An investigation of the pedagogical orientations of Grade 8 Chemistry teachers in Orchestrating Practical Demonstrations at schools in Oshikoto Region, Namibia

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Abstract
The use of practical work is ubiquitous in almost every science classroom globally. It is advocated for by the Namibian National Curriculum for Basic Education [NCBE] for a country to become a knowledge-based society which should be achieved through engaging learners in hands-on practical activities. Regardless of the calls from the NCBE for learner-centred practical work, teachers in the Oshikoto Region resort to enacting practical demonstrations. This mixed methods study investigated the pedagogical orientations of teachers in Oshikoto Region when orchestrating grade 8 chemistry demonstrations. The study involved two phases. During Phase I, quantitative data were collected through a questionnaire survey that was administered to 87 Grade 8 Physical Science teachers. Phase II involved the collection of qualitative data by means of class observations and semi-structured interviews of 10 teachers purposefully selected from a pool of 87 teachers who completed the questionnaire.

The findings revealed that 56.3% (49 out of 87 teachers studied) in the Oshikoto Region exhibited a preference for teacher-orchestrated demonstrations rather than entrusting practical activities to learners. Contextual factors such as a lack of resources to conduct practical work, insufficient curriculum time allocated for practical lessons and large class sizes were considered to influence this preference. The results further showed that through teacher-orchestrated demonstrations, teachers regularly applied certain pedagogical actions. These included inviting learners to make a prediction, asking learners to explain their observations, and facilitating a class discussion after the demonstration. This suggests that although demonstrations were teacher-orchestrated, teachers interacted with learners through these actions to ensure that they were cognitively engaged. Therefore, the study recommended that the NCBE should allocate more timetable time for practical work in science classrooms, science teachers should be engaged in continuous professional development on practical work and they should also be encouraged to make use of readily available materials to do practical work in the absence of the traditional, practical work equipment.

Keywords: *practical work; teacher-orchestrated demonstrations; pedagogical orientations, Chemistry*

Introduction and background

In almost all countries globally, science scholars acknowledge the role of practical work in teaching and learning science. Like other countries, the importance given to practical work is recognised in Namibia. According to the Ministry of Education, Arts and Culture, in the Physical Science curriculum for junior secondary phase (JSP), the importance of studying science subject is to increase the learners' knowledge and understanding of the world they live in, critical thinking, investigating phenomena, interpreting data, and also applying knowledge to practical skills (Namibia. MoEAC, Syllabus, 2015). The natural sciences area as one of the key learning areas in the NCBE "contributes to the foundation of a knowledge-based society by empowering learners with the scientific knowledge, skills and attitudes to formulate hypotheses and to investigate, observe, make deductions and understand the physical world in a rational, scientific way" (Namibia, MoEAC. NCBE, 2018, p. 13). For this knowledge-based society to be achieved, the said curriculum document further emphasised that the approach to teaching and learning science should be based on the paradigm of learner-centred teaching approach which is meant to recognise the vast knowledge learners bring to class. Moreover, the knowledge-based society could also be achieved through exposing learners to as many practical work in science from the early grades as possible. The curriculum document further specifies and makes suggestions of possible practical activities and/or demonstrations that teachers should enact at the end of each topic (Namibia. MoEAC, Syllabus, 2015).

Practical work varies in form and intention. According to Millar, Le Marechal, and Tiberghien (1999) if researchers are to explore the effectiveness of practical work in achieving educational goals, then there is need to provide clarity about the different types of practical work, their different purposes, and pedagogical approaches for each type. Despite calls for learners to do independent scientific inquiry where they have an autonomy in formulating their own investigation and planning an inquiry, factors such as lack of resources, large classes, and the lack of class time have resulted in teacher-orchestrated practical demonstrations being the prevalent form of practical work in sub-Saharan countries (Ramnarain, Nampota, & Schuster, 2016).

This study investigated the pedagogical orientations of Physical Science teachers when orchestrating chemistry practical demonstrations at schools in Oshikoto Region, Namibia. The first author is a High school Physical Science teacher in this Region and has particular interest in understanding how other teachers enact chemistry demonstrations in their classrooms. Most schools in Oshikoto Region, especially in Omuthiya Circuit, where the first researcher teaches, are under-resourced in terms of science facilities, such as laboratories. The Education Management Information Systems (EMIS, 2017) report shows that out of 94 schools where Physical Science is offered as a subject, only 47 are equipped with science laboratories. The benefit of teachers using demonstrations in such a context has been recognized. Treagust (2007) points out that demonstrations can increase learners' cognitive involvement.

The value of demonstrations is also advocated by the Namibian Ministry of Education, Art and Culture and, it is prescribed in the Physical Science curriculum for JSP, (Grade 8 and 9), that learners should be exposed to practical activities, approaches and demonstrations during instruction (Ministry of Education, Arts and Culture [MoEAC], 2010, 2015). The Physical Science JSP curriculum consequently outlined that, relative to the general and specific objectives to be achieved at the end of each topic or area of content, teachers should decide when "it is best to convey content directly; it is best to let learners discover or explore information for themselves or when they need directed learning" (Namibia. MoEAC, Syllabus, 2015, p. 4).

