THE EFFECTIVENESS OF AN OUTREACH INTERVENTION TO PROVIDE TEACHERS WITH THE SKILLS TO IMPLEMENT PRACTICAL AND EXPERIMENTAL WORK IN THEIR CLASSES

by

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DECLARATION

I, Robert Simon Solomon, declare that the contents of this dissertation/thesis represent my own unaided work, and that the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

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ABSTRACT

Practical work in Science is considered to be an important component of science education. However, teachers in poor schools in the rural areas generally find it difficult to conduct practical work.

An outreach project 'Science for Rural Communities' was launched to address this problem. The purpose of this study was to investigate the nature and coherence of the project and its influence on science teachers' content knowledge, skills and classroom practice. The research is situated within a qualitative interpretive paradigm and has adopted an evaluative research design, underpinned by grounded theory as a method of analysis. The use of an evaluative framework normally used for curriculum innovation was adapted for the exploration of impact of the teachers' professional development project.

Teachers reported that they benefitted from participation in the project in various ways, such as increased conceptual understanding of science knowledge, improved practical skills and enhanced confidence. However, there were some inconsistencies identified in terms of project intentions and project outcomes. The suitability of the evaluation framework for teacher professional development programmes is discussed

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ACRONYMS, ABBREVIATIONS AND TERMINOLOGY

Ass	Assessment Standards
CAPS	Curriculum Assessment Policy Statement
CEMSTE	Centre for Mathematics, Science and Technology Education
CIF	CPD Intervention Format
CK	Contextual knowledge
CPD	Continuous professional development
CDE	Centre for Development and Enterprise
CPUT	Cape Peninsula University of Technology
DoBE	Department of Basic Education
DoE	Department of Education
ESKOM	Electric Supply Commission
Expo	Exhibition
FAS	Foetal Alcohol Syndrome
FET	Further Education Training
GET	General Education Training
GPK	General pedagogical knowledge
IRT	Item Response Theory
Los	Learning Outcomes
OBE	Outcomes Based Education
PCK	Pedagogical content knowledge
Pd	Professional development
RNCS	Revised National Curriculum Statement
SAARMSTE	Southern African Association for Research in Mathematics, Science and Technology Education
SCK	Subject content knowledge
SCORE	Science Community Representing Education
SET	Science, Engineering and Technology

SWAP	Schools' Water Project
TIMSS	Trends in International Mathematics and Science Study
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCED	Western Cape Education Department

CHAPTER ONE: INTRODUCTION OF THE STUDY

1. Introduction

1.1 Background to the study

In an attempt to address the inequalities in education of apartheid South Africa, the newly democratically elected government of 1994 consolidated the previous racial education departments, which represented various ethnic groups into one national department of education (Jansen and Taylor, 2003). Even though the National Treasury dedicates the largest allocation of the national budget to education, the results are disappointing, as acknowledged recently by the Basic Education Minister, Angie Motshekga, who summarised the state of affairs in the following way:

"While we are doing well on enrolments, our weakness is in the quality of education." (Motshekga, 2010)

The weak quality of education manifests itself in various forms. One of the major concerns is the unequal distribution of quality education for learners in different communities (Taylor and Yu, 2009). The situation in the rural areas of South Africa is of particular concern. The new, unified government inherited an education system with 36% unqualified and under-qualified teachers (Wildeman, 2000).The highest concentration of these teachers was found in schools in the rural areas, and in specific provinces such as the KwaZulu-Natal, North West and Eastern Cape Provinces.

Historically, education in South Africa impacted differentially between and within ethnic groups according to privilege, class, language and financial access (McKinney and Soudien, 2010). Generally the most disadvantaged learners were within the rural communities. Post 1994, these marginalised communities continue to face more complex problems as compared to people from urban and peri-urban areas.. Their challenges include frequent unemployment (or in many areas earning barely a basic living wage), resulting in a high occurrence of domestic violence, alcohol abuse, poor housing, health issues, and a lack of food security (Wilcockson, 2010).

1.2 Science Educational Challenges and the Rural Poor

Turning to science education specifically, several surveys indicate the distinctly lower science achievement of learners from rural areas. The Trends in International Maths and Science Study (TIMSS) Report 2003 (Martin, Mullis, Gonzalez & Chrostowski, 2004) reveals the performance of South African learners in relation to 50 participating countries and the comparative results in levels of Science. Chapter 4 of the TIMSS report addresses the results under *The South African Science achievement in an international context.* TIMSS utilized the Item Response Theory (IRT) method: a scale of 800 points and a standard deviation of a 100 points was used to calculate the achievement scores and discusses the results for Grade 8 learners, indicating substantial differences between learners in Singapore (the highest achievers at an average score of 578), the average country scale score of 474, and learners in South Africa with the lowest average score at 244. It is of note that the South African scores displayed the widest disparities between students when compared to any other participating country.

The 2011 Annual National Assessment (Department of Basic Education, 2011), which was benchmarked against international standards, suggests that matters have not improved. In Grade 6 the average annual scores for Maths was 30%, well below international norms. The disparities between urban and rural learners are evident. In general, learners in rural areas achieved significantly lower scores than those in urban areas (Centre for Development and Enterprises informing South Africa Policy, 2011).

In a detailed analysis of the factors influencing the low achievement in the TIMSS study, Reddy, Van der Berg, Janse van Rensburg and Taylor (2012) suggested that, amongst others, the large size of science classes may be a contributing factor to learner underachievement. The New National Revised Curriculum of 2005 was implemented and the teacher-learner ratio changed to an official 1:38, i.e. one teacher per class of a maximum of 38 learners; but in reality the numbers, specifically in rural areas, exceeded this education policy stipulation (Hartley and Treagust 2006, Makola, 2005). In the South African rural context, the challenge of overcrowding is complicated by the schools' dire lack of resources and teaching materials, transport and communication problems, and minimal parental support, especially where classes are still held in abject conditions or under a tree (Baruth, 2009). Within many schools serving the poorest communities and in farm schools, multi-grade classes share the only space available (Joubert, 2010).

The nature of effective support for science teachers in these circumstances is the focus of this study.

1.3 Teacher professional support

Numerous teacher support projects exist, many of which have been researched in terms of their effect. Loucks-Horsley, Love, Stiles, Mundry and Hewson (2003) assert that any professional development (PD) programme should improve classroom practice, and not only impact on teachers' understanding, skills or attitudes. Many studies on facilitating improved teacher practice (Brown & Clement, 1991; Viennot & Rainson, 1999) point out that a range of factors, both inside and outside the classroom, influence teachers' pedagogy. As Shulman (1987) points out, teachers draw on four types of knowledge: their subject content knowledge (SCK), their pedagogical content knowledge (PCK), their general pedagogical knowledge (GPK), and the contextual knowledge (CK) of their students and the curriculum for teaching. Professional development programmes may aim to improve any one or a combination of these four knowledge areas. In line with recent professional development programmes in South Africa (Rogan & Aldous, 2005; Department of Education, 2009), this study focuses on a combination of the first two areas, that is, SCK and PCK.

A social constructivist view of learning (Vygotsky, 1978) is often used to underpin professional development interventions. This approach recognizes that new ideas are incorporated in teachers' practices based on ideas that they already hold, and that teacher learning is most effective in a social setting, thus amongst peers. Sense-making as a social context is a particularly powerful notion for PD interventions for teachers from rural schools, as their contexts and experiences are comparable and need little mutual explanation. In this respect, a study done by Dillon, Osborne, Fairbrother and Karina (2000) found that science teachers in primary and high schools in England wanted a user friendly network through which they could develop and strengthen their professional practice, rather than a series of workshops dominated by a facilitator. This idea of peer interaction as a vehicle for professional development reportedly supports the sustainability of change.

However, the extent to which a professional development intervention is sustainable, that is, the integration of promoted practices in a teacher's normal pedagogy, depends on many factors. Fullan (2001, p. 39) highlights a change in belief about teaching, or about the teacher's role as the foundation for lasting reform in the nature of classroom interactions. He also indicates that change in classrooms can be stimulated by the adoption of new or revised learning materials, or by the integration of new teaching approaches. This research project focuses on the latter.

An evolutionary model of teachers' changing practice helps to interpret why teachers respond in different ways to adopting and adapting curriculum innovation (Johnson, Monk & Hodges, 2000; Monk, Johnson & Swain, 1998; Monk, 1999; Johnson, Monk & Swain, 2001). An evolutionary perspective assumes that the range of pedagogic strategies that teachers use in their classrooms is selectively retained because they survive in particular classroom conditions.

The key research, summarised above, indicates several factors promoting the impact of a PD intervention in terms of a change in classroom interactions. These factors are related to the teachers (for instance, their beliefs, or their subject content knowledge), the teaching context (classroom conditions; the curriculum) or the nature of the change being promoted (new learning materials; novel teaching strategies; a teacher support network). However, this study explores how the structure of the PD intervention and its coherence contributes to effective change in science teaching practices.

1.4 Strengthening science and technology teaching

The South African curriculum documents, RNCS (DoE, 2002) and CAPS (DoE, 2011), list several purposes for practical work. Firstly, practical work is seen as a learning experience for improving conceptual understanding of the relevant key ideas in physics, chemistry and technology (Gabel, 2003). Secondly, practical work is seen as providing experiences of essential phenomena (Ng and Nguyen, 2006) such as a discharge of static electricity, an exothermic reaction, or the relationship between pliability of materials and their temperature. Equally, practical work is seen to allow for the development and practice of procedural skills related to scientific reasoning (SCORE, 2008).

Notions of interactive learning, and learning by experiencing, and doing, justify the emphasis on practical work as a learning strategy. Brown, Collins and Duguid (1989) argue that many methods of didactic education assume a separation between knowing and doing. They contend that activity and dealing with situations are integral to cognition and learning.

In reality, research in South African schools (Taylor & Vinjevold, 1999) has identified a legacy of didactic teaching in which the sole teaching aid is the chalkboard. Science experiments are often limited due to a number of reasons. For instance, Johnson, Scholtz, Hodges and Botha (2003) note that the historically disadvantaged schools of the Western Cape generally have large under-resourced classes. Science equipment is in short supply, and often teachers are not sufficiently trained or confident to do practical work in the classroom.

Indeed, teachers often claim that lack of science equipment and laboratories prevent them from teaching science practically. However, there is evidence that many teachers who have equipment do not use it. It appears, therefore, that apart from work overloads, the main reason why teachers do not use practical approaches is that they may not be confident of their practical skills, and do not understand the science concepts that they teach using a practical approach. This claim is well demonstrated in schools that have science equipment. For example, as part of the ZENNEX research project (Muwanga - Zake, 2004) schools in Butterworth have been given Somerset Micro Science Kits, and all of the high schools in the area had some science teaching equipment. In the 21 schools visited, only five seemed to have attempted to use the science teaching equipment. In the other 16 schools, the equipment was found to be gathering dust or neatly stored in boxes that had never been opened. Similarly, visits to three Masifunde Project schools in the Free State Province during 2000 revealed an assortment of unused science teaching equipment. All schools had some expired chemicals and broken or poorly maintained physics equipment, some of which teachers could not identify.

Within the rural environments as described in section 1.2, the need for science laboratories, standard science equipment and skills for using these are considered only remotely attainable as teachers and schools are faced with a myriad of other challenges and needs. Within the context of the challenges of rural education *'Science for Rural Communities*' an outreach intervention, was launched in 2004 in line with the government's initiative to improve conditions for these marginalised communities.

1.5 The intervention: Science for Rural communities

Curriculum advisors from the Educational Management Development Centre (EMDC) in Worcester, approached representatives of the Centre for Mathematics, Science and Technology Education (CEMSTE) at the Cape Peninsula University of Technology (CPUT) and requested some assistance in training and motivating teachers to shift from their normal didactic 'chalk and talk' approaches, to ones that would incorporate practical work. It was their experience that the teachers in the deprived schools in the rural areas generally do not include practical work in their science and technology classes.

In response to this request, CEMSTE put together an outreach project that would address these needs. The outreach project focused on alternative practical approaches, in which the teachers could make and use easily available equipment as opposed to depending on the traditional, more expensive equipment associated with experiments and practicals in Physical Science and Technology. It was hoped that this would eliminate the teachers' common excuse that they do not have resources.

Approaches to outreach can range from providing a social service to a community, to professional outreach in which there is an interaction with, or a service to, professionals in the field. Such work usually draws on the knowledge and expertise of a professional at an institute of higher learning. (Singleton, Burak & Hirsch, 1997; Lynton, 1995). Another form of outreach is service learning. This is envisaged as a kind of community outreach which is credit bearing. Students provide a service to the community and learn from the community, which forms an integral part of their course requirements. In South Africa, the commitment to service learning has been consolidated as part of the requirements for all programmes in institutions for higher learning (Rep. of SA, 1997; Favish, 2003; Fourie, 2003). However, the outreach project in this study does not involve student accreditation and is driven largely by professionals at the higher education institutions who would like to share a particular practically-orientated teaching methodology with in-service teachers.

The outreach programme was targeted at schools in Breederivier-Overberg (now referred to as Cape Winelands) located in a rural district consisting predominantly of poor farm labour communities., The ethnic majority is designated as coloured and experiences a multitude of social and economic problems carried over from the Apartheid era.

Farm labourers in the Western Cape were subjected to scheduled daily "feeding" of alcohol known as the TOT System, whereby farmers compensated workers for their labour and hence exacerbated alcoholism. Although the South African Parliament introduced a new *Liquor Act in 2003* outlawing the TOT or "DOP" system, the rural farming community of the Western Cape inherited a phenomenon called Foetal Alcohol Syndrome (FAS). Breederivier-Overberg is statistically one of the worst affected areas globally, as confirmed by Rosenthal, Christianson and Cordero (2005). It remains a polarised community with huge gaps in income, and variations between first and developing world conditions within sectors such as housing, health, education and family income. Thus teachers need to cope with hungry, lethargic learners with low levels of concentration. Employment for the polarised communities includes mainly labour intensive jobs, hence limited access to finance, which therefore affects people's decisions about future opportunities for their children. Poor families prioritise the need for schooling as a basic requirement, with the highest priority on literacy and numeracy.

