot do everything… So you can only do the demonstration and sometimes you can only give learners some worksheet on the experiment to practise and then they will have the answer…

Physical sciences teachers are burdened with tasks such as preparing equipment, solutions and reagents for practical science lessons, plus purchasing materials and equipment (Mizzi, 2013). Andre expressed himself thus,

> Do you know what; time is a big issue because I mean like how long will it take you if you have forty-five learners in a class and each one have to do that practical, you must set it up, prepare before and you must still assist them while they are busy so that they don't copy so that is also a bit of a challenge if they have to do that individually now…

To ameliorate this situation Andre had a suggestion:

> …if schools could have laboratory assistants… like at university… to assist science teacher… the experiments could be done well to assist learners. It would help with the organisation and the cleaning …the teacher could dedicate more time to teaching…

Accountability measures and high stakes testing

Teachers expressed that they were 'under pressure' to enhance learner achievement rates in national examinations and 'common tests'. Siyanda, expressing her frustrations commented:

> …the department says we need 100 percent, we need quality results, we need 100 percent quality results, but it is not happening… it's too much pressure for teachers so sometimes you just teach for the examination…

Teaching for examinations in the case of the practical experiments might mean teachers are prioritising completing tasks with learners irrespective of the quality of learner experiences. Furthermore, because there are no practical examinations in the school system the practicals that learners conduct throughout the year are assessed by the teachers themselves and they contribute to learners' final grades at the end of the year. In an environment where teachers feel 'pressured' to enhance achievement rates in high stakes examinations, it is plausible that this pressure may compromise instruction. Besides, not all the recommended practicals are assessed in the 'common tests' that South African learners sit to gain marks that determine whether they progress to the next grade or not. This may lead teachers focusing on only those practicals that are assessed. Andre commented that "…it's like honestly the impression for some teachers might be that only those formal (those that are assessed) are important …so they deal with those ones only…". Introducing high stakes practical examinations in the South African schooling system may enhance the implementation of the practical components.

Having presented results from the document analysis and those from the interviews, below we triangulate and discuss these findings.

Discussion

The integration of the document analysis and the interview results enabled us to respond to the research questions and hence shed light on teachers' perception on the reforms in terms of the practical components, including the opportunities and obstacles that teachers confront in their implementation of the components. As the sample is from one district, and therefore not representative of the whole country, the results may not be generalised to the whole of South Africa. However, through member checking, triangulation of the different results, explaining, and justifying the methodology, we ensured that the results are accurate depictions from the participants and the methods we employed. The key results indicate the prescription of experimental practicals as being on two levels: firstly, from the National (federal) Department of Basic Education, a list of experiments is provided for grade 11 physical sciences teachers. Secondly, at the provincial level, local authorities provide detailed write-ups that serve as lesson plans for the recommended practicals which teachers should conduct with learners. In our view, the prescription for physical sciences practicals epitomises the overly prescriptiveness of CAPS which has been reported elsewhere (Ramatlapana & Makonye, 2013; Grussendorff et al, 2014). On further analysis, these write-ups provide limited opportunities for what recent research considers as good instruction in science laboratory work. Instead, they offer mostly recipe-like procedures that learners have to follow. Nevertheless, the participants in this study perceived these changes in a positive light, citing reduced workloads for themselves.

From an implementation research perspective, policymakers may have enhanced clarity on what teachers should do and how they should do it. The prescription of practical experiments in the curriculum may have significantly reduced the gap between policymakers' expectations and teacher practices (as inferred from teachers' perspectives). However, this might have been achieved at the expense of teacher autonomy and creativity, including the large space needed for possible contextualisation of practical activities. A rare truce between policymakers and teachers might have been attained at the expense of good practices. For these participants, neither inquiry-based learning, teaching for scientific practices nor scientific competencies were priorities.