Literature review on practical work in science teaching and learning

The literature abounds with numerous characterizations of the construct "practical work". To this end, science scholars seem to gear their understanding towards the inclusion of hands-on activities in their descriptions of what practical work encapsulates. This is reflected in the definition by Lunetta, Hofstein, and Clough (2007) who described practical work as "learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world" (p. 2). Woodley (2009) concurs with their definition as she defined practical work in science as "a hands-on learning experience which prompts thinking about the world in which we live" (p. 49). According to Roth et al. (2006), practical work may be broadly classified into whole-class practical activities and independent practical activities. Whole-class practical activities involve mainly teacher-orchestrated demonstrations of phenomena and objects, whereas independent practical activities involve activities "carried out by the students themselves, usually working in small groups" (Millar et al., 1999, p. 33). Whole-class teacher-orchestrated demonstrations range from simple displays of objects such as the model of the heart to display objects related phenomena or showing how substances react with oxygen. This study focused on the enactment of teacher-orchestrated demonstrations, and the pedagogical orientations that teachers display during these demonstrations.

Hattingh, Aldous, and Rogan (2007) identified four levels into which science practical work may be classified. The four levels are positioned in terms of decreasing learners' autonomy in carrying out practical work. Level 1 involves mainly teacher-directed demonstrations, whereas level 4 involves learner-directed activities. Table 1 shows the four levels of practical work defined by Hattingh et al. (2007). It is evident that levels 1 and 2 refer to practical work in the form of demonstrations. For level 1 practical work, a teacher uses demonstrations to help learners develop an understanding of science concepts by using materials or specimens that are easy to obtain within a given environment. For level 2 practical work, a teacher still leads demonstrations, but learners are partly involved as they assist teachers in planning and carrying out demonstrations. Levels 3 and 4 reflect an inquiry-based approach where more autonomy is entrusted to learners in investigating phenomena through practical activity.

Table 1: Four levels of complexity in Science practical work: A classification framework

Level	Types of science practical work
1	Teacher uses classroom demonstrations to help develop concepts. Teacher uses specimens found in the local environment to illustrate lessons.
2	Teacher uses demonstrations to promote some form of learner inquiry. Some learners assist in planning and performing the demonstrations. Learners participate in closed (cook-book) practical work. Learners communicate data using graphs and tables.
3	Teacher designs practical work in such a way as to encourage learner discovery of information. Learners perform guided discovery type practical work in small groups engaging in hands-on activities. Learners can write a scientific report in which they can justify their conclusions based on the data collected.
4	Learners design and do their own 'open-ended' investigations. Learners reflect on the quality of the design and data collected and make improvements when and where necessary. Learners can interpret data in support of competing theories or explanations.

Adapted from Hattingh, Aldous and Rogan (2007)

Despite reformed school science curricula that underlie inquiry-based science education, practical work in the form of teacher demonstrations remain ubiquitous in the science classes in Namibia (Namibia. MoEAC. NCBE, 2018) and globally (Basheer, Hugerat, Kortam, & Hofstein, 2017; Daluba, 2013). Ramnarain (2010) suggests that a demonstration "involves learners watching the teacher generating and collecting data" (p.3). In a demonstration, learners are expected to link the data collected by the teacher or the phenomena they observed to the predictions they made prior to the activity. Similarly, Odom and Bell (2015) described a demonstration or lecture demonstration (as they are synonymously referred to in literature) as referring to learners "watching the teacher do experiments, lecture demonstrations are teacher-led with students passively observing the results, the teacher may pose questions or ask for predictions, but students are not physically engaged with science materials or socially engaged with peers" (p. 88). Odom and Bell (2015) further stated that "although laboratory science became more common in the twentieth century, demonstrations have continued to be a mainstay in science classrooms" (p. 87). The reason that demonstrations are not yet completely phased out of teaching science, are the constraints hindering the effective implementation of practical work in science such as lack of resources and larger classrooms (Odom & Bell, 2015).

Ramnarain (2010) postulated that teachers use demonstrations to familiarize learners with procedures of inquiry. During this type of demonstrations, a teacher places learners' focus on the event or phenomenon being demonstrated. During a practical demonstration, the Predict–Observe–Explain (POE) method and discrepant events are the most useful aspects of a demonstration. According to White and Gunstone (1992), within a POE method, learners are expected to predict what will happen, then observe what is happening and only then will they be able to explain their inferences. Shivolo (2018) gives an example of a demonstration where the POE method is applied. He refers to the expansion of solids, using a ball and ring apparatus where "learners are expected to predict what would happen to the metallic ball before it is heated, with respect to moving through the metallic ring once it is heated, and then through observation, they are able to explain their initial prediction" (p. 29). The POE and discrepant events can therefore help learners develop skills such as hypothesising, experimentation and drawing conclusions (Ramnarain, 2010).

Demonstrations can also be used to illustrate discrepant events "where learners observe unexpected results that are contradictory to their normal experience or expectations" (Ramnarain, 2010, p. 41). According to Shivolo (2018) discrepant events may be better described in terms of a demonstration on the unusual behaviour of water between 0 °C and 4 °C. Learners are believed to think that if water is cooled below 4 °C, it would contract like any other substance, but through observation, they would expect unexpected results.

Conceptual framework

This study was informed by the two conceptual frameworks: the pedagogical content knowledge (PCK) and the teachers' pedagogical orientations.

Pedagogical content knowledge

In 1986, Lee Shulman identified "PCK as a central element in the knowledge base of teaching" (Friedrichsen, Van Driel, & Abell, 2011, p. 359). PCK is the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful, yet adaptive to the variation in ability and background presented by students (Shulman, 1987). Shulman (1987) further described PCK as representing the "blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction" (p. 8). Moreover, "PCK includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons" (Shulman, 1987, p. 9). PCK is therefore an important element in teaching science in that it is of special interest because it identifies the distinctive bodies of knowledge for teaching science (Shulman, 1987). Shulman's original emphasis was on the following knowledge elements: content knowledge and/or subject matter knowledge (SMK), general PCK, the knowledge of the curriculum, knowledge of learners, knowledge of the educational contexts and knowledge of the educational ends, purposes and values (Magnusson, Krajcik and Borko (1999). The Shulman PCK model, however, lacked the element of orientation to teaching science of which Magnusson et al. included as a crucial aspect of PCK. As one of the significant constructs of this study, orientations, also pedagogical orientations to teaching science will be discussed in the next section.