1.6 The purpose of the study

The purpose of this study is to investigate the nature and coherence of a professional development programme and its influence on science teachers' content knowledge, skills and classroom practice. By placing the *Science for Rural Communities* project under the spotlight, the study hopes to illuminate the utility and benefits that can be derived from such initiatives for Science Teaching in general and Science Teachers in particular.

1.6.1 Research Questions

The following research questions are addressed:

1. What is the relationship between the intended and the implemented intervention programme?

2. How did the teachers experience the intervention?

3. What were the perceived outcomes as a result of the teachers' participation in the outreach programme?

1.6.2 The conceptual framework

In order to explore the nature and coherence of a professional development programme, the study draws on a conceptual framework originally conceptualised by Goodlad (1979). Based on elaborations of Goodlad's framework by Van den Akker (1998, 2003, 2010) this study investigates the impact of the outreach programme by exploring the nature and coherence of the intended, implemented, experienced and achieved programmes. This evaluation framework is known as the CPD Intervention Format (CIF) Model. In brief, the four aspects of the conceptual framework are defined as the *Intended Programme* describing the original vision underlying the programme in the form of the stated objectives or programme theory; the *Implemented Programme* including the actual instructional process as implemented; the *Experienced Programme* referring to the actual learning experience as perceived and /or experienced by teachers; and the *Achieved Programme* highlighting the resulting learning outcomes of the teachers after participating in the outreach programme.

1.7 The structure of the thesis

This thesis contains five chapters. In chapter 1, the context of the study is described as the provision of support for science teachers working in rural areas under seriously disadvantaged conditions, including a lack of laboratories and science equipment. A brief overview of current knowledge on factors influencing the impact of professional development programmes points to a need to establish the relationship between the nature and coherence of a PD intervention and related classroom change, thus providing the justification for the study. The intervention used as a focus of the study is briefly introduced. This chapter culminates in the specification of the research questions and the conceptual framework guiding the study.

Chapter 2 provides a critical review of the literature in three areas of knowledge. Firstly, the debate about the purposes of different types of practical work is summarised. The views of teachers, on the issues relating to the use of practical work in their teaching, alternative approaches to practical work and the impact of science competitions are discussed. Secondly, an overview is provided of various types of teacher professional development, and the intended purposes of such interventions. Thirdly, the factors and conditions influencing the impact of professional development interventions are discussed extensively, leading to my position regarding the characteristics of the intervention of this study. The conceptual framework for this study is drawn from the literature on curriculum implementation, refined and made applicable to this study.

Chapter 3 presents the methodology adopted for this study, and its relationship with the research questions. The qualitative design of the study within an interpretive paradigm is justified emphasising the voice of the teacher. Data sources and their data collection methods from documents, group, and individual interviews are detailed. Grounded theory analysis strategies are described as applicable for this study. The various measures taken to improve the trustworthiness of the study are discussed, including the possible factors weakening the study's validity.

Chapter 4 presents the findings and analysis of data. Here each of the research questions is addressed and discussed in the light of the evidence. The structure of the chapter follows the sequence of the research questions. The results of grounded theory analysis are formulated as a set of assertions with supporting evidence from the data. Where appropriate, data from multiple sources is presented as evidence for the assertions made, thus applying the principle of triangulation.

Chapter 5 presents the conclusions. The evidence on the coherence between the different forms of the intervention and its impact is highlighted. A critical reflection on the methodology that has been used, as well as on the appropriateness of the conceptual framework for the investigation of the impact of a professional development programme, is included. Limitations of the study and suggestions for further research are also presented.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature on practical work in science classrooms as the key components of this teacher professional development programme involved skilling teachers in conducting practical work and further encouraging them to use the expertise they have developed in their classrooms. An additional expectation was that they would prepare learners to participate in a science competition as a culmination of the program thus the literature review also explores the impact of science competitions in the South African context. Models of teacher professional development and teacher change as well as research frameworks of CPD interventions are examined in order to inform the study.

My research primarily focuses on the perceptions of teachers about the impact of a teacher development programme on their practice, and to a lesser extent on the way in which their participation contributed to an event such as the science competition for learners.

2.2 Practical work in science classrooms

As far back as in 1987, Tobin and Gallagher (1987) indicated that the traditional approach of simply following set procedures when doing experiments makes low cognitive demands on students. In their review of laboratory based activity in science instruction, Sutman, Schmuckler, Hilosky, Priestly and Priestly (1996) refer to an approach supported by Roth and Roychoudbury (1994) and by Tobin, Kahle and Fraser (1990) involving a learning environment that includes hands-on activities that allow for concept construction or modification, complemented by follow-up periods of discussion. They claim that this approach leads to improvements in three major areas, that is, in students' attitudes to science (see also Holstermann, Grube & Bogeholtz, 2010), in their practical manipulative skills and in their cognitive learning. Millar (2004) points out that practical work has a central role in a vision of science which acknowledges the interdependence of improving students' scientific knowledge and their knowledge of science as a form of enquiry.

Watson (2000) indicates that practical work may be used in a variety of formats which may be practicals, following recipes, open-ended investigations, skills training, teacher demonstrations to promote discussion about phenomena and to raise questions, problem solving activities, and heuristic practical activities designed to help students infer generalisations. This implies that the nature of learning from doing practical work will depend on the format chosen by the teacher and experienced by the learner. More recent work by Abrahams, Reiss and Sharpe (2011) re-emphasises the important link between 'hands on' and 'minds on' by pointing out that for any learning to take place, teacher decisions on the nature of practical work in class should be informed by an

understanding of the need to ensure that practical work does not just involve "doing" with observables but also requires students to think about, and engage with, scientific ideas and terms. (p. 40)

Hoffstein and Lunetta (2004) express a similar notion by pointing out that

… teachers need knowledge, skills and resources that enable them to teach effectively in practical learning environments. They need to enable students to interact 'intellectually' as well as 'physically' involving hands-on investigation and minds-on reflection. (p. 49)

At the same time, these authors do indicate that recipe following should not necessarily be seen as a derogatory term for classifying practical work. Recipe following, they claim, has a place if the purpose is to get students to produce a desired phenomenon or acquire a very specific manipulative skill.

In developed countries, the debate around the value of practical work occurred more than two decades ago. Wellington (2005) refers to the critical voices that question the value of practical work in school science. Wellington points out the irony that the most critical voices come from those countries in which practical work is well established.

'..those doing it, question it, those who strive to do more are less sceptical' (p. 99)

According to Hattingh, Aldous and Rogan (2007) who write in the South African context, practical work has the potential to contribute to meaningful learning in science if it is performed on a regular basis. They suggest that learners can gain an understanding of existing scientific knowledge and concepts from teacher-determined practical work. On the other hand, the higher levels of practical work, that is, those which are more open-ended and under student control, can help learners experience how new knowledge claims can be generated and substantiated.

Other views in countries where science teaching is still very textbook based (Kim & Chin, 2011), as in South Africa for example, indicate that laboratory work '*brings to life what is explained in the textbook…..and as a result learning is enhanced'* (Mji & Makgato, 2006).

In developing countries (Kapenda, Kandjeo-Marenga, Kasanda & Lubben, 2002; Rogan, 2004) the role of practical work in science learning has been underemphasised because of the lack of resources. To a large extent, learning science has been theoretical, even though the underlying value of practical work has been acknowledged. In Africa, there have been some attempts to address this lack of resources with the use of science kits (Bell and Bradley, 2002). For example, the Somerset micro-scale chemistry kits have been used effectively for the development of chemistry concepts (Haggard, 2001) and positive attitudes to learning chemistry (Harrison, Shallcross, Norman, Sewry & Davies-Coleman, 2011). I elaborate on the use of science kits in section 2.2.2 below. It should be noted that the use of micro-scale chemistry kits is still dependent on the traditional use of laboratory equipment, albeit on a small scale. It also presupposes that teachers have the ability to use the kits, or that they are provided with detailed worksheets to enable the novice teacher to use the kits. The current intervention tries to address this lack of resources through another route, that is, through the use of teaching strategies and artefacts that are not heavily reliant on traditional class laboratory work.

2.2.1 Teachers' views of the role of practical work in learning

In terms of learning, a large number of teachers in developed and developing countries see practical work as the crux of science learning (Abrahams & Millar, 2008; Kapenda et al., 2002). For many teachers, practical work provides the evidence for existing scientific knowledge and for developing new knowledge. Traditionally, teachers use practical work in order to illustrate and consolidate the understanding of science concepts. However, even this might be problematic if clear connections are not made between the practical task and the theoretical underpinnings or concepts. For instance, Hart, Mulhall, Berry, Loughran and Gunstone (2000) point out that it is important that students have sufficient relevant content knowledge prior to the practical activity and are aware of the purpose of the practical in relation to their other learning experiences. Thus, for worthwhile learning to be achieved, teachers need to link the hands-on experience in the laboratory and relate this to the scientific concepts and phenomena observed or experienced in everyday life.

Alternatively, teachers view the role of practical work as developing student understanding of the nature of science (Lederman, 1992) ranging from the view that scientific knowledge is a fixed body of knowledge, to scientific knowledge which needs to be identified and appropriated, to the view that science knowledge is changing, socially constructed and subjective. In all cases, the evidence from practical work is essential to the development of scientific understanding. Vhurumuku, Holtman, Mikalsen and Kolsto (2006) provide an illustration of ways of developing students' views of the accepted version of the changing, socially constructed and subjective nature of science through practical work. It is ironic that teachers' views of the nature of science often determine the format of the practical (see Tsai, 1999). The practical tasks may be closed and textbook driven in the case of the perception of the nature of science as a fixed body of knowledge, or consist of open-ended investigations for teachers with a view of the nature of science as changing, subjective and socially constructed.

2.2.2 Practical work and curriculum requirements

The move towards open-ended investigations and authentic scientific inquiry, though included as a requirement in the science curricula of many countries, has not been easily attainable. According to Hume and Coll (2008) much of the practical work that students engage in is still focused on recipe-style laboratory exercises and a 'control of variables' model of science investigation. Neber and Anton (2008) strongly suggest that teachers need to emphasise the pre-experimental phase of an inquiry cycle. This would involve assisting students in generating key questions that would transform laboratory work into intentional and directed activities, rather than simply following a pre-determined procedure.

The open-ended approach is particularly challenging to South African teachers, as open-ended investigations have only relatively recently been a requirement for the new science curriculum (DoE, 2001). Teachers already had difficulties in conducting recipe- driven practicals, (Rogan, 2004) for a variety of reasons, such as lack of qualification in science, lack of confidence in conducting practicals, and lack of laboratory equipment.

A study done in South African schools (Hattingh, Aldous and Rogan, 2007) indicates that the requirement in the curriculum prior to 1994 simply involved following instructions provided in worksheets. The new curriculum (DoE, 2001) had more challenging requirements which included planning investigations and critical evaluation of methodology and data. Hattingh *et al.* (2007*)* developed a classification framework to categorise the complexity of science practical work ranging from Level one which consisted of teacher demonstration to Level four which involved open ended investigations by the learners themselves. They found that even after several years of implementing the new curriculum, most teachers in the study operated at Level one. Another interesting finding was that there appeared to be no link between the provision of resources, and the capacity of teachers to provide higher levels of practical work. The motivated teacher, even in the most poorly resourced school, will find a way to do a variety of practical work. It might be that challenging school contexts, for example, poverty, social problems and large classes, can affect teacher motivation. However, the link between teacher morale and the context of the schools in which they teach is not a focus of this study.

Another study in South African schools (Ramnarain, 2010a) where open-ended investigative work takes place, reports that teachers and learners perceive the benefit of autonomous science investigations to be motivational, to facilitate conceptual understanding, and lead to the development of scientific skills. Ramnarain (2010b) indicates that closed investigative tasks represent teacher control and decision-making, while open-ended investigations are linked to learner autonomy and decision-making. The author presents a three-stage classification framework characterising investigations which shift from teacher controlled and planned, to autonomous and learner controlled. The three stages are structured, guided and open. According to Ramnarain, the evidence presented in the study confirms that most investigations fall into the 'structured' category.

Ramnarain (2010b) notes that research on learner autonomy at under-resourced schools where teachers use improvised material for practical work may be of interest to the science education community in Southern Africa. Whereas this study focuses on the promotion of open-ended practical work in under-resourced schools, it does so from the teacher development perspective, and less so from the classroom implementation perspective. It could be that managing open-ended investigations is more challenging and time-consuming than managing closed practicals. The more didactic teacher may feel more comfortable with demonstrations and recipe-type practicals than with the more learner-centred, open-ended practicals, where aspects may emerge that they cannot control.

A specific aspect of the curriculum requirement is the format of assessment. Evidence shows that if practical work is not included as an assessment component for examination, then its status is reduced significantly (Gott & Duggan, 2002). Many teachers will be tempted to reduce or omit any form of practical work completely (Rogan, 2004; Towndrow, Tan, Yung & Cohen, 2010). However, if teachers see the value of practical work as a way to consolidate content knowledge, they may choose to select specific 'structured' practicals as a worthwhile exercise. Often, however, this will be in the form of a demonstration rather than students doing it themselves (Kapenda et al., 2004).

2.3 Alternative approaches to practical work

Several science kits have been developed and promoted as attempts to encourage South African science teachers to do practical work in the classroom, as well as to stimulate learners' interest in studying science and technology. In her evaluation of the use of science kits, such as the MTN-SUNSTEP project and the Schools' Water Project (SWAP), Isaacs (2009) points out that teachers are positive about the usefulness of the kits in both projects. However, the two science kit promotion projects resulted in two very different outcomes. Isaacs compared the two initiatives and concluded that the former was based on a deficit model of teacher professional development which is expert driven, and hence was unsustainable. The latter initiative involved the active, visible support of education curriculum officials and project organisers, occurred over a longer period, and provided opportunities for teacher reflection. In addition, the kits were free. This participatory approach assured a more sustained use of the kits.