While it is difficult to understand the intentions of the authorities in terms of the kind of approaches they expected, it can be inferred that at least at the provincial level expository approaches were prioritised. Brief notes on inquiry in the preamble of curriculum documents may not necessarily mean that policymakers intended inquiry-based learning to be the main approach. Curriculum documents should be more specific about which skills laboratory work should develop and devise practical work that allows developing those skills (Josephsen & Hvidt, 2015). The write-ups provided at the provincial level present missed opportunities to cater for the development of scientific competencies, scientific practices or inquiry-based approaches. Also, the limited flexibility in the presentation of the CAPS may hamper teachers' ability to respond to the varying needs of learners. Provincial authorities might be toeing the national departmental line on CAPS, which has already been described as a program of instruction that is teacher-centred (Grussendorffet al, 2014). A complex interplay of factors could be the reason policymakers, authorities at provincial level and teachers might be shying away from an emphasis on learner-centred approaches, towards teacher-centred approaches. These include, among others, the emphasis on matric results achievement rates and the politics surrounding it, as well as the reduced conviction that learner-centred approaches can improve learner achievement rates.

While they made efforts to reduce the gap between policy and practice by improving on clarity, policymakers may have created new challenges that jeopardise good instruction. The new emphasis on practicals in the CAPS may be viewed as a new element that has resulted in increased connections among the existent elements in an already complex curriculum implementation process. Policy makers and other stakeholders could manoeuvre the complex terrain better by looking at implementation through the lens of complexity theory. Despite the improved clarity in curriculum documents, teachers still confronted time constrains, heavy workloads and deficiencies in practical knowledge skills needed in some of the new experiments. Participants testified that no follow-up workshops targeting laboratory skills had been conducted. The challenges to be competent in both chemistry and physics practical skills are magnified in times of reforms when new topics and increased emphasis on experimental practicals are introduced.

Time constraints are a complex phenomenon. Inadequate practical skills, large administration workloads, large content or complex content, may all lead to challenges that can manifest as time constraints. However, for these teachers who do not have laboratory assistants, setting up experiments, overseeing the practicals with the learners and cleaning up the glassware before their next class can still be overwhelming, even for the expert teacher. Emphasis on high stakes test achievement rates may constrain teachers' practices and judgements towards developing good practical skills in learners. The tension between accountability and curriculum coverage goals versus inquiry-based approaches have been reported elsewhere (Nariman & Chrispeels, 2016; Simmons & MacLean, 2018). Such dissension could be evidence of some deeper ideological conflicts existent in the South African schooling system (Mnguni, 2018). If education innovations of the past four decades have been characterised by great ambitions, albeit falling short in reforming teacher classroom practices (Cohen, 1990), the CAPS practical components lack such ambitions. If implementation research of recent times has often decried poor implementation of seemingly progressive reforms, the reverse, where less ambitious curricula are 'well implemented' is not a better option.

Conclusion

Teachers perceived the inclusion of a list of recommended experiments for the physical sciences as positive. Previously, teachers had to decide what experiments to conduct with the learners. Apart from the list, at the provincial level teachers are also provided with practical lesson plans that they are must use in their laboratory classes. The written practical lessons offer limited opportunities for teachers to develop higher cognitive skills or skills related to inquiry-based learning, or scientific practices or scientific competencies. While the present curriculum seems to have reduced the 'implementation gap", this might have been achieved at the expense of good science laboratory practices such as the development of scientific competencies, or scientific practices.

Physical science teachers who participated in this study still grappled with other challenges such as time constraints, large workloads and pressures for high achievement in high stakes examinations. Based on this study, we concluded that the participants shared almost similar challenges with regards to the implementation of practical activities, despite differences in school location. We recommend the provision of laboratory assistants in schools to reduce the apparent heavy workload on physical sciences teachers. Bold statements on inquiry-based approaches in the preamble of curriculum documents are not sufficient for changing classroom practices. Policymakers must clarify what skills in laboratory activities should be developed in learners and the provided write-ups must indicate and offer opportunities on how the development of the specified skills can be achieved.

Acknowledgements

We would like to acknowledge the South African National Roads Agency (SANRAL) for partially sponsoring this study.

This work is based upon the thesis: Gudyanga, R. (2017). *Physical sciences teachers' perspectives and practices on the new Curriculum and Assessment Policy Statement*. Unpublished PhD thesis, University of the Free State, South Africa.
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Please cite as: Gudyanga, R. & Jita, L. C. (2019). Teachers' implementation of laboratory practicals in the South African physical sciences curriculum. *Issues in Educational Research*, 29(3), 715-731. http://www.iier.org.au/iier29/gudyanga.pdf