De Jong, Veal and Van Driel (2002), indicated that PCK can be designated at three levels: general PCK, domain-specific PCK and topic-specific PCK. It is for this reason that Magnusson et al. (1999) described PCK as a "teacher's understanding of how to help students understand specific subject matter including knowledge of how specific subject topics, problems and issues can be organised, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction" (p. 96).Wei and Liu (2018) revealed that although there seems to be no commonly accepted conceptualisation of PCK, agreement has been reached on two essential elements of Shulman's (1986) PCK model which focused on the knowledge of the representations of specific subject matter and understanding of students' learning difficulties and wrong conceptions (Van Drielet al., 1998). Wei and Liu (2018) further described subject matter as being "somewhat elusive, however, and some insights can be obtained from the discussion of subject matter knowledge in the literature" (p. 2).

According to Grossman, Wilson and Shulman (1989) SMK comprises four broad categories: (1) content knowledge – the "stuff" of a discipline; (2) substantive knowledge – knowledge of the explanatory framework or paradigms of a discipline; (3) syntactic knowledge – knowledge of the ways in which new knowledge is generated in a discipline; and (4) beliefs about the subject matter –

feelings and orientations towards the subject matter. Based on the four categories of SMK as espoused by Grossman et al. (1989), Wei and Liu (2018) believe "practical work, or experimentation, is an integral part of Natural Sciences subject matter across the four categories" (p. 2). While practical activities in the science classroom have been projected as playing a vital role, traditional teaching of teacher "talk and chalk" are dominant strategies. Friedrichsen et al. (2011) specified that science teachers' practices are influenced by many factors such as the social and policy context in which science is taught, SMK, PCK as well as their attitudes and beliefs about teaching science.

Teacher pedagogical orientation when orchestration practical demonstrations

According to Magnusson et al., (1999) an orientation is defined as "a general way of viewing or conceptualizing science teaching" (p. 97). Anderson and Smith (1987) also used the term 'orientations' to describe teachers' "general patterns of thought and behaviour related to science teaching and learning" (p. 99). Hewson and Hewson (1987) conceptualise a pedagogical orientation similarly as they refer to it as a "set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature of content of science and students and the learning which the teacher uses in making decisions about teaching, both in planning and execution" (p.194).

In this study, pedagogical orientations were therefore viewed as science teaching orientations and described as the knowledge and beliefs teachers have about teaching science at a particular grade level (Magnusson et al., 1999). Figure 1 depicts the simplified version of teaching science according to Magnusson et al. (1999).

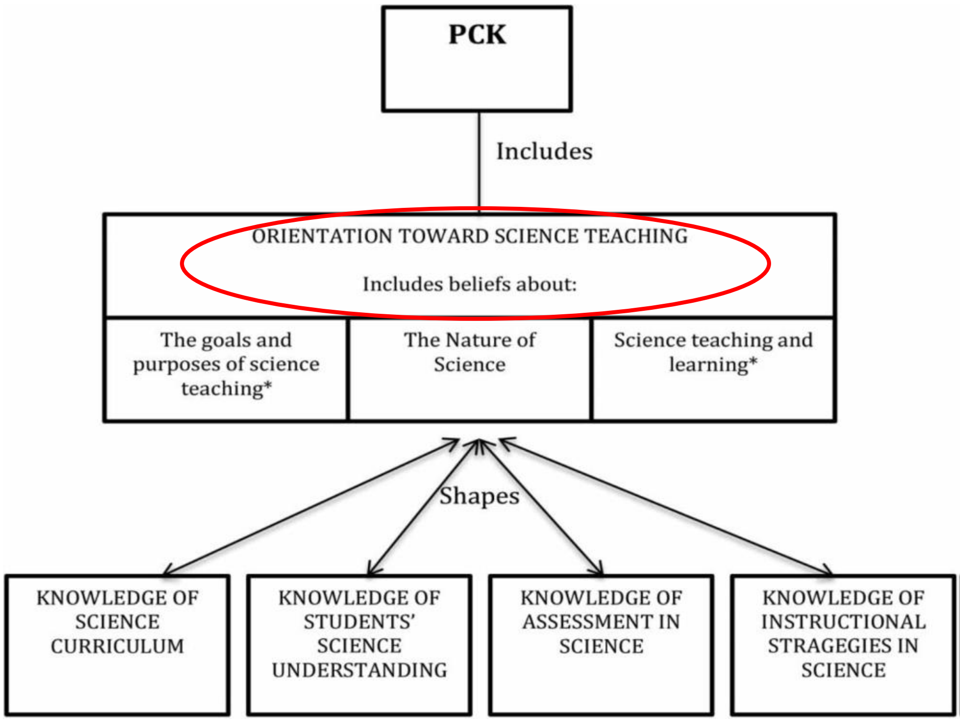

Figure 1: The Simplified Version of Teaching Science (Adapted from Magnusson, Krajcik, & Borko, 1999)

In Figure 1, orientation (circled in red) towards science teaching is projected as a construct of PCK. Orientation towards science teaching is also presented as being influenced by knowledge of science curriculum, knowledge of students' science understanding, knowledge of assessment and knowledge of instructional strategies. Magnusson et al. (1999) further outlined that the orientations are generally organised according to the emphasis of the instruction. In the Grossman et al. (1989) PCK model, one of the four broad categories of SMK revolve around teachers' beliefs about the subject matter – feelings and orientations towards the subject matter. Tables 2 and 3 outline the "goals of teaching science that a teacher with a particular orientation would have and the typical characteristics of the instruction that would be conducted by a teacher with a particular orientation" respectively (Magnusson et al., 1999, p. 97).