In a sober assessment of the use of micro-scale science kits in Africa, Bell and Bradley (2002) point out that the initial concerns, i.e. the lack of practical work in developing countries, which stirred the initial interest in the use of micro-scale science kits, are not diminishing. These concerns about the lack of practical work in science classes in developing countries have increased. As a result, they report that a global micro-science project, spearheaded by UNESCO and in collaboration with Ministries of Education, aims to introduce the micro-scale concept into needy countries through short-term teacher workshops. Despite the initial enthusiasm of teachers, the use of the kits could not be sustained in many schools. The authors point towards the lack of teacher experience in conducting practical work, the loss of equipment and diminishing stock, together with a lack of a plan to replenish depleting stock. The inertia of the educational system, the lack of donor funding and the normal human resistance to change were reported as additional reasons militating against the sustained use and uptake of the micro-scale science kits. Despite this inability to sustain the use of the micro-scale kits, their use is still being adopted as part of government policy in many countries, such as the Cameroon, Mozambique and Tanzania, as a solution to doing hands-on practical work in the class room.

As an alternative to traditional laboratory experiments, a structured set of pencil-and-paper activities was introduced to South African schools in the 'Teaching Science to large classes' project, in an effort to develop science process skills (Johnson, Hodges, Botha, Wilson, Monk, Sadeck, Watson, & Scholtz, 2000; Johnson, Scholtz, Botha & Hodges 2003; Scholtz, Watson & Amosun, 2004). The activities responded to the curriculum requirement of developing students' views on the nature of science. Though suited to all types of contexts, the activities were particularly directed at large, under-resourced classrooms where equipment, as well as teacher expertise in practical work, was lacking. It met with some success, to the extent that it was incorporated as an assessment requirement for science in the General Education and Training band in the new curriculum (DoE, 2001).

2.4 The impact of science competitions in South African contexts

Science Expos have been organized in South Africa and elsewhere in order to promote the uptake of science and technology as career choices by young South Africans. One such initiative has been the ESKOM Expo for Young Scientists. Alant (2010) argues that despite the noble intention of inspiring young people from disadvantaged backgrounds, the ESKOM Expo tends to marginalise the eager participants from these backgrounds through issues of language and representation, leaving them somewhat disappointed.

Similarly, Taylor (2011) observes that the experience of an Expo left a group of township learners with a sense of failure in a context where they were exposed to the more technologically advanced projects of participants from better resourced schools. Despite their high expectation in the run-up to the Expo, the outcome was disappointing for the township participants. They did not feature as finalists in the Expo and they perceived this outcome as them having failed. Aspects related to the quality of their projects such as inherent project weakness, lack of resources and lack of help from adults, were cited by participants as reasons for their failure. Taylor also discusses an interesting notion of 'luck' expressed by learners. The view that they were unlucky to be allocated unfair judges shifts the emphasis away from considering the quality of their own work and hence the outcome was seen as out of their control.

In contrast, Ramnarain and de Beer (in press, 2011) suggest that one way of allowing opportunity for authentic engagement in science practical work may be by allowing students to create a hybrid space in which the world of school science and their social world are merged. They acknowledge factors that serve as barriers to implement autonomous science investigation include constraints such as lack of resources, the tight time-tabling schedules of the school, large classes and inflexible syllabus requirements. In their case study, however, Ramnarain and de Beer report on successful open science investigations in which students, preparing for a science Expo, were supported by their school teacher as well as parents and experts in their home environment. The science Expo served as a driver and impetus for the student investigations. The authors observe that within these hybrid spaces, the students appeared less constrained by the conventions of school culture and were able to effectively appropriate support, both from the school and the home. The students involved were all enthused by their experience and felt motivated to work harder at their school science.

In my study, the participating schools are all from poor, rural areas, so the aspect of comparison between rich and poor schools as highlighted by Taylor (2011) would not apply.

2.5 Models of professional development and teacher change

Kennedy (2005) ranked nine models of continuous professional development (CPD) according to their capacity to support participants' professional autonomy and transformative practices. She ranked the CPD models according to increasing capacity for teacher autonomy, from transmission mode models, through transitional and then transformative categories.

The *transmission mode models* allocate the major role to the 'expert'. These models include training models (focusing on replicating desirable behaviour), deficit models (remediating participants' lack of skills or understanding, e.g. addressing the introduction of new topic as nanotechnology or astronomy in the science curriculum), award bearing courses, and cascade models of CPD (with the previously-trained leader exemplifying behaviours to the participants). The category *of transitional CPD models* highlights the role of the group of experts. These transitional models include standards-based models (familiarizing participants with required learning outcomes, and how to achieve these), mentoring or coaching models (often involving senior peers) and community of practice CPD models (providing learning from a diversity of experts who take on different roles, for example, curriculum advisors, teachers and teacher educators.) The socio-constructivist approach to professional development aligns very well with the transitional CPD model as teachers' ideas and abilities are acknowledged and they operate within social settings. Lastly, the *transformative models* specifically focus on the individual's practices. These models include action research (by the participant), and tailor-made activities supporting contextual change of self-identified own practices.

Kennedy argues that the purpose of the CPD could determine the types of models used. She notes that CPD, which is conceived as fulfilling the function of preparing teachers to implement reforms, may be supported most appropriately by a 'transmission' view. However, CPD which is intended as supporting teachers in contributing to and shaping education policy and practice aligns itself more naturally with transformative models. Kennedy cautions that while the capacity for professional autonomy may be greater in transformative models, it does not imply that this potential capacity will necessarily be realised.

Whereas Kennedy's (2005) classification is based on different formats of CPD, Desimone, Porter, Garet, Yoon and Birman (2002) focus on the impact of CPD interventions according to the content. Even though the CIF model used in this study also focuses on the impact of the professional development intervention. It does so by exploring the process involved, such as the intended, implemented, experienced and achieved programme. They note that there is some indication in the literature that professional development that focuses on pedagogy embedded in specific content such as mathematics or science is more helpful than if the focus is on general pedagogy or general management strategies. Fetters, Czerniak, Fish and Shawberry (2002) go beyond pointing towards the impact of pedagogic content knowledge (Shulman, 1987) as CPD content, and note that - as a pre-requisite - teachers need to know their subject matter and be knowledgeable about the pedagogy of teaching. Lack of skills and science content knowledge leads to anxiety which impacts on the overall benefit of the professional development programme on the participant. Ironically, in South Africa, many teachers selected to participate in CPD programmes are normally the ones who struggle with knowledge and skills in science, as they are often under or unqualified in science teaching.

The approach used by the SCALE Immersion Model of Professional Learning (Lauffer and Lauffer, 2009) is useful in that it requires participant teachers to immerse themselves in the role of learners of concepts or skills, as well as reflect on and practice the appropriate pedagogy as teachers. In this way, this approach links the three areas of teacher knowledge, that is, subject content knowledge, (general) pedagogic knowledge and pedagogical content knowledge (Shulman, 1987). Participants are allowed to try out appropriate teaching and learning strategies in a safe environment (Joyce & Showers, 1988) as well as in authentic classroom spaces. However, Johnson, Monk and Hodges (2001), in their evolutionary model of teacher development, caution that only those practices that fit with social and material constraints of the school environment, along with the personal biographies of the teachers, may survive in the classroom.

2.6 Research Frameworks for teacher professional development.

I use Borko's (2004) situative perspective on teacher learning to review existing research on teacher professional development. Such a perspective takes account of individual teachers as learners as well as of their participation in professional learning communities. Although Borko's study refers to research programmes in the United States, many of the insights can be related to aspects of teacher professional development in Southern Africa. Borko identifies three phases around which researchers organize their research. Phase 1 researchers focus on an individual professional development program at a single site. Phase 2 researchers study a single professional development programme enacted by many facilitators at more than one site. Phase 3 researchers focus on multiple professional development programmes enacted at multiple sites. Borko points out that most of the professional development communities' work has been in Phase 1 where researchers typically study the professional development programme, and the teachers-as-learners and the relationship between the two. The facilitator and the context remain mostly unstudied. Within this classification, I can identify my study as a Phase 1 type study. Borko cites evidence that successful professional development programmes with ongoing school-based support can strengthen teachers' content knowledge and instructional practices. Lauffer and Lauffer (2009) provide evidence which indicates that, even though strong professional development communities can foster teacher learning, research reveals that the development of teacher communities is difficult and time-consuming. Along the same line, Borko points out that teachers in professional development communities are likely to discuss ideas and materials that are related to their work, yet discussions that support a critical examination of teaching are fairly rare, thus professional learning may be sporadic.

My study draws on Guskey's (2002a) levels of impact when evaluating models of professional development. Guskey notes that the three major goals of professional development programs are (i) a change in teachers' attitudes, beliefs and understanding; (ii) a change in their classroom practices; and (iii) a change in learning outcomes of students. He points out, though, that significant change in teachers' attitudes only comes about if they see evidence that changed practice will bring about improved outcomes for the learners.

'*They believe it works because they see it work and that experience shapes attitudes and beliefs'* (Pg 383)

He asserts that effective change in teacher practice will not occur by training alone, nor even training followed by implementation. Only evidence of improved learning as a result of implementation contributes significantly to changes in attitudes and beliefs, and results in sustained educational improvement.

Guskey presents five levels of evaluation when considering the impact of a professional development intervention.

- Level 1 evaluates the participants' reaction to the intervention such as their perceptions, feelings and opinions on the CPD experiences.
- Level 2 ascertains the learning that has taken place by measuring the knowledge and skills gained by participants.
- Level 3 assesses the organisational support (of the school, and the Department of Education) that contributes to sustaining change.
- Level 4 evaluates how the new knowledge and skills attained as a result of the intervention impacts on the professional practice of the participants.
- Level 5 looks at the extent to which the CPD activity improved student learning.

Based on his assertion that teachers' attitudes are affected by improved student learning when trying out an innovation, it seems Guskey could have included a level 6 in his impact model. Level 6 could examine teachers' attitudes towards sustaining practice once they have tried out the innovation.

2.7 Factors that impact teacher professional development

King and Newmann (2001) point out that traditional approaches to professional development have focused on how individual teachers learn. Although they consider this to be important when linking teacher learning (Guskey's Level 2) to student learning (Guskey's Level 5), they propose that a broader construct needs to be considered when embarking on teacher professional development programmes, that is, school capacity for change. To them, the school capacity is an important measure of the potential for success in influencing the quality of instruction, and hence student achievement. They propose three dimensions of school capacity, which are (i) the knowledge, skills and disposition of individual teachers, (ii) the strength of the professional community among the staff as a whole, and (iii) the programme coherence within school. Fetters, et al. (2002) note that the beliefs and dispositions that teachers bring to a professional development experience shape how they make sense of, interpret and implement curriculum reform efforts.

Banilower, Heck and Weiss (2007) point out that there has been consensus in the literature on some characteristics of effective professional development interventions for teachers. These include the use of active learning methodologies, emphasising the improvement of content knowledge, ongoing and sustained support over time and situating professional development in classroom practice. While in agreement with these key elements, Supovitz and Turner (2000) also posit the importance of working towards a common set of professional standards as well as linking staff development to whole school improvement. However, in terms of the typology of models for CPD by Kennedy (2005), such requirements may not be generally applicable to all models of effective CPD, but only to transitional models. Fetters, et al. (2002) extend this list of characteristics of effective CPD interventions by noting that opportunities for reflective analysis are critical to help developers adjust their programmes to address local needs. Boyle, Lamprianou and Boyle (2005) refer to a growing awareness of alternative forms of professional development such as focusing on teachers working together and sharing expertise in the same school, working together with teachers in other schools, and in-school programmes and support, all highlighting the increasing popularity of transitional CPD models. Boyle *et al.* further point out that traditional approaches to professional development (the transmission mode models) such as short workshops or conference attendance, might foster awareness or deepen knowledge and skills, but they are not enough to fundamentally change teachers' practice. They suggest that activities that are longer in duration, allow teachers the opportunity to practice and reflect on their teaching, and are embedded in on-going teaching activities will encourage meaningful change in their practice. These activities can be supplemented by in-school support, teacher networks and coaching and mentoring arrangements. Jita, Loyiso and Ndlalane (2009) explored the use of teacher clusters or networks as a vehicle to help challenge and change science teachers' knowledge and classroom practices in South Africa. They argue that allowing teachers to share, challenge and reflect on classroom practices within the clusters in a goal-directed, supportive, collaborative environment, seems to provide better opportunities to challenge and change teachers' content knowledge and pedagogic content knowledge.

2.8 Conclusion

In this chapter I examined different aspects of the purpose and use of practical work as well touched on the benefits and limitations of science competitions in the South African context. I also reviewed models of teacher professional development. Finally, I explored the way in which these key features present themselves in my exploration of the impact of the intervention.

CHAPTER THREE: METHODOLOGY

3.1 Introduction:

The main aim of this study is to ascertain the nature and coherence of an outreach programme and its impact on science teachers' practice in the classroom. This chapter discusses the choice of research design and the techniques applied to gather and analyse information on the impact of the outreach programme. The insights gained from the research will be used to improve and refine further interventions.

The study is guided by the following questions:

1. What is the relationship between the intended and the implemented intervention programme?
2. How did the teachers experience the intervention?
3. What were the perceived outcomes as a result of the teachers' participation in the outreach programme?

The first question investigates the alignment of the envisaged (intended) programme with the executed (implemented) programme. The second question explores teachers' perceptions of their experiences of the intervention, and thus refers to the experienced programme. Lastly, the third question focuses on teachers' views on how the intervention impacts on their professional development and classroom practice, that is, the achieved programme.