Table 2: The goals of different orientations to teaching Science

Orientation	Goal of teaching science
Process	Help students develop the "science process skills." (e.g., Science-A Process Approach [SAPA])
Academic rigour	Represent a particular body of knowledge (e.g., Chemistry).
Didactic	Transmit the facts of science.
Conceptual charge (Roth, Anderson, & Smith, 1987)	Facilitate the development of scientific knowledge by confronting students with contexts to explain that challenge their naive conceptions.
Activity driven (Anderson, & Smith, 1987)	Have students be active with materials; "hands-on" experiences.
Discovery	Provide opportunities for students on their own to discover targeted science concepts
Project-based science	Involve students in investigating solutions to authentic problems.
Inquiry	Represent science as inquiry
Guided inquiry	Constitute a community of learners whose members share responsibility for understanding the physical world, particularly with respect to using the tools of science.

Adapted from Magnusson et al. (1999, p. 100)

Table 3: Nature of instruction associated with different orientations to teaching Science

Orientation	Characteristics of instruction
Process	Teacher introduces students to the thinking processes employed by scientists to acquire new knowledge. Students engage in activities to develop thinking process and integrated thinking skills.
Academic rigour	Students are challenged with difficult problems and activities. Laboratory work and demonstrations are used to verify science concepts by demonstrating the relationship between particular concepts and phenomena.
Didactic	The teacher presents information, generally through lecture or discussion, and questions directed to students are to hold them accountable for knowing the facts produced by science.
Conceptual change	Students are pressed for their views about the world and consider the adequacy of alternative explanations. The teacher facilitates discussion and debate necessary to establish valid knowledge claims.
Activity driven	Students participate in "hands-on" activities used for verification or discovery. The chosen activities may not be conceptually coherent if teachers do not understand the purpose of particular activities and as a consequence omit or inappropriately modify critical aspects of them.
Discovery	*Student-centred*. Students explore the natural world following their own interests and discover patterns of how the world works during their explorations.
Project-based science	*Project-centred*. Teacher and student activity centres around a "driving" question that organises concepts and principles and drives activities within a topic of study. Through investigation, students develop a series of artefacts (products) that reflect their emerging understandings.
Inquiry	*Investigation-centred.* The teacher supports students in defining and investigating problems, drawing conclusions and assessing the validity of knowledge from their conclusions.
Guided inquiry	*Learning community centred.* The teacher and students participate in

	defining and investigating problems, determining patterns, inventing and testing explanations and evaluating the utility and validity of their data and the adequacy of their conclusions. The teacher scaffolds students' efforts to use the material arid intellectual tools of science, towards their independent use of them.

Adapted from Magnusson et al. (1999, p. 101)

Magnusson et al. (1999) identified several types of orientations as indicated in the tables above, but for the purposes of this study only the *didactic* and *academic rigour* orientations (circled in red) are considered because they are both a typical example of teacher-orchestrated orientations. Magnusson et al. (1999) noted that within a didactic orientation, a teacher has the "goal to transmit the facts of science" (p. 100). Magnusson et al. (1999) further claimed that it is through this approach that a teacher is believed to present scientific phenomena to learners through the discussion and/or lecture approach. By this means, questions are used as the teaching style for which learners are expected to reproduce facts established through science. On the contrary, academic rigour requires that a teacher has the goal of representing a particular body of knowledge to learners, where learners are challenged with difficult problems and activities to solve (Magnusson et al., 1999). Moreover, Magnusson et al., (1999) outlined that academic rigour involves laboratory work and demonstrations which are used to verify science concepts by demonstrating the relationship between particular concepts and phenomena.

Pedagogical orientations manifest in pedagogical actions which may include types of questions asked, the use of prompts, and facilitating collaboration and reflection (Gervasoni, Hunter, Bicknell, & Sexton, 2012). In accordance with this conceptualization of pedagogical orientation, this research investigated the pedagogical orientations of Namibian Physical Science teachers when enacting teacher-orchestrated chemistry demonstrations in Grade 8. In terms of this conceptualisation of pedagogical orientation, the following aspects in Namibian teachers' pedagogical orientations with regards to practical demonstrations are investigated: teachers' pedagogical preferences; pedagogical actions; and views on the learning outcomes. Accordingly, the research was guided by the following question:

1. What pedagogical orientations do Grade 8 teachers display when orchestrating chemistry demonstrations?

Methodology

This study adopted a "sequential explanatory mixed methods" design (Creswell, 2002). A mixed method is described by Creswell and Plano Clark (2011) as an approach which conglomerate both quantitative and qualitative data in a single study. They further showed that the centrality of this amalgam is to enable the researcher to have a thorough understanding of the research problem at hand rather than using either approach alone. For a sequential explanatory mixed-method approach, qualitative data are used to explain and elaborate quantitative findings (McMillan & Schumacher, 2010). McMillan and Schumacher further explained that quantitative and qualitative data collection is implemented in two phases, this study primarily put an emphasis on the quantitative methods over the qualitative methods. First quantitative data are collected, and this is followed by qualitative data.