3.2 Theoretical Perspectives

The research is situated within a qualitative interpretive paradigm. The interpretive paradigm focuses on highlighting the voices of the people involved (Creswell, 2008), and it deals with how individuals perceive and understand their worlds. Waghid (2000: 262) points out that the self-understanding of the individual forms the basis of all social interpretation or explanation in interpretive education theory. Self-understanding of individuals within their particular contexts determines the realities and the actions of the individual. Hence, the methods I have chosen focus on individuals' perceptions and understandings of their experiences, in this case experiences within a specific professional development programme, and experiences of the related actions within the context of their classroom teaching. Therefore, data has been collected through individual interviews, focus group discussions, and stimulated response narratives (Cohen, Manion & Morrison, 2011). Although observation of selected classroom practice could have served to stimulate teachers' narratives, here observations of the intervention workshops have been used as the main stimulus of teacher narratives. In line with interpretive research practice (Clough & Nutbrown, 2007), an initial questionnaire was given to all participating teachers to allow them to describe their background, normal pedagogy, teaching experience, and expectations of the experiences within the intervention.

3.3 Research design

As the purpose of this study is to determine the impact of an intervention programme for science teachers, I have adopted an impact evaluative research design.

The Simple Logic Model (W.K. Kellogg Foundation, 2004) is often used for evaluation studies. It presents the evaluation approach in terms of a comparison of operational inputs with intended outcomes on the one hand, and actual measured outcomes and impact on the other. However, this positivist approach is more suited to a quantitative study with a pre-post, experimental-control quantitative evaluation design (Cohen et al., 2011), which is not the focus of this study. An additional major limitation of this Simple Logic Model is that an input-output evaluation approach does not consider the process of an intervention, which is the interest of this study. Instead, the process of an intervention is more usually studied with a qualitative research design (Merriam, 2009).

Babbie and Mouton (2001) identify the following features for a good qualitative research design which include a detailed engagement with the object of the study, selecting a small number of cases to be studied and openness to multiple sources of data. All of these features are emphasised in this study.. The number of teachers is small and the focus is on perceptions/experiences of individuals.

The reflective evaluation approach (Byrne, 2007) relies on participants reflecting on their own learning as a result of their participation in a process. This evaluative approach is closer to the impact evaluation required fro the current study. One of the key data instruments is the reflective diary, where participants record their progress over time. As the current study examines a short-term intervention, reflective evaluation is not an appropriate choice. However, this does not exclude participants in this study from reflecting on the impact of the intervention on their own development within one-off interviews.

Clardy (2001) reports on the use of the 'Learning History Approach' in evaluation. He uses this approach for evaluating the impact of a course on 'Change in the Workplace'. Participants' ideas and comments on the course are recorded while the programme is in progress. The advantage is that this approach emphasises the views on the process of the intervention, and allows for both formative and summative evaluation (Stufflebeam, 2001a). In this case the intervention is supported by a web-based instructional system (Blackboard 5), and data on learners' experiences are collected as part of the interaction with this system. This replaces the standard interview method of data collection. This method of data collection was considered unsuitable for the current research project because of limitations in the ICT resources to which participants have access. Equally, the method of continuous self-reporting by the participants is considered time-consuming and intrusive (Bogdan & Biklin, 2006) with regard to the teachers' primary aim: their own professional development.

The work by Stufflebeam (2000) is frequently used as an evaluation research design that includes the process of change resulting from the intervention under study. Stufflebeam's model documents the Context, the Inputs, the Process and the Product (CIPP) of an intervention. Careful instruments have been developed for recording changes in all these four factors (Stufflebeam, 2001b). Stufflebeam's model is normally used for large-scale and long-term interventions, which is not applicable to the intervention under study. However, Stufflebeam's model is partly used for this study in the sense that all four of his dimensions are considered in the impact evaluation design, which draws from curriculum research.

The specific impact evaluation design used in this study is based on previous work by Goodlad (1979). This design has been chosen since it evaluates the impact of curriculum innovations in particular.

As indicated in Chapter 1, in order to investigate the impact of an outreach programme for science teachers, representations adapted and described by Van den Akker (1998, 2003) and Van den Akker, Fasoglio and Mulder (2010), were used to form a framework which distinguishes between the intended, implemented, experienced and achieved programmes. The framework for the analysis of this study on the impact of a professional development intervention is based on a combination of the model by Hartley and Treagust (2006) for evaluating outreach programmes, and the Van den Akker (2003) model for evaluating the impact of school science curricula. Hence, it focuses on a professional development programme for teachers rather than on school curricula. This combined model identifies the following formats of the outreach programme:

1. Ideal programme (the vision of the outreach programme);
2. Formal programme (as written in project plans, funding proposals, operational aspects etc.);
3. Perceived programme (notions of aims, objectives, activities by programme staff);
4. Implemented programme (activities during workshops, in-school support, by programme staff);
5. Experienced programme (teachers' experiences/reflections on the programme);
6. Achieved programme (changes in teachers' understanding, skills, attitudes);
7. Enacted programme (changes in teachers' behavior in class/science clubs).

Table 3.1: Formats of the Outreach Programme

Formats	Description	Research Questions (RQ)
Intended programme	Ideal programme (vision)	RQ 1: What is the relationship between the intended and the implemented programme?
	Formal programme (operational)	
Implemented programme	Activities during workshops and in-school support	
Experienced programme	How teachers perceive and experience the workshop and teacher reflection on the programme	RQ 2: How did the teachers experience the intervention?
Outcomes Achieved programme.	Changes in teachers' skills, understanding and attitudes	RQ 3: What were the perceived outcomes as a result of the teachers' participation in the intervention?
Outcomes Enacted programme.	Changes in teachers' behaviour in the classroom	

The analysis in this study focuses on formats 1, 2, 4, 5, 6 and 7, that is, the ideal, formal, implemented, experienced, achieved and enacted programmes. The perceived curriculum, format 3 (i.e. notions of aims, objectives and activities of programme facilitators) was not explored as the intent of the study was to get a perspective through the eyes of the recipients of the programme, that is the teachers, because they are the practitioners in the classroom.

It should be noted that format 7 (the enacted programme) does not appear in the models by Hartley and Treagust (2006) or by Van den Akker (2003) but is necessary for answering research question 3, which refers to the change in behaviour of the teacher in the classroom as a result of the intervention.

Most importantly, the impact of the outreach programme will be investigated by determining the coherence or match between the four curriculum aspects of the programme as described: that is, the intended curriculum comprises formats 1 and 2; the implemented curriculum comprises format 4; the experienced curriculum comprises format 5; while the achieved curriculum comprises formats 6 and 7.

3.4 Data Collection

Four techniques were used for data collection, that is, document analysis, observations of workshop activities, video recording of group feedback sessions, and audio recording of individual interviews. The data collection process (data trail) is summarised in Figure 3.1.

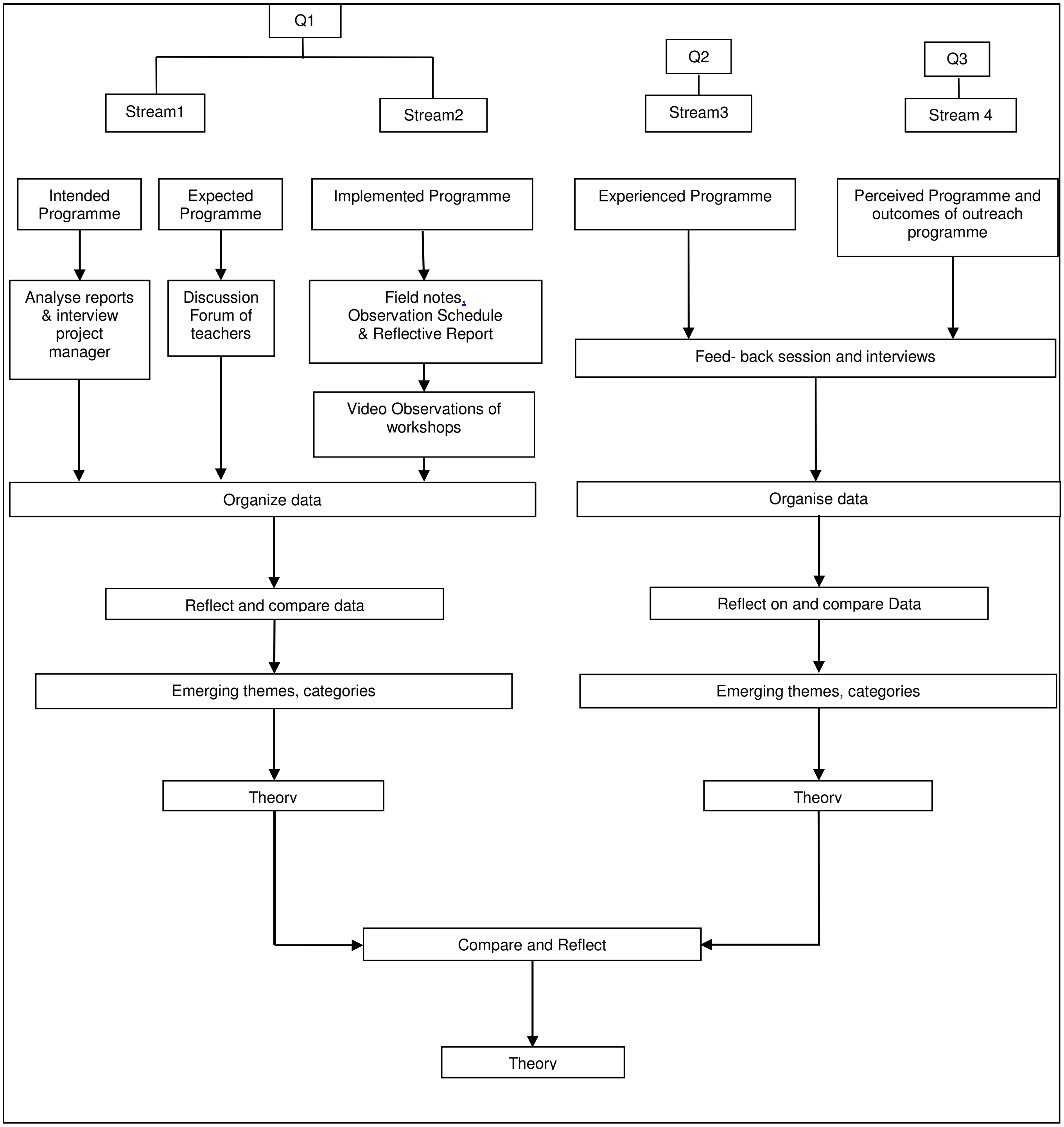

Figure 3.1: Data collection streams

3.4.1 Data Stream 1

Data for describing the intended programme was collected from the project proposal documents, an interview with the project organiser as well as introductory statements made on the opening of the intervention programme by the programme manager. Teachers' expectations of the programme were obtained from a questionnaire as well as a feedback session before the start of the workshops. The purpose was to examine the extent to which intentions for the programme and teacher expectations match.

3.4.2 Data Stream 2

Data for describing the implemented programme was obtained from video recordings of the actions and verbal contributions of participants during the three workshop sessions. As one of the presenters at one of the workshops, I also reflected on the activities as they unfolded (Stream 2). Records of what happened in each workshop, as well as reflections on specific incidents were recorded in an observation schedule. The observation schedule was developed and used to record and describe the events in each workshop. Reflections on the description of the intended and the implemented curriculum were used to address Research Question 1.

Initially, the observation schedule took the format of the intended sequence for each workshop, as presented in the workshop programme. These were: demonstrations, theory, practical participation, and show-and-tell. However, with the first attempt at filling in the observation schedule from the video transcriptions, the categories were not very helpful as the presenters did not specifically adhere to the intended format. I devised a different observation schedule which included broad categories that were applicable to all three sessions. This focused on the operational aspects of the interactions in the workshop sessions.

Table 3.2: Observation schedule template

Categories	**Description of events**	**Researcher's reflections**
Methodology used by presenter		
Nature of the activity		
Operational aspects		
Teacher interaction		

3.4.3 Data Streams 3 & 4

The data required for addressing research questions two and three was collected in two phases. The first phase was to get feedback on the overall impression of the whole group of twenty participating teachers (twelve high school and eight primary school teachers). Twelve of the teachers had attended a similar series of workshops the previous year, and several of these volunteered comparative reflections. The second phase involved more detailed semi-structured individual interviews with four teachers.

3.4.3.1 Phase 1: Group feedback sessions

Three focus group discussions, in which all twenty participant teachers were involved, took place the day after each workshop. At the end of each workshop day the participants were instructed to think about the workshops and give feedback the following morning. This allowed more time for reflection. The feedback sessions were video recorded, and the discussions were transcribed verbatim. During the feedback session the presenters from the previous day were not present, allowing the teachers to talk freely about how they experienced and perceived the workshop. The emphasis was on their perceptions of their learning during each workshop and its impact on their own practice. Attempts were made to draw views from all participants. Participants were asked to comment on how the activities they experienced in the workshops could be used in their own classrooms, how these could address their needs and whether they envisaged any challenges or problems in implementation. Teachers' responses were then used to develop categories and sub-categories. An open coded grounded theory (Babbie, 2007) approach (see below) was used for a preliminary analysis of the data from the feedback sessions in Phase 1. If one uses the open coding approach, then the categories are not predetermined but emerge from the analysis of the data (Babbie, 2007)).

3.4.3.1 Phase 2: Individual semi-structured interviews

The three main themes emerging from the group discussions (impact of the programme; addressing curriculum matters; recommendations for future programmes) were used to devise the questions for the individual interviews. A general theme was added to allow for any additional aspects that the teachers felt were important. The semi-structured interview schedule can be found in Appendix D.

The purposive sample of interviewees consists of four secondary school qualified science teachers, who were selected since they were known to have views and a willingness to voice these. All had more than 5 years' experience in teaching science. Content competent, qualified science teachers with Bachelor of Science degrees were chosen so that content knowledge would not be a factor when exploring their pedagogy with respect to practicals. They were all in the 2nd year of the intervention programme. They all taught in the FET phase which is from Grade 10 to Grade 12. There were three female teachers and one male teacher; however, gender was not a criterion for selection.

The above schools are all in poor, rural parts of the Western Cape, the Overberg Region. The medium of instruction is Afrikaans, which is the home language of the teachers as well as of the majority of the learners. The learners come from the surrounding areas. The communities range from very poor to lower middle class. The schools are faced with socio-economic challenges such as poverty and unemployment amongst parents and families.

Interviews took place in the schools where the teachers taught. The venues used for the interviews were the laboratories or classes where they would normally do the practical work. The interviews were audio recorded and transcribed. The context of their working environment was recorded by using field notes.

My questions were semi-structured so that respondents could elaborate as they felt (Creswell, 2008). As a result of this leeway, many of the questions that I would have asked later were already covered earlier on in the interview. Some aspects were volunteered by teachers without specifically being asked. In individual cases a small number of specific questions have not been answered, as the respondents elaborated on other aspects which they felt were more important. I did not return to these questions to fill the gaps. However, the responses were detailed enough to draw meaningful inferences about teachers' reasoning underlying the reported experiences.

3.5 Data analysis

Grounded theory as a method of analysis is a systematic qualitative procedure used to generate a theory that explains, at a broad conceptual level, a process and action or an interaction about a substantive topic (Babchuk, 2009). I have chosen this as a method of analysis as it is well suited to qualitative studies in which there are multiple data sources available which enable constant comparison resulting in an emergent theory. Babchuk (in press) comments that grounded theory analysis generates theory from practice and such theory can, in turn, be used to further inform practice. I concur with Dick (2011) who notes that there is some similarity with action research.

Haig (1995) says that grounded theory analysis begins by focusing on an area of study and by gathering data from a variety of sources, including interviews and field observations. Once gathered, the data is analysed using coding and theoretical sampling procedures. According to Dick (2011), purposive sub-sampling is appropriate in order to increase the diversity of the data collected. Subsequently, theories are generated with the help of interpretive procedures, before being finally written up and presented.

Creswell (2008) presents three types of grounded theory analysis. They are the systematic approach (where there are three stages of coding which assist in developing categories from the data collected), the emerging approach (where theory emerges from the data), and the constructivist approach (where the focus is on the importance of meanings individuals bring to the focus of the study). Glaser (1992), one of the grounded theory developers, stresses that underlying any of these research approaches around the principle of grounded theory analysis, is that the theory emerges from the data rather than using specific pre-set categories for scrutinizing the data. He further writes that the focus is on connecting categories and emerging theories, not simply describing categories. Dick (2011) agrees with this approach. He suggests that the key issues that emerge be noted after each bout of data collection, comparing constantly. The task of the researcher is to identify categories and subcategories and their properties, noting the links between them. Once one is unable to add more categories, that is, when the core category and the linked categories saturate, then one can move on to sorting.

For the analysis of this study, a constructivist approach in grounded theory is used in line with the work done by Charmaz (1990). Charmaz focuses on the views, values, beliefs and feelings of individuals and uses active code labels to describe the emerging patterns, which are similar to the approach in this study.

3.6 Validity & trustworthiness

The investigation focuses on the nature of the intervention as well as on the perceptions of, and outcomes for, the participating teachers. Feedback from the key informants, that is, the teachers, the presenters and the organisers, were used to provide a variety of contexts and thus different lenses for seeing the same issues.. Babbie and Mouton (2001) assert that multi-perspective data sets are generally considered to be one of the best ways to enhance validity in qualitative research. In this study, individual interviews, feedback sessions, workshop observations and programme reports all serve as sources of data which can be combined in various combinations to address each of the research questions.

For validity of data analysis, a second researcher (the supervisor) was asked to independently establish themes and categories within the data sets related to the various research questions. Emerging themes and categories were compared and any discrepancies were discussed. Consensus was reached on an agreed set of themes and categories as the provisional coding scheme. Subsequently, all of the data was interrogated independently using a provisional coding scheme. The allocation of codes to specific utterances in the interview or observational data was then compared. The inter-coder agreement was 82% which is a satisfactory level of analysis reliability. Again, any differences in code allocation were discussed and a consensus reached as to the placement of response excerpts in the final themes and categories identified. Even during this process of code allocation, the coding framework was consolidated and modified on details.

In the interviews, the teachers were allowed to speak in their preferred language so that they could articulate their responses more accurately. Accommodating for formulating views in the home language was designed to increase the validity of the data.

I was aware that during the feedback sessions, the teachers may be hesitant to critique aspects of the programme, thus endangering the reliability of their responses. In order to increase this reliability, the presenters for the particular session under discussion excused themselves so that teachers felt more comfortable to express their honest opinions. By the time I did the individual interviews, the teachers were fairly comfortable with me and expressed themselves freely. At both the feedback and interview sessions, teachers were informed that the critique, both negative and positive, would inform any subsequent intervention, and hence the organisers would appreciate their honest responses, as this would add value to the process.

In order to increase the trustworthiness of the study a conscious attempt has been made to clarify the context (Creswell, 2008), within which this study was conducted. This context relates to the intervention, the teachers, and the schools they work in.

3.7 Ethical issues

A letter was written to the Western Cape Education Department to request permission to interview the teachers. In the letter, the research project was described and the interview schedule was submitted. Permission was granted. The participating teachers also provided informed consent that the data could be used for research purposes and that their anonymity would be upheld.

CHAPTER FOUR: FINDINGS AND ANALYSIS OF DATA

4.1 Overview of the chapter

In this chapter, I present the findings of the data according to the three research questions indicated previously, that is, the nature and coherence of the intervention, the experienced programme and the outcomes of the intervention for the science teachers.

4.2 The relationship between the intended and the implemented programme

The aims, objectives and philosophy of the intended programme, which comprises the ideal and the formal programme as presented by Van den Akker (2003), were explored through interviewing the project manager as well as analysing the project report. The exploration involved identifying the broad, underpinning intentions of the ideal programme as well as the aims and objectives of the formal programme. A further analysis of the coherence between the intended and the implemented programme was conducted. This will provide a clear sense of what the project tried to achieve as well as expose or delineate what assumptions underpin the provision of the outreach programme.

4.2.1 Intentions of the ideal programme

During an interview with the project manager, he indicated that the overall rationale of the project was to develop science and technology experts who can serve as role models for future learners from rural communities. The focus was on schools in the rural Breederivier and Overberg areas which have been largely excluded from support with curriculum innovation due to their distance from urban areas.

> *The underlying philosophy that I have for this outreach is that we develop a first generation of scientists, engineers and technologists from the rural communities which can then come back and serve as role models for learners, learners that are on the programme in the schools*. (F/1/26-29)

This overall vision, along with the broad aims as adapted from the project report (listed below), can be considered to be the ideal programme as presented by Van den Akker (2003) and Van den Akker, Fasoglio and Mulder (2010).

The broad aims listed in the project report

- *To support teachers and learners in the learning and teaching of science and technology,*
- *To raise awareness and participation of learners in science activities,*

- *To draw learners' attention to science and technology in their everyday lives and how it relates to their curriculum activities in school,*
- *To expose learners to the possibilities in SET careers,*
- *To develop a culture of science learning in the region,*
- *To provide potential role models in SET.*

(Hartley, 2008)

4.2.2 Intentions of the formal programme

The formal programme, as suggested by Van den Akker (2003) and Van den Akker, et al. (2010), is a way of elaborating on, or concretising, the vision in real terms. This can be presented as plans, guidelines and written objectives for implementation.

In the interview, the project manager highlighted the following specific intentions which serve to realise the vision of developing a culture of science learning in the region. These are more specific than the overall vision indicated previously. They comprise three foci, that is, the improvement of teachers' science knowledge and practical skills, the strengthening of teachers' skills in managing science clubs, and the provision of a science fair competition. This science competition serves as a platform where learners can demonstrate their achievements and to gauge the nature of the input of the teacher.

The specific aims of the outreach programme are indicated as follows in the project report:

A. *Teacher training in which the focus is on the development of content knowledge, practical and experimental skills, and pedagogical strategies to facilitate this in the classroom.*

B. *Training and supporting teachers to run science clubs at their respective schools in which they will develop science activities.*

C. *The culmination of the process was the holding of a science competition. The science competition was a way of evaluating the extent to which the training that was provided for the teachers had been implemented.*

(Hartley, 2008)

The underlying assumption for the programme is that changes and improvement in teachers' content knowledge and pedagogy will impact directly on their learners' performance. However, this project interpretation, with a focus on teacher change, implies that programme impact is measured by considering its influence on teachers, and not on the learners. This interpretation of the project is the basis for this evaluation.

Two observations are relevant. Firstly, apart from the first objective, all stated objectives focus on changes in the learners. This focus on learners is in line with the ultimate vision for the programme of encouraging learners to further their careers in science and technology and serve as role models for young people. The programme also facilitates a science competition as a platform where learners can demonstrate their achievement. This science competition provides an opportunity for measuring learner final outcomes directly. However, as the project manager clearly indicates, the conduit for realising this vision of learner change is the teacher. As a consequence, the programme manager (and probably the whole project team) targeted efforts at bringing about changes in teachers. A change in teachers' content knowledge, pedagogical content knowledge, practical skills, and science club management skills is assumed to impact directly on their learners. However, this project interpretation with a focus on teacher change implies that programme effects are measured by considering its impact on teachers, and not on the learners. This interpretation of the project is the basis for this evaluation.

Secondly, the objectives are worded in terms of input by the programme rather than in terms of measurable outcomes for the learner (or teacher), that is, what the learner will be able to do. The emphasis on intended programme inputs may have consequences for the evaluation of the programme's impact. Considering strictly these stated objectives, the measurement of the programme's achievement may well be limited to an inventory of manpower, facilities, resources (financial and in terms of materials), etc. However, this study goes beyond an input evaluation and documents teacher responses to these inputs.

4.2.3 Teacher expectations of the programme

The main expectations of the teachers emerged from a questionnaire teachers completed before their involvement in the programme, as well as a video-recording of the first discussion forum with them (Fig 3.1, Data Stream 1). These expectations may be grouped in four clusters, that is, science content knowledge; pedagogic content knowledge, practical skills, and skills involved in running a science club.

Firstly, teachers expected to gain additional science content knowledge. This included some clarification of science concepts and principles they considered problematic. In addition, they looked forward to being informed about new topics that had recently been introduced in the curriculum.

Secondly, teachers expected to strengthen their pedagogical content knowledge. They emphasised that they wanted to be able to use their improved content knowledge in class, specifying that they looked forward to practicing simple strategies to present certain aspects of science in class. This expectation was often expressed as finding alternative ways of teaching familiar topics.

Thirdly, teachers expected to extend their repertoire of practical skills. This would relate to practical work connected to the new topics in the syllabus. In addition, the expectation was for more practicals which would serve to make science fun and 'come to life'.

Lastly, teachers expected to gain guidance on the development of science clubs. Often these expectations were not stated in much detail as few teachers seemed familiar with the phenomenon of science clubs and science fairs.

These four expectations match well with the objectives stated by the project manager.

In addition, participating teachers had two more expectations for the outreach programme, both centred on teaching resources. Firstly, there was an expectation that the intervention would result in the development, or at least the availability, of new teaching resources. Secondly, and more specifically, several teachers expected the formation of a sustained network between participating schools, particularly with the aim of setting question papers.

One could assume that the expectations expressed by the teachers are an admission that they may have a lack in any of the aspects mentioned. The project could then legitimately address these needs. If teachers perceive that their expectations are being met, it could add value to the worth of the programme from their perspective.

4.2.4 Description of the implemented programme

At the start of the intervention the project manager shared the broad aims of the project with the teachers. However, the three-day intervention is a small component of the broader vision, which focuses on teachers' content knowledge, conceptual understanding and practical skills in which teachers are expected to try out what they have learnt in the classroom.

The implementation of the project consisted of three phases, namely, teacher workshops, school visits on request of the teachers to assist them with the development of science clubs; and lastly, the organization of an annual interschool science competition for learners of teachers involved in the workshops.

The teacher workshops consisted of three consecutive days of highly interactive sessions for science and technology teachers with a focus on practical work. The fourth day was allocated to the Western Cape Education Department. The science curriculum advisors shared aspects of the new curriculum with the participating teachers. This evaluative study focuses primarily on the teachers' perceptions of the workshops which comprised the first phase (aim A) of the programme. It was hoped the teachers would learn skills that would enable them to facilitate practical work in the classroom and in the science clubs (aim B) as well as assist them to prepare the learners for the science competition (aim C).

Three day-long workshops were planned, focusing on chemistry, physics and technology, respectively. Each workshop was presented and facilitated by a presenter experienced and qualified in the relevant discipline. Each day was divided into three sessions starting with a science demonstration in session one, whereby teachers observed alternative ways of teaching particular concepts and principles in the curriculum, which they may have difficulty in teaching in the class. In session two, teachers were provided with hands-on activities and were given guidance to confidently conduct practicals by themselves. The third session of the day was intended for teachers to demonstrate a practical to their peers. This, however, did not take place because of a lack of time. At the start or end of the day, a feedback session was scheduled where teachers could express their experiences or could critique the activities. As the workshop was short and intensive, presenters kept within the curriculum parameters set by the education department as far as possible. Teachers' activities were curtailed on occasion, because of time constraints, at the expense of further conceptual development.

In the following section, the implemented programme will be described by looking at the teaching strategies used by the presenter, the nature of the activity, operational aspects, as well as the interaction of the teachers as outlined in the categories of the observation schedule (Table 3.2.)

4.2.4.1 Day 1: The Chemistry workshop

.The presenter said explicitly that he would focus on three curriculum aspects, that is, content, skills and attitude. It was apparent that the presenter concentrated on the Grade 12 curriculum and always related classroom activities to what possible questions could be asked in the final matriculation examination for Grade 12. The presenter started off with rates of reactions, handing out work sheets with two experiments.