The process of collecting data during this study therefore comprised two phases. Phase **I** involved collecting quantitative data by means of a questionnaire survey, with 87 Physical Science teachers from Oshikoto Region in Namibia completing the questionnaire. The questionnaire used in this study was adapted from an online survey in the United Kingdom administered by Durham University called 'Practical Work in Science-Science Teachers survey.' The permission to use this questionnaire was granted by my supervisor (Prof. Umesh Ramnarain) as he formed part of the initial survey. The questionnaire is structured into sections that comprise items relating to learning outcomes of chemistry demonstrations, the type of demonstrations teachers use, the impact of contextual factors on the types of demonstrations, and teachers' pedagogical actions during demonstrations. The questionnaire was validated for the above constructs by a panel of three science education researchers at the University of Johannesburg. The adapted questionnaire was piloted with 3 Namibian Grade 8 Physical Science teachers to establish the readability of items before it was adopted for this study. The piloting revealed that the questionnaire was well designed and asked all that was required and hence no changes were made to the questionnaire Phase **II** involved the collection of qualitative data by means of classroom observations and thereafter semi-structured interviews. This process involved 10 teachers, purposefully selected from a pool of 87 surveyed teachers, who had indicated a preference for teacher-orchestrated demonstrations.

Questionnaire data (quantitative) were analysed using IBM's Statistical Package for Social Sciences (SPSS) software which involved the calculations of percentages and generations of graphs. The analysis of classroom observation and interview data were facilitated by using ATLAS.ti 7 software and were subsequently coded deductively, and classified, to determine patterns in explanations for teachers' chosen options in the questionnaire survey. Such patterns and trends were later interpreted by means of Thematic Analysis (TA) and translated as assertions which were corroborated by excerpts from classroom and interview data. According to Clarke and Braun (2013) TA is described as a "method for identifying and analysing patterns in qualitative data" (p. 3).

Discussion of the Findings

The findings from the analysis of the questionnaire survey were integrated with the findings from the interviews, and classroom observations into a coherent whole. The interview and classroom observation explained some of the findings which emerged from the questionnaire analysis. This integration of quantitative and qualitative data supported the production of assertions (Gallagher & Tobin, 1991) on the pedagogical orientations of grade 8 teachers when orchestrating chemistry demonstrations. These assertions are presented next.

Assertion 1: Pedagogical preference for teacher orchestrated demonstration

In the questionnaire, teachers were asked to indicate their preference for either doing a teacher-orchestrated demonstration or for entrusting practical work onto learners. Responses to the questionnaire showed that 56.3% of teachers expressed the preference to orchestrate demonstrations, whereas 43.7% indicated that they would entrust learners to carry out practical work. In the investigation of the role of contextual factors informing this choice, there was a section in the questionnaire where teachers were asked to rate the degree of the impact of certain contextual factors on a scale of 1 to 5, where 1 indicated "no impact" and 5 indicated a "high impact". The analysis of data revealed that teachers considered the availability of equipment and resources, the amount of lesson timetabled time for practical activities, and the number of learners per class (class size) as key factors in their decision to do teacher-orchestrated demonstrations rather than having learners do practical activities. These finding are presented in Table 4.

Table 4: Rating of contextual factors in decision to do teacher-orchestrated demonstrations

	Degree of Impact				
Contextual factors	No impact 1	2	3	4	High impact 5
Availability of equipment and resources N (%)	2(2.3%)	4(4.6%)	5(5.7%)	19(21.8%)	57(65.6%)
Lesson timetabled time N (%)	3(3.4%)	2(2.3%)	16(18.4%)	24(27.6%)	42(48.6%)
Class size N (%)	0(0%)	11(12.6%)	7(8.1%)	31(35.6%)	38(43.7%)

Note. N = number of teachers who made this choice.

From this table, it is evident that 76 teachers (87.4%) rated either 4 or 5 the impact of the availability of resources in their decision to do teacher-orchestrated demonstrations. A similar result was noted for the impact of class size where 79.3% of teachers rated the importance of this factor as either 4 or 5. For lesson timetabled time, 75.9% of surveyed teachers rated the impact level of this factor as either 4 or 5. In the interviews the teachers elaborated upon the influence of these contextual factors on their preference for doing demonstrations compared to learner-centred practical work. The following excerpt from a teacher interview highlights the problem of a lack of resources teachers experienced and how this impacted on their decision to do demonstrations:

> *Due to the fact that the provision of resources when it comes to science, that's not so good and we don't have enough resources, at the same time we are trying to save so that we can do other practicals, I could not give learners to do individual or group works, rather I demonstrate and [it is] for them to observe (T16).*

The excerpt below elaborates upon how the lack of teaching time left the teacher with little option other than to do a whole class demonstration:

> *The purpose of, to demonstrate to the whole class was just to save time, because demonstrating group or going from group to group, is very time consuming and a lesson is just 40 minutes, so that was just to save time and to finish with the demonstration at once (T83).*

Assertion 2: Teachers perceive that teacher-orchestrated demonstrations lead to a variety of learning outcomes

In the questionnaire, teachers were asked to respond to a list of six envisaged learning outcomes for teacher-orchestrated demonstrations by rating them on a 5-point scale, where 1 indicated that the learning outcome was "unimportant", 2 indicated that the learning outcome was "of little importance", 3 indicated that the learning outcome was "moderately important", 4 indicated that the learning outcome was "important" and 5 indicated that the learning outcome was "highly important". Teachers considered the following learning outcomes as either "important" or "highly important" during teacher-orchestrated demonstrations: helping learners to understand science concepts (97.7% teachers); developing learners' science skills such as handling apparatus (93.1% teachers); stimulating learner interest in science (95.4% teachers); helping learners to observe physical changes in science phenomena (95.4% teachers); and developing social skills in learners (96.6% teachers). Figure 2 exemplifies these responses.