The teachers sat in four groups of about five people at a table ensuring that the primary and high school teachers were sitting together, reading through the activities.

Teachers were compelled to physically look for and select relevant chemicals and equipment that they would normally not use, displayed on a table in the centre of the room. They were encouraged to hone their observation skills by identifying smells and colour changes, as well as their skills of measuring, timing and calculating. At first it looked chaotic as teachers moved back and forth collecting equipment, but the room settled down to a hive of activity at each table where stop watches, electronic scales, gas burners and measuring cylinders were being used to mix chemicals.

Some teachers explained to others how the experiment should be done and what reactions should take place. Conceptual meaning was often developed. For instance, a teacher exclaimed at one table "*Oh, when you dilute or heat it, it changes the rate of reaction*"; and some teachers referred to textbooks they brought along. Thus, the intended improvement of content, skills and attitudes were realised. Primary and high school teachers were equally involved in the activities.

In the second session, the presenter focused on the Grade 12 topic of electrochemistry. He gave an introduction on the theoretical background of electrochemistry and gave five hands-on practical activities to participants to do in their groups. The groups were managed in the same way as in the earlier session. After teachers decided on the equipment they needed, the presenter supported groups with setting up their experiments, asking probing questions about the interpretation of the results, and how it relates to concepts in electrochemistry. After each activity, the presenter demonstrated and explained key concepts related to each experiment. He ended the session with possible questions for the Grade 12 end of year examination.

Time was a factor, as some activities looked rushed with many experiments done within a short period.

4.2.4.2 Day 2: The Physics workshop

The presenter started the day off with an "ice breaker activity" which was more minds-on than hands-on. He used toys and gadgets to draw teachers to engage with the "how's" and "why's" of the activity in a fun but scientific manner. Teachers were made aware that they could use similar techniques with their learners when starting a lesson in order to easily get their students' attention, sharpen their observations skills in a fun way, and to extract answers or ask questions through interactive demonstrations.

With the activity that followed, the presenter organised the teachers in four groups of about five and issued each teacher with five cards, numbered one to five. He then used a power point presentation which had scientific questions on wave theory, with five possible answers, numbered one to five. Each teacher had to hold up the card with the number that they thought was the correct answer. If there were teachers holding different numbers in the group, heated discussions would follow in an attempt to reach consensus. This debate continued when opposing groups' numbers did not match. Each question took a minimum of five minutes. There were about 20 questions that they dealt with in this manner. The presenter informed the participants that this activity could be done with learners. It was a way in which teachers could identify existing misconceptions in the class. The discussion of each question was followed by giving the correct answer and a brief explanation. The presenter promised to elaborate and consolidate later, but due to lack of time, this consolidation, with a potential focus on emerging misconceptions, did not take place. As an alternative, the presenter indicated that the activity served as stimulant for teachers to go and read up and learn more later.

There was a more intense participation from the two high school groups than from the primary school groups. The groupings were voluntary, yet primary schools teachers ended up sitting together and high school teachers gravitated towards one another. The activity with high school teachers' participation took teachers out of their comfort zone and compelled them to think and discuss through the conceptual aspects related to wave theory. The numbers they chose on many occasions were not identical, which indicates that they did not have a clear conceptual understanding of wave theory. The primary school teachers, particularly, struggled with the concepts which were pitched at a higher level, and were therefore less active in participating in the discussion. Even though the teachers did not engage in traditional practicals as prescribed in the curriculum, they managed to engage with scientific concepts in a stimulating and interactive way. The focus of the activities was on pedagogical content knowledge (PCK), as a way of using these strategies in class, which were pointed out by the presenter.

During the final activity they were given a formula to use in which they had to find the wavelength of a particular musical note. They then had to fill a test tube with water to the measurement they had pre-determined in their calculation, using rulers. For instance, blowing over the test tube could produce C sharp if the level of the water was correct. Once they all completed the activity the teachers were grouped according to the musical notes and the teachers ended up playing the national anthem, conducted by the presenter.

4.2.4.3 Day 3: The Technology workshop

As a presenter for the technology workshop, I will relate this section in the first person. Unable to observe myself in action, but required to complete the observation schedule, I observed the video recording of the technology session only.

I began the workshop by stating that the focus would be on content and skills. I acknowledged that only the primary school teachers present taught technology, and that the focus of the session was more geared towards technology as a subject. However, I indicated that I would try to focus on the teaching of electronics so that both high school and primary school teachers could benefit, as this topic was new to most teachers. Electronics forms part of the Grade 11 physical science curriculum, as well as the senior phase of technology education.

The focus for the day was for teachers to identify components, interpret circuit diagrams, construct an electronic circuit and explain how a simple electronic circuit works. Teachers also learnt how to use multi-meters and observed how simple home-made interactive teaching aids and kits could be made and used. Thus manipulative and construction skills, conceptual understanding of electronics, as well as the related pedagogy of teaching capacitors and semi-conductors were addressed.

I started by demonstrating how capacitors charge and discharge, using a cell and a bulb. I then used a signal generator to show how it allows selected frequencies through a tuning capacitor of a radio. I continued with the introductory theory of electronic components such as resistors, light emitting diodes (LEDs), diodes and transistors and demonstrated how the components operated, using a home-made interactive teaching aid.

I then distributed purpose-made electronics kits and instructed teachers to build three simple circuits with no more than four components in each one. Even though the teachers again organised themselves into four groups of five teachers, I informed them that for this practical session I expected them to work as individuals. I wanted each individual to experience building the circuits themselves so that they could get the benefit of the learning experience. The kits were given to the teachers to use in their classrooms afterwards.

I ended the session with a Grade 11 activity during which teachers built a different circuit in groups of three, using capacitors, resistors and a light emitting diode. They had to time the discharge rate, using a stop watch, and plot a graph at ten second intervals till the LED light was extinguished. I walked around giving guidance and responding to questions when asked. In conclusion, I reminded the teachers that charge and electrons are abstract concepts and that learners are likely to be confused at the beginning of a lesson. It would help if simple demonstrations or hands-on practical tasks could be given to strengthen these theoretical concepts.

Insufficient time was a factor, as there was too much new information for teachers to absorb in a short period. During the individual activity, while working on their own circuits, most teachers tended to group together in order to support each other, although some individuals continued to work by themselves. As electronics was new for most teachers, they were hesitant and unsure of whether they were doing the right thing. They preferred going through trial and error in a group. They were in awe of their own achievements when they succeeded in making a circuit work. For example, when the LED lit up, exclamations of surprise were uttered. The whole process seemed rushed because of project time-table constraints. More time for discussion and consolidation was necessary. As people work at different paces, there were some teachers who were finished with their practicals while others were still struggling to complete their circuits. The teachers who were still busy with their practicals then requested help from those who had already finished. Even though all the teachers were unable to complete all the circuits in the allotted time, they did manage to complete at least one circuit during that first session. There was content overload, even though it was at introductory level, as a lot of the theory was new to the teachers. It was evident that both high and primary school teachers were operating at the same level, conceptually, with their practicals. In one practical, a primary school teacher finished all his circuits ahead of the other teachers.

4.2.4.4 Extra-curricular activities: The science competition

Most of the experiments conducted at the science competition were ones that were done during the workshop. It seems that teachers depended quite heavily on the practicals that they were exposed to in the workshops. Out of the sixteen schools that participated, learners in only three schools conducted different practicals.

The science competition brief to the schools offered 10 minutes to a team of a maximum of 10 students, to present as many experiments as they would like. The time schedule was tight and teams came up in rapid succession. The focus was on participation. The main criterion for judging was alignment of the curriculum content with the practical performed.

4.2.4.5 Extra-curricular activities: The science clubs

Of the teachers who were in the 2nd year of the programme, only 1 primary school teacher and 1 high school teacher took up the challenge to start science clubs. It was hoped that the science competition would act as a catalyst to encourage more teachers to start science clubs. Teachers were informed that the workshops would provide them with practical knowledge and skills that would enable them to start science clubs at their schools, in line with the aims of the intended intervention programme. During the workshop they were provided with a booklet containing chemistry experiments. However, the participants reported that no guidance was provided in terms of the operational aspects of starting and sustaining science clubs. Participants thus identified an important inconsistency between the intended and the implemented intervention programme. As there were no guidelines for the development of science clubs in the intended formal programme, it would serve no purpose to investigate the nature of the existing science clubs when considering research question 1, which is an exploration of the relationship between the intended and the implemented programme.

4.2.5 Reflections on intended and implemented programme.

The data for the analysis of the coherence between the intended and the implemented programme was based on five sources, namely, the project manager's interview, the project report, observation schedules, video observations of workshops, as well as reflective reports (Figure 3.1, Data streams 1 and 2).

I used the aims as presented in the formal programme as a basis for gauging the relationship between the intended and the implemented programme.

In general, the workshop activities supported Aim A of the formal programme very well, as they focussed on teachers' content knowledge, practical skills and attitudes to doing practical work in class. However, there was no time in the workshop to focus on teachers' own pedagogical strategies as stated in the aim. They were exposed to the pedagogical strategies of the presenters, but were not given an opportunity to try out some teaching techniques themselves.

There was very little emphasis in the workshop on providing guidance to the teachers for Aims B and C that is, preparing for the science competition as well as running science clubs. The teachers were provided with a booklet of experiments that they could use in the science clubs and for the science competition. However, no guidance was given on the use of this booklet. It seemed as if the organisers assumed that the teachers could facilitate these experiments on their own without additional support. The teachers relied on the network that they had built up during the three-day workshop, where they assisted and asked advice from each other. Only when they needed resources, did they make requests from the project organisers. Electronic communication for assistance was more prevalent. As these two phases were intended to sustain what was introduced during the workshop sessions, they do require more explicit attention. This was a good opportunity to deal with the operational aspects of Aims B and C, as the project did not make provision for structured in-school support, unless requested by an individual teacher.

The topics dealt with in the Chemistry and Physics workshops (Workshops 1 and 2) were familiar to the high school teachers and an integral part of the old and the new Physical Sciences curriculum. Hence, the purpose here was to extend teachers' understanding and skills base. Many theoretical concepts were challenging and foreign to the primary school teachers, yet they were able to do the practicals as they were provided with clear instructions and could draw on the high school teachers for assistance. The Chemistry workshop focused on Grade 12 content and practicals using traditional equipment. A thorough coverage of science process skills occurred during this session, more so than in the Physics session. This did not address the needs of the primary school teachers sufficiently. The organizers should be sensitized to this aspect. The Physics session was different in that it exposed teachers to innovative approaches of consolidating scientific concepts. . The teachers needed to use a formula to determine the wavelength of a musical note by blowing over a test-tube filled with a pre-determined level of water. The use of argumentation to stimulate critical thinking and scientific reasoning in this task (Zohar and Schwartzer, 2005; Simon, Erduran and Osborne, 2006; Webb, Williams and Meiring, 2008) as well as integrating physics with other disciplines like music was a novel approach. The third workshop was on electronics, which is new content for both Physical Science and Technology teachers. The participants were very unfamiliar with both the theory and the practice of electronics. The focus here was on providing participants with an introduction to the subject, rather than extending and consolidating existing knowledge. Interestingly, the teachers all operated at the same level.

Time constraints were a common problem for all three workshops. There was not sufficient time to deal with conceptual aspects adequately. One way of addressing this is to reduce the number of practicals or have more frequent sessions throughout the year. Teachers need the chance to absorb, reflect and implement whatever they have learnt. An opportunity for teachers to practice what they have learnt should be accommodated within the programme.

4.3 Teachers' perceptions of the intervention: the experienced programme

The analysis of teachers' perceptions of their experiences in the intervention programme was based on two sources, that is, the three feedback sessions during which teachers reflected as a group and the individual interviews (data streams 3 and 4). The feedback sessions and the interviews were video-and- audio-recorded, respectively. Transcriptions of the recordings were analysed to identify emerging categories and sub-categories. An open- coded grounded theory approach was used as a method of analysis. If one uses the open coding approach, then the categories are not predetermined but emerge from the data. The data was read and reread a number of times in order to identify, and then refine, the emerging categories. As mentioned in Chapter 3, a second researcher validated the categories identified, where an inter-coder agreement of 82% was reached.

During the feedback session, the lead questions were quite broad, so that the participants were able to articulate their own perceptions and feelings. This is in line with the constructivist approach to grounded theory methodology. Their responses constituted Data stream 3 and were used to identify broad themes, categories and subcategories as indicated in Figure 4.1 Based on the data from the individual interviews (Data stream 4), the categories were further consolidated and developed, with some additional categories added.

Initially, four core categories emerged from the group interview data gathered during the three feedback sessions. These core categories included effects of the programme; impact on teachers; needs and wants of teachers; and recommendations for future programmes. Upon closer inspection of the data, subcategories emerged from the four core categories. This was more useful as it provided a basis for a deeper analysis of teachers' perceptions of specific aspects of the programme.

After analysis of the individual interviews (Data stream 4) the four core categories were subsumed into two broad themes. The first theme focused on teachers' perceptions of the nature of the intervention together with its envisaged impact on their own practice (Figure 4.1). This theme represents the experienced curriculum, and thus addresses research question 2. The second theme (Figure 4.2) focuses on teachers' attributes which refers to their needs and wants, as well as their ideas on the nature of science teaching and learning and of practical work. These attributes could influence the way in which an intervention project may impact on how they operate in the classroom or in extramural science-related activities. This theme addresses research question 3, which refers to the enacted programme. The core and subcategories related to each of these two main themes are indicated.

In line with interpretive methodology, teachers are quoted extensively in order to allow their voices to articulate their own perceptions and lived experience.

4.4 Theme 1: The experienced programme

In representing the teachers' experiences of the workshop, I chose not to indicate the teachers' perceptions for each workshop separately, as a detailed narrative of what happened in each workshop has already been given in 4.2.4. Rather, I focus on common threads that emerged from the three-day programme as a whole and present these, based on the emerging core and subcategories as indicated earlier. In this way, key lessons can be drawn that would inform subsequent interventions.

As indicated in Figure 4.1, within the theme focusing on the intervention, teacher perceptions may be grouped into four core categories, that is, perceptions on the delivery of the workshop, on its impact on teachers, on recommendations for improvement of the workshops, and on their role in relation to extracurricular activities. A narrative of the analysis will follow for each of these four core categories. Data for the respective subcategories comes from the feedback sessions and the individual interviews.

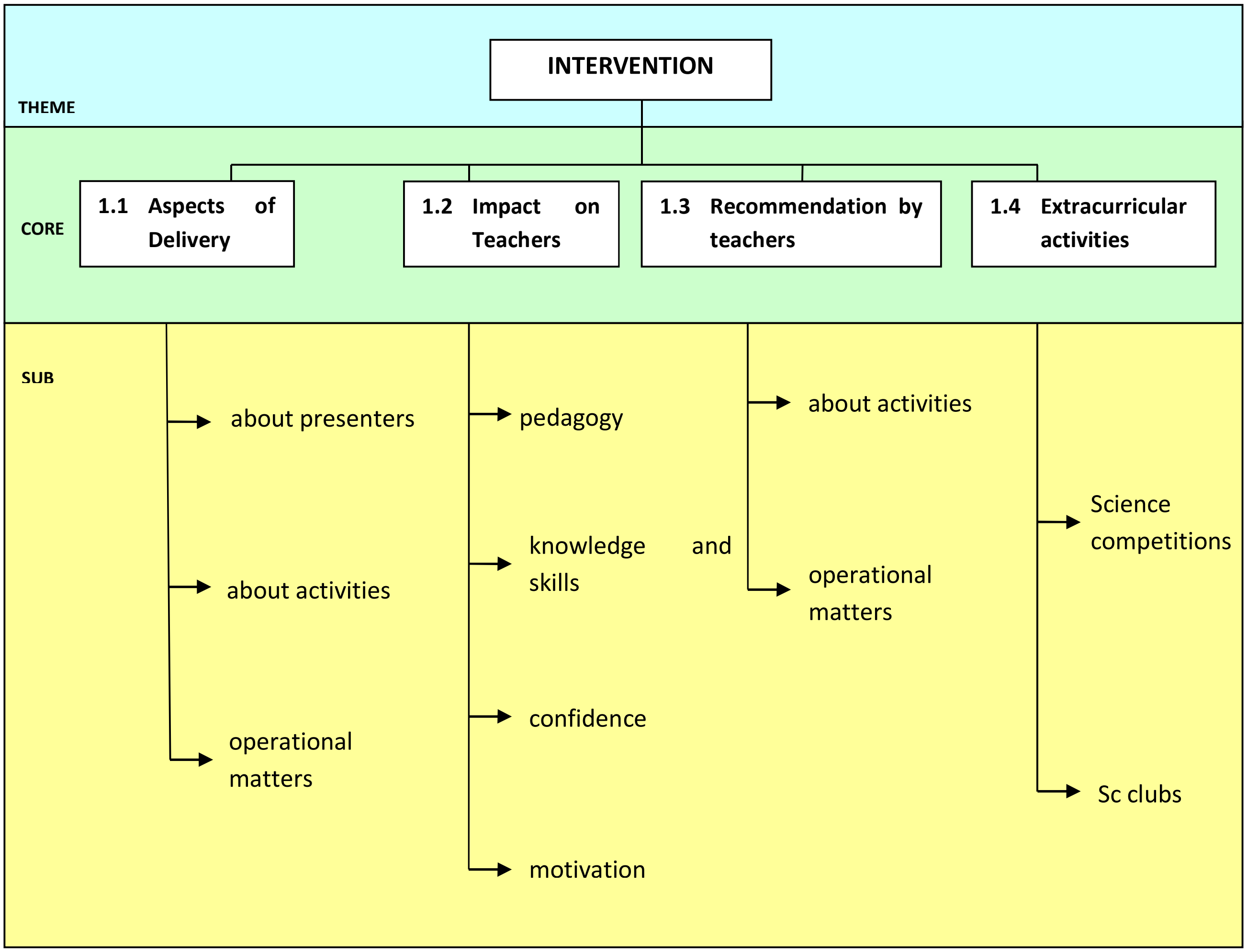

Figure 4.1 Theme 1: Teachers' perceptions of the nature and effect of the intervention

4.5 Core Category 1.1: Aspects of Delivery

Three subcategories emerged as part of the core category of teachers' perceptions on aspects of workshop delivery. These subcategories of teacher perceptions focused on the quality of the presenters, the workshop activities, and operational matters of the delivery. The issues that emerged with respect to each subcategory will be discussed in turn.

4.5.1 Perceptions of the workshop delivery: the presenters

In general, respondents held the view that the presenters were competent, challenged them and stimulated their interest, as illustrated by the following three quotes respectively:

> *You can be sure that I won't attend the workshop if I did not think that you* (the presenters) *were good (A10/4-6)*

> *The theory that [the physics presenter] did with us was very good, for all the questions he asked in the beginning which we answered, it sparked a person's interest (E1/5-7)*

> *Yesterday morning while I was sitting here I kept myself clever and concurred with everything. But later as the day continued he sparked something in me to read over certain terms. I am very enthusiastic to empower myself to read more, so that I inform my class. (E5/2-5)*

From the feedback sessions it was clear that teachers were confident in the ability and competence of the presenters. They appreciated that concepts and practical work were linked as, in their opinion, this added to the value of the practical work.

4.5.2 Perceptions of the workshop delivery: the activities

When teachers judged the workshop activities, three issues emerged: (i) the way the practical activities relate to theory, (ii) the extent to which they identify progression across grades, and (iii) the ways they illustrated novel teaching strategies.

4.5.2.1 The link between practical activities and theory

Teachers who participated in the previous year's outreach programme appreciated the move towards incorporating more content together with the practical activities.

> *It [the workshop] has changed. In the beginning we didn't have a lot of content, it was just more the practical stuff and the fun part. Now we are getting more into the content. It's really nice. (B8/22-24)*

The value of the link between practical work and the related theory was seen in two ways. Firstly, teachers expressed the view that this practical-theory link broadens the background knowledge of the teacher, which is seen as positive even if it does not directly transfer into the classroom. Secondly, the explicit link between practical work and the underlying theory will strengthen the conceptual understanding of the learners. Both justifications for valuing the combination of hands-on practical work with theoretical exposition are illustrated by the quotes below.

> *Those difficult stuff come alive in front of us [through the pracs] and that is very good. …..I started to feel like I want to go into this field….(E3/8-10)*

> *It was a nice Prac. The children like to see things… but it's not right, they must understand the Prac. They like to see - it must be fun. But I think the understanding, we must add it in. Link those things. (A2/6-8)*

They appreciated that concepts and practical work were linked; this added to the value of the practical work.

4.5.2.2 Practical activities and progression across the grades

The issue of progression in the development of learners' understanding of concepts and experimental processes was raised in various forms. For instance, teachers realised that practical work on a given concept may be introduced early in the school in a simple form, and then be made more complex for older learners, as illustrated by the four quotes below:

> *The sequence that you did things in was very good, because we worked from easy to difficult. It was very useful (A8/8-9)*

> *Yesterday, the practical investigation was clear: you can start in grade 7, even grade 5, with something very small, to get them used to the scientific process such as stating the hypothesis, so that they can get used to it (E10/25-27)*

> *I can now see the link, my grade 9s need to be on a specific level [of experimental skills] so that they can go through to grade 10. (E10/14-16)*

> *For me, yesterdays' session was an eye opener….I could see what I must do to apply it in the GET. I must apply different strategies so that my learners can become more effective…….{E2/23-25).The session yesterday was very good for me, so later when the learners go to high school, they will know a lot….(laughter)'(E2/27-E3/1-2)*

The senior phase of the GET band straddles both primary and high school. That is, Grade 7 is in the primary school, and Grades 8 and 9 are in the high school. This curriculum discontinuity was perceived as a major difficulty in facilitating meaningful progression. The teachers thought that it was useful to develop insights into how to deal with progression from lower to higher grades, and the practical work during the outreach programme was seen as a useful attempt to bridge the gap.

4.5.2.3 Practical activities as opportunities for novel teaching strategies

Several teachers pointed towards the practical activities they participated in as role modelling for teaching strategies they could use in their own classes. They referred to strategies specific to practical work.

> *I liked the Practicals with the motor and the electricity pracs. That was usually where I failed the children because we never had enough clips, or enough batteries in the school. But now with that [demonstration kit] on the board, everybody can see what happens… like we did two circuit boards to build on. It was difficult to work on the bench and then make everybody see, but now we are taking it up [vertical]. That was very, very nice for me.(B2/7-14)*

Several teacher mentioned that they had realized

> '*how effective group work can be'*,(E7/23)

While others focused on the experience with simple resources, noting that:

> *I can now show them [my learners] what practical, simple and cheap resources you can get and start to make some practical activities, to make it exciting for learners.(E8/4-6)*

In addition, specific teaching strategies used during the workshops were commented on negatively, as illustrated below.

> *We should have done more of the practicals ourselves but a person understands - the work does not lend itself to do [hands-on] practicals. It's based more on demonstrations. But wouldn't a person want to be more interactive? Then, for me it would be very good, because it's the very theme that we [teachers] are struggling with. (E1/12-16)*

Teachers indicated that they had developed new insights into how to use innovative, cheap and easily available resources, for example, the use of the electronic kits; but more importantly they could transfer what they had learnt to their own classrooms without much effort. Even though teachers reported that the argumentation and music activities in the physics session were fun and made them think about the physics concepts, it may not be as easy to replicate in their own classrooms as it requires a high level of PCK as well as a musical ear.

4.5.3 Operational matters

Three specific challenges were pointed out in relation to the organisation of the workshops: the fact that the workshop participants included both primary and high school teachers, the requirement of workshop participants consistently to work in groups, and the language of communication during the workshops.

4.5.3.1 Mixing primary and high school teachers

The issue of primary and high school teachers being in the same workshop was discussed at length during the feedback sessions. Some of the primary school teachers were not necessarily trained as science or technology specialists and had difficulty coping with the content. Even so, there was an ambivalent response to the fact of having primary and high school teachers in the same workshop. On the one hand, high school teachers expressed very positive views emphasising the need for linking the learner experiences across their schooling, as illustrated below.

> *I think it is very important to have these sessions for both phases [GET and FET], so that there can be a link, especially so that the primary school teachers can see what they have to do to prepare learners for high schools.(E6/6-8)*

Several primary teachers acknowledged that they found the science and technology content challenging, but felt more confident with developing and practicing the practical activities. The primary school teachers indicated that they appreciated having a better understanding of the concepts and thus have a better idea of what happens when their learners go to higher grades. These sentiments are represented in the two quotes below:

> *I am GET, so unfortunately I get lost [at high school level],but there was some times when I was back on board again, especially when I start to planning activities …so it must be a positive session, to take back to my learners and as well as educators.*
>
> *(E8/1-4)*
>
> *Yesterday's session was an eye opener… I could see what must I do to help learners, so that they become more effective in the GET. I must apply different strategies so that my learners can become more effective… So uh…it was an eye opener for me as well, especially the use of different graphs, how to work with the graphs. (E2/23-27)*

Although the issue of the grade level the workshop ought to address featured prominently, it was felt that new topics, such as electronics, were presented at the right level of understanding.

The participants themselves did not reach a conclusion on this matter. They appreciated the fact that being together allowed them to view progression in concepts and skills from lower to higher grades. However, at times they felt that an emphasis on their specific grade-related needs was lacking. For some primary school teachers there was an overload of content, which was not necessarily applicable to the level they teach. They did, however, indicate that it is worthwhile knowing what the learners at high school need, as this puts them in a better position to prepare their learners at the lower levels. It might be useful if subsequent interventions have joint as well as separate sessions to cater for general and specific needs where appropriate.

4.5.3.2 Practice of practical activities: alone or in groups

Most teachers voiced the view that the strategy of engaging in practical tasks as groups can be replicated in class. However, when it came to teacher-learning, a discussion arose around working individually versus working in groups. The two quotes below depict the former and the latter positions respectively:

> *I would prefer to do something on my own, but I understand that we have to work in groups at times and not on your own.(E6/26-27)*

> *Things that I'm very sure of, like old stuff, I would like to do that alone, but sometimes I'm struggling with something and I don't want to ask because I must do it alone now. So sometimes I want to work in a group.*(A9/5-8)

There were mixed reactions to the grouping in the activities. Some felt that more individual work would have allowed them to develop their skills further. Others felt that they benefitted from group work, especially if they were less confident in the concepts or the skills, and could learn from each other. Individual and group work was done, which caters for both sentiments. It seemed that organisers were aware that people learn differently, so a varied approach to the workshops in the implemented programme accommodated all types of learners. (Gardner, 1983)

4.5.3.3 The language of communication during the workshop activities

The terminology and pedagogic and scientific language used during the workshops was an issue, as most teachers were English second language speakers. As a result, one teacher remarked that she

> '*found it difficult to understand in English – I had to read through the question four to five times to understand [what was asked]*'.(E4/16-17) Group discussions often reverted to the home language of most participants, that is, Afrikaans.

Firstly, the use of English in the workshops needs to be considered, when most of the teachers are 2nd and 3rd language English speakers. This is a general problem which pertains not only to workshops in this intervention. The majority of the teachers were Afrikaans speaking with a few Xhosa speaking teachers– they taught at Afrikaans- medium or English-medium schools. Facilitators were therefore compelled to conduct their activities in English, which was a common language. However, at Afrikaans- medium schools, the teachers teach in Afrikaans and interact with their colleagues and learners in Afrikaans which is generally their home language as well. The textbooks they use are also in Afrikaans. It is therefore not surprising that they found the English facilitation challenging. Code-switching to Afrikaans was occasionally used in order to accommodate queries from Afrikaans speaking teachers, but this was clearly not felt to be sufficient.