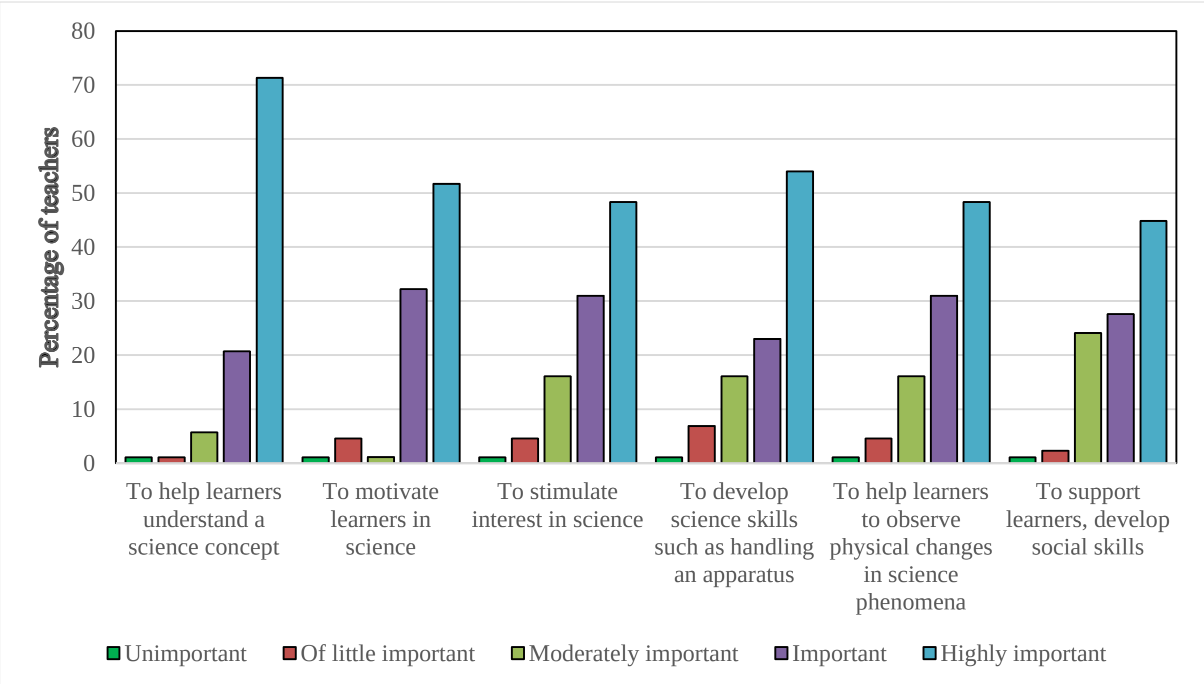

Figure 2: The learning outcomes for Orchestrating Chemistry Demonstrations

With regards to the learning outcome of supporting learners to understand a concept, the teachers expatiated on this benefit during the interviews. The following responses were elicited:

> *Learners were able to explain expansion in solids, that's why I demonstrate to them how expansion take place in solids, by using a ball and ring (T3).*

> *Yeah, the learning outcome is for the learners to understand that once matter is heated, they can expand, especially solids can expand just like gas and liquid particles (T9).*

> *Well, the learning outcomes or basic competencies so to say, I want to see that learners should be able to describe the test and the results of various gases as per the syllabus stipulation (T83).*

It would appear from the above responses that the demonstrations provided an opportunity for learners to visualise phenomena, and this visualisation led to conceptual understanding. This benefit was also revealed in their assessment of "helping learners to observe physical changes in science phenomena" where a great majority of teachers recognised its importance. This is evident in the excerpt below:

> *The learners were observing as I, the teacher was busy with a demonstration, but they were also active at some points because they have to answer questions that I have asked them, and they also have to feel the test tube when we were doing the demonstration to see if the test tube has become hot or colder (T2).*

Teacher maintained that demonstrations enabled the development of science process skills in learners. Although the demonstrations were teacher-orchestrated, teachers maintained that during the demonstrations they often invited learners to assist them by setting up the apparatus or reading measurements from devices. This is revealed in the following passages from the interviews:

> *The role of the learners was to observe when the teacher is doing the demonstration, it was also to participate, for example they were asking questions and also to help, to assist the teacher for example in holding some of the materials during the experiment (T25).*

> *The role of the learners in the lesson was to observe the experiment, they have to observe, and they have to answer questions, and also, they have to handle the apparatus since I called one learner to come and help in the demonstration (T76).*

The development of social skills was also considered a strong outcome of demonstrations. Teachers held the view that during demonstrations sufficient opportunity needed to be provided for learners to interact with each other. This interaction appeared to be at the stage where learners were asked to explain their observations. Here teachers saw the exchange of ideas within a social setting as potentially contributing to the development of social skills.

Assertion 3: The pedagogical actions of teachers are supportive of an interactive approach in teaching Science

In a section of the questionnaire, teachers were asked to indicate an option on the frequency within which they displayed certain pedagogical actions when orchestrating demonstrations. Teachers were required to elect one of the following options for each listed pedagogical action: no demonstrations; a few demonstrations; about half the demonstrations; most demonstrations or all demonstrations. The data analysis revealed that teachers either did "most demonstrations" or "all demonstrations" and they displayed the following pedagogical actions: ask learners to predict the results (89.7%); talk and show the experiment while learners listened (67.5%); ask learners to explain their observations (95.4%) and ask learners to compare their observations to their predictions (78.5%). Figure 3 depicts the results obtained in this regard.

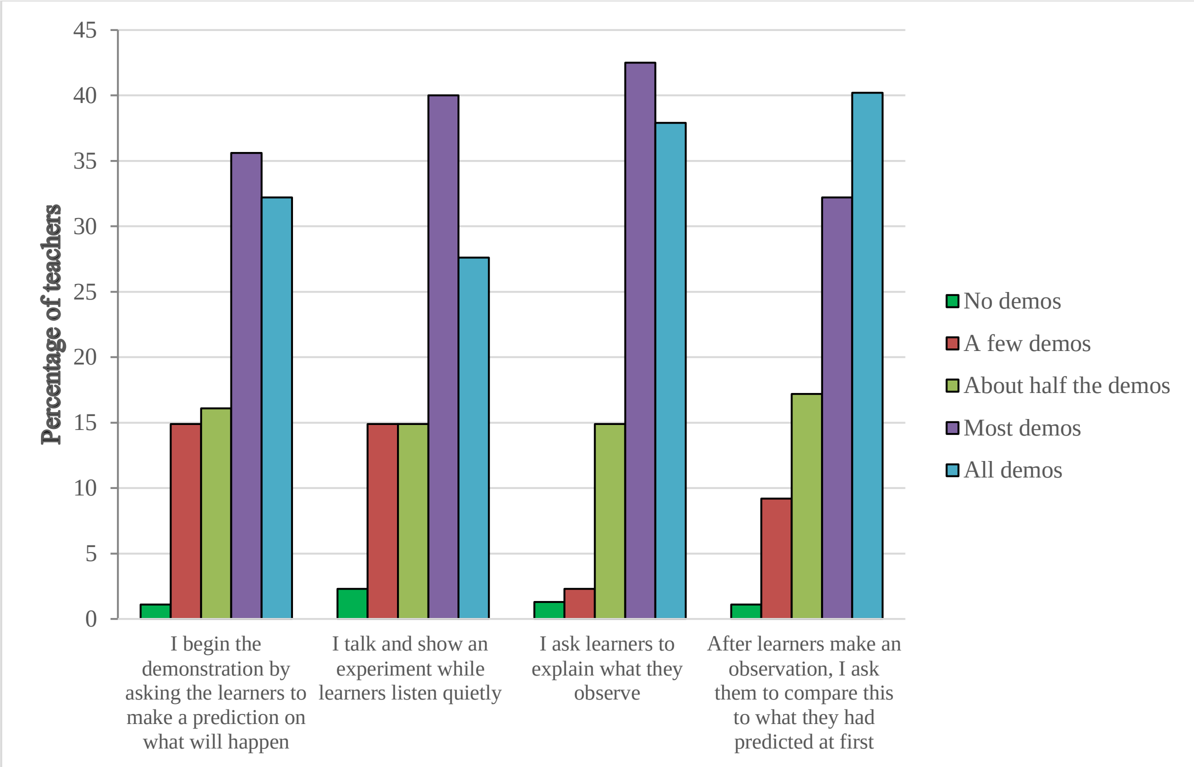

Figure 3: Teachers' pedagogical actions in Orchestrating Chemistry Practical Demonstrations.

During classroom observations of teacher-orchestrated practical demonstrations, it was evident that the teachers employed various pedagogical actions. These observations resonated with their responses to the quantitative questionnaire where teachers responded that they frequently employed several pedagogical actions when conducting practical demonstrations. It emerged from these observations that teachers employed both interactive and non-interactive approaches when leading teacher-orchestrated demonstrations. This enabled the researcher to classify their pedagogical actions as being interactive or non-interactive. The observed pedagogical actions are reflected in Table 5.

Table 5: Interactive and non-interactive approaches to teaching Science

Interactive approach to teaching science	Non-interactive approach to teaching science
There is a teacher-learner and learner-learner interaction in new knowledge construction	The teacher talked and carried out the demonstration while learners listened quietly.
After the demonstration, teacher facilitates and engages learners in a class discussion, where learners explain their observations and are scaffolded in constructing new knowledge	There is no teacher-learner and learner-learner interactions.
This approach does not resemble the predict-observe-explain (POE) approach, as learners are not asked to make predictions prior the demonstration, however teacher starts demonstration, and only ask learners to make observations and he/she ask them	The teacher was in control of the demonstration, learners were not engaged in the demonstration apart from observing. Learners were asked to explain their observations; however, the teacher also, at some point tried to explain learners' observations and then consolidated the learners' answers.
to explain their observations and later concludes by consolidating learners' responses	In this approach, the teacher demonstrated to the whole class either to confirm a law/science principle and/or to affirm the science concepts which he/she taught theoretically.
There is less teacher-learner interaction, learners assist the teacher during the demonstration by handling apparatus	

Although learners are asked to make observations during the demonstration, they are not engaged in class discussions after the demonstration	No new knowledge was constructed by the learners as they passively watched the demonstration and compared the results of the demonstration to what they were taught in a theory lesson.

Figure 4 shows a framework/typology that's had been developed from this study which categorised the teachers' pedagogical approaches in orchestrating chemistry demonstrations as being interactive and non-interactive as also presented in Table 5.

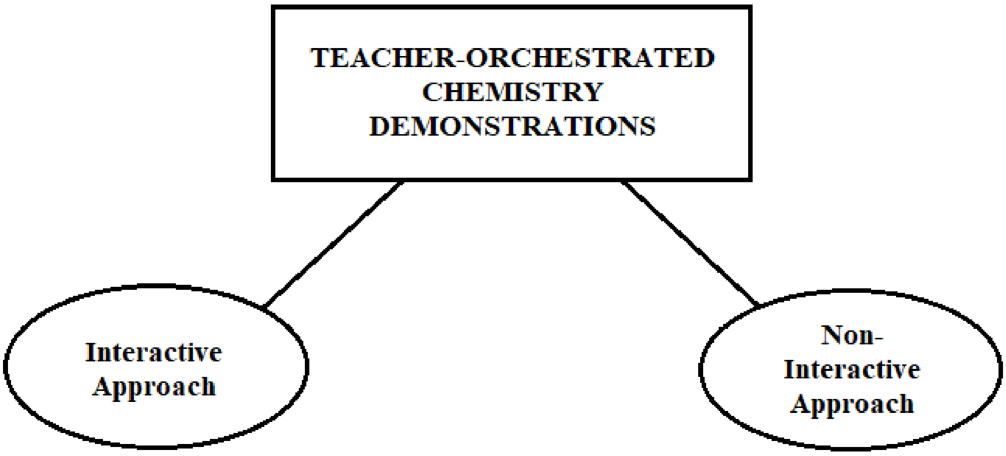

Figure 4: Typology for Teacher-Orchestrated Chemistry Demonstrations

Although in large measure there was resonance between the pedagogical actions claimed by teachers in the questionnaire and the actions observed in the lessons, there was also some discrepancy between these two datasets. For example, 89.7% of teachers indicated in their questionnaire responses that they asked learners to predict the results in either "most demonstrations" or "all demonstrations". However, in none of the observed lessons did teachers enact this action. So, in large measure the teacher invoked the learners to "observe" the phenomena and "explain" their observations of the POE strategy that was developed by White and Gunstone (1992) but did not provide an opportunity for them to make a prediction on the result.

This finding is illustrated in a lesson taught on the expansion of solids. After showing the metal ball passing through the ring, the teacher failed to ask the class to make a prediction on what would happen to the ball when it was heated. This was an opportunity lost for the teacher to get learners to articulate their ideas. The teacher proceeded to heat the ball, and then showed the class that it no longer passed through the ring. The learners were asked to describe what they had observed, and thereafter to advance an explanation for this observation. They were prompted here by the teachers referring the learners to the particle model of matter.

Conclusion

Although a larger study is necessary to provide a broader overview of the practical work in Namibian science classes, the findings for the Oshikoto Region given it being typical of other regions in the country may have significance for the entire country. The findings revealed that, given the existence and influence of contextual factors that teachers in Namibia experience, such as lack of resources to conduct practical work, insufficient time allocated for practical lessons and the issue of large class sizes, it would appear from the results of this study that in Oshikoto Region teacher-orchestrated demonstrations are regarded as being the most effective forms of practical work by which learners can derive learning benefits, such as acquiring an understanding of science concepts, developing practical skills and developing an interest in science.

In terms of the levels of practical work presented by Hatting, Aldous, and Rogan (2007), it is evidently clear that the practical work is predominantly levels 1 and 2, where level 1 is strongly teacher-centred demonstrated, and level 2 albeit still a demonstration reflecting more effort at learner engagement. From the findings it can also be seen that although the demonstrations are teacher orchestrated, the pedagogical actions of the teacher suggested that the learners were cognitively engaged. During the demonstration learners were requested to make observations and they were prompted to explain their observations. After the demonstration, learners were engaged in class discussions. From this, an inference could be made that the chemistry demonstrations conducted by teachers in the Oshikoto Region of Namibia took on a form of a whole class demonstration.

Although this state of affairs in the science classroom did not adhere to the prescripts of the school science curriculum, the findings reflected that teachers acknowledged the important role that practical work played in science learning. This is a significant baseline from which teachers can innovate their practice by exploring opportunities by which inquiry-based learning maybe gradually infused into their practice. Rogan (2003) maintains that, the implementation of an innovation should occur in manageable steps. He introduces the notion of a Zone of Feasible Innovation (ZFI), by analogy with Vygotsky's zone of proximal development to suggest that the implementation of a reformed curriculum needs to be gradually progressed in stages. This implies that if the existing practice of a teacher in practical work is dominated by teacher-centred demonstration, it is unreasonable to demand a quick transition to guided or open inquiry.

A gradual transition for Namibian teachers would be that they introduce a new teaching strategy like the Predict-Observe-Explain (POE) that could be used in association with demonstrations. Further research might thus explore the feasibility of implementing a POE strategy in Namibian science classrooms where contextual factors identified by this study have significance.

Recommendations

The successful implementation of practical activities in Physical Science largely relies on the preparedness of teachers who are the primary agents of change. The Namibian government has embarked upon the development, formulation and reformulation of several policies in terms of the provision of the educational curriculum.

However, there seems to be less effort on the continuous professional developing of teachers in teaching practical science. In an attempt to significantly improve the quality of science education in Namibia, there is a need to strengthen the issue of continuous professional development of teachers in terms of teacher training in teaching with practical work as early as primary schools. It is therefore recommended that:

- The Ministry of Education, Arts and Culture should budget enough money for the construction of functional and adequately resourced science laboratories especially at schools in rural areas, as from primary level so that teachers begin involving learners in practical work as early as primary school to do away with teacher-orchestrated demonstrations which are found to be the predominant and effective forms of practical work at schools in Oshikoto Region

- Laboratories that are already existing at some schools must be renovated to provide conducive learning environments to conducting practical activities.

- MoEAC should design and develop compulsory practical science examination as a form of formal assessment from Grade 8, which is the inception grade of the secondary phase. This is to enable these learners to become competent in higher grades where they are expected to write an alternative to practical work paper.

- The NCBE should be revised to allocate more time for practical work to allow teachers to encourage effective involvement of teachers and learners in doing practical work as compared to the current 9% of the total teaching time per week (56 periods per cycle) equating to five 40-minute lessons on a seven-day cycle allocated to the natural sciences learning area

- Teacher training institutions should incorporate in their curriculum, modules on facilitating practical work for novice and pre-service teachers. For practicing teachers, in-service continuous professional development (CPD) training on teaching through practical work is recommended.

- Teachers are also encouraged to teach practical work using locally available, low-cost materials in the place of lack of traditional laboratory equipment.

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