4.6 Core category 1. 2: Impact on Teachers

According to the teachers' perceptions, the workshops added value to their professional development and impacted positively in three different ways. They perceived impact on their classroom pedagogy, their knowledge and skills of the broad area of science and technology, and on their confidence and motivation to teach science and technology. The perceptions in each of these sub-categories are reported on below.

4.6.1 Perceived impact on pedagogy

Similar to the comments on the pedagogic aspects of the practical activities reported in the previous sub-category, teachers indicated more generally that participating in the workshops urged them to project their own workshop experiences as classroom activities.

These perceptions went beyond copying the modelled learning experiences in class, but teachers expressed an empowerment to re-conceptualise the activities for their own contexts

> *I really like the placards [used in the icebreaker physics activity]. It gave me the idea of making smaller cards, and you can paste it on the board.........It gave us ideas to which we can adapt to.(E7/2-4)*

> *Personally for me, the [scientific] terms are unknown to me, but while sitting in the session I was thinking how must I present it in my class for the primary school students and how will it fit in with the senior phase. Although I did not understand the terms I could sketch a picture of how the higher grades could fit it in.(E4/10-14)*

Another teacher, a non-science specialist, explains how being part of the programme has made him more creative in developing new teaching strategies and resources, and developed a reflective approach to his method of teaching.

> *Traditionally, a science person is the nerdy one, and now all-of-a-sudden we [non-science people] are also developing a culture of developing things. I'm sure in the future, as teachers we will also start to develop things: 'I've tried this, this year, I've tried that, this year.'(C6/12-16)*

4.6.2 Perceived impact on knowledge and skills

Generally it was felt that the content input usefully added to and extended the science knowledge base, especially among under- or unqualified teachers, as illustrated by the comment of one of the participants:

‘ *It’s really nice. It’s like a course’ (B8/24).*

Another teacher elaborates that the programme provides a second chance of learning the science content:

> *You see, that is nice of this programme: even now I don’t have the money to go and study further. Now we are getting into it from another source. It’s helping me build my knowledge base - that to me is empowering, because I always felt ashamed because I didn’t study straight Science, but now I can also talk to other people about Science. (B8/37-41)*

Participants appreciated a challenge to their content knowledge and skills. Several teachers mentioned that the challenging theory was also motivating to delve deeper into the content. Initially participants felt uncomfortable when new or difficult concepts were introduced. However, with the progression of the workshops, after grappling with the concepts they started to think and to develop insights.

> *Yesterday’s session I felt that… in the morning we were definitely challenged. I think it’s good to expose your mind to more things, even if you don’t understand them. What we’ve found out later during the day and this morning, was, that some of the concepts even if you didn’t understand them, they stuck with you and now you’ve got that interest to explore further. (E1/19-24))*

With hindsight, most indicated that challenging them was good and it motivated them to search for opportunities to learn more. Challenging teachers for learning should therefore remain a major part of the intervention.

There has been a personal growth of confidence which both surprised and stimulated some teachers. For example, during an individual interview session a teacher indicated that she no longer shies away from demonstrating experiments in class and allowing students to do practicals. She credits the workshop experiences for her changed classroom attitude and behaviour, and explains her increased confidence in this way.

> *I’m more confident with doing experiments. You know how many things I take out of lab nowadays? (laughs) And if you came here in 2005, when I came here for the first time, this lab was closed, I mean for almost that whole year! And suddenly I take out anything, and I do it [experiments] except for electricity - not yet! (giggles) I’m still strange with that, but all the other stuff, I just take it out. I put on the Bunsen burner and let the grade 11 and 10s see what I do. I am even doing grade 9 experiments with a class of 50 in my class. (D10/18-25)*

With respect to the skills component, some teachers indicated that they needed more practice in the practical work in order to become comfortable with the method. One recommendation could be that organisers think about how to create opportunities for them to practice before introducing it to the students.

4.6.3. Perceived impact on confidence and motivation

As illustrated in the previous quote, several teachers linked an increase in confidence in teaching through practical activities to their perceptions that the workshops strengthened their competence in science knowledge and skills.

Teachers expressed the view that a feeling of confidence about understanding the related concepts is a condition for building confidence in planning and performing practical activities in the regular classes.

> *I must first feel comfortable [with the practical] before I can change it I'm still learning [the concepts]…like electronics, I mean it is new to all of us.(E7/15-17)*

In the interview, teachers indicated that the acquired knowledge motivated them in the enactment of the role of the science teacher.

> *I am very stimulated…..and to empower myself I am going to read more and share this with my class.(E5/3-5)*
>
> *There's always something to learn. I find it exciting. I just like being part of the Science and keeping it alive. Personally, it helps a lot to keep me motivated and to keep the Science alive.(B1/43-44)*
>
> *They can't believe I'm enjoying school every day. With kids like this, I'm just doing the things I like, and the things I've been taught [during the workshops].(D10/31-32)*

Another teacher expressed the empowerment by the outreach programme, indicating that it showed that there are no longer any excuses for not doing practical work, as appropriate resources, teaching materials and teaching strategies were shared at the workshops.

> *Through your Outreach Project you are showing that: 'Ok, it's no longer a matter of I draw a circuit diagram to show electronics on the board'. You showed a circuit board, and how it can be developed quite easily; and all-of-a-sudden, myself, I also engaged with it and it was quite a new territory to go in.(C4/14-19) How are we going to get teachers to really get down to the nitty-gritty and get people to engage with it in a practical sense? Your Outreach Project is key(C4/23-25) - You walk out of there and you think: 'It's time to step it up now. I can't just carry on the way I've been. There are things that I can do' (C4/27-29).*

4.7 Core category 1.3: Recommendations by teachers

Several suggestions for improvement of the intervention were made by some participating teachers. Some of these recommendations focused on the nature of the activities, whilst others concentrated on the preparation for the workshops, thus on organisational matters.

4.7.1 Recommendations for improving the activities

As mentioned earlier, teachers appreciated the provision of task sheets for practical activities. Groups worked through these themselves during the workshops, thus increasing their confidence in using them. Brushing up on the related science and technology theory during the workshops was also appreciated. Teachers recommended that for future workshops this background content knowledge could also be documented, together with the practical activities, as illustrated in the following quote:

> *We saw the prac, but the theory that goes with it is often fast and then it's nice to see it. But we don't come back [to it], or write out the things the next week. We leave it. And when it came to that chapter, we can't remember: What did we do then?(A4/5-8)*

This is a useful suggestion as it allows for consolidation of the activities, and enables the teacher to refer to the documents later for use in the classroom.

4.7.2 Recommendations about operational matters

Suggestions for improving the organisation of the intervention related to the planning, not the implementation, of the workshops. The first suggestion intended to increase the match between teacher needs and their experiences during the workshops by surveying the background of the participating teachers before selecting the content of the programme.

> *Maybe you should do a background study of where certain people are: in the intermediate phase and senior phase and so forth… when you prepare your theory… and where does it fit in terms of learning outcomes.(E5/15-18)*

The second suggestion intended to increase the impact of the workshop experience by allowing participants to prepare beforehand. Particularly, advance knowledge of the subject content included in the workshops was considered helpful for those not familiar with these content areas.

> *If you have another workshop you must just inform us of the topics, so we can read through those topics. Because sometimes you mention something and there were teachers from other schools, primary schools, that mentioned:" What is that guy talking about?"So maybe before a workshop you can just say: 'This will be the topics for the week' (A8/11-17)*

The suggestions are worth considering, as the former assists the organisers with their planning, while the latter may assist those conscientious participant teachers with their preparation for the workshops.

4.8 Core category 1.4: Extracurricular activities

The reason for the science competition was twofold: that is, to encourage teachers to do practical work with their learners in the science classroom, and for learners to conduct their own practicals. The organisers also regarded the science competition as a catalyst from which to develop science clubs. The knowledge and skills teachers gained in the workshops could be used to prepare for the science competition, and could also be applied in the science club. Teachers were guided by the curriculum in determining activities in the classroom; however in terms of the science clubs, no format was provided.

Although teacher comments dealt less frequently with extracurricular outcomes of the intervention, they expressed the view that the programme rightfully focuses on science competitions and science clubs since these practical activities motivate students to learn science and technology, to develop their investigative skills, and their understanding of science concepts.

In the interviews it emerged that participation in the science competition stimulated learners to read up more, and to assist teachers with practical work in the classroom.

> *The science competition has value for the children, yes. They have exposure, they have building of their confidence, going out and finding out how this things work, using the right terminology. They don't always get it right, but at least they go to the library and look up stuff, and for them I think it builds their confidence. Now I can use them and say: 'you're my lab assistant'!(B5/29-34)*

4.8.1 Extra-curricular outcomes: Science competitions

Most of the experiments conducted at the science competition were ones that were done during the workshop, with a few exceptions of alternative equipment being used. It seems that teachers depended quite heavily on the practicals that they were exposed to in the workshops. In general, teachers felt that preparing learners for the science competition was fun but challenging for the teacher. However, such a challenge was not seen as daunting or off-putting. The challenge for the teacher was seen to increase for subsequent science competitions, since new experiments need to be identified each time.

> *The competition started in 2006, and then at first it was new to us. The easiest thing to do was for us to get started. Here's the Curriculum, let's take THAT from the curriculum. But every year I think this thing will grow because teachers will be challenged to think out of the box now. (C7/2-6)*

Two issues arose specifically related to the workshops. Firstly, teachers attended the workshops in order to identify experiments they could suggest that their learners to perform for the science competition. However, they realized that ideally learners themselves should be given the leeway to determine the experiments they wished to perform, as illustrated in the quote below.

> *So it challenges us as teachers… it challenges our resourcefulness – finding experiments to demonstrate [for the learners]. Obviously it would be nice to let your learners be part of the process. (C6/18-20)*

Secondly, the issue of differentiating between practical tasks suitable for high schools and primary schools during the workshop emerged. Such a differentiation would give better guidance to teachers when preparing for the science competitions within their own schools. The issue arose because the primary and the high school practical projects at the competition tended to be similar, resulting from the fact that primary and high school teachers attended the same workshop.

> *There must be some kind of continuity between the primary schools and the secondary schools in terms of practical tasks. It can't stop and start somewhere. I would like to have pracs, yes. But I don't like the primary school learners to do the same pracs – that is Sugar and Dehydration - because I know they won't understand it. (A4/26-30).*

Countering this argument for targeting practical projects at different levels, another teacher noted that, regardless of learners' initial content knowledge, the practical work instilled an interest in the younger learners and therefore motivated them to continue with studying science.

> *Most of the learners that attempted that experiment, they had no knowledge of Ammonium Salt. Those learners are now in my grade 11 Science class, and they are there because of doing the experiments in grade 9. (C3/4-7)*

It seems that motivating learners in science at a younger level could contribute to fulfilling the overall vision of the programme, that is, encouraging learners to choose science as a career. They need to make their subject choices at the end of Grade 9. If they do not choose physical science, then they are eliminated from furthering any future career in a science-related field.

4.8.2 Extra-curricular outcomes: Science clubs

Teachers' sentiments indicated that it was challenging enough to try new things themselves, let alone getting the learners to do it. They seemed to think that the success of the science clubs depended on the extent to which students were interested and enthusiastic about participating.

> *The problem is learners who are interested in Science Clubs here, they are already the Sports people, the Chess playing people, the Drama Group people, so they are overloaded already, but they are willing. So the learners that is doing nothing, they don't want to do anything. We can change them for a while but it won't last. And I don't want to start things that is not going to last. So we must select a group first. That won't be very easy but if we select the right group they will do it. But I think the area in which our school is in, it's not a good area. The learners' attitudes, we must first change that. Because sometimes being good [excelling] is seen as bad, and that's a problem that we must overcome. But I think with enough effort we will have learners who will want to join a Science Club. (A6/10-21)*

Teachers perceived teacher commitment as a second variable in determining the success of a science club. In general, teachers with wide responsibilities may have a diminished chance to carry through with a science club, for example, the science club teacher who says:

> *'me myself, my programme is very full: it's netball, and it's athletics club, and it's school. Here you see all the registers of the classes I teach' (laughs) (A6/21-23)*

Another busy and enthusiastic teacher indicated that his passion for science drove his commitment and willingness to organise and manage a science club. As it is an extracurricular activity, it is not bound by curriculum and time constraints.

> *For me at this moment, running a Science Club after hours is even more exciting because now I'm not in a restricted time-frame within the curriculum because now I can do whatever I want. On top of it, I'm not currently teaching Science- I'm teaching Mathematics- so I'm not pressured by the Curriculum. I do have the time and I do have the interest within the Science. (C8/4-9)*

It emerged that the participation in the science competition was seen as more successful than participation in the science clubs, as each have different demands.

Science clubs are an after-school activity and require regular attendance. At many schools, learners are bussed home immediately after school, so they are unable to attend. Moreover, many keen learners are already participating in a number of extra-curricular activities. The teacher, on the other hand, needs to dedicate time and attention to something that is good to do, within the context of many other tasks.

In contrast, the science competition is a single event towards which teachers and learners can work for a shorter period of time. It also brings external rewards in terms of exposing and acknowledging the work that they do at the event.

4.9 Theme 2: Teacher attributes

Theme 2 dealt with the enacted programme and the factors shaping the enactment of the experienced programme. In this study, the enactment of practical work in the classroom following the workshop experiences is described from the point of view of the teacher. The data from feedback group discussions and individual interviews served as sources for this theme, but relevant views came through more strongly during the interview sessions. In Theme 2, teacher attributes are discussed in two core categories, i.e. *teachers' needs and wants*, and their *ideas on science and practical work*, see Figure 4.2 below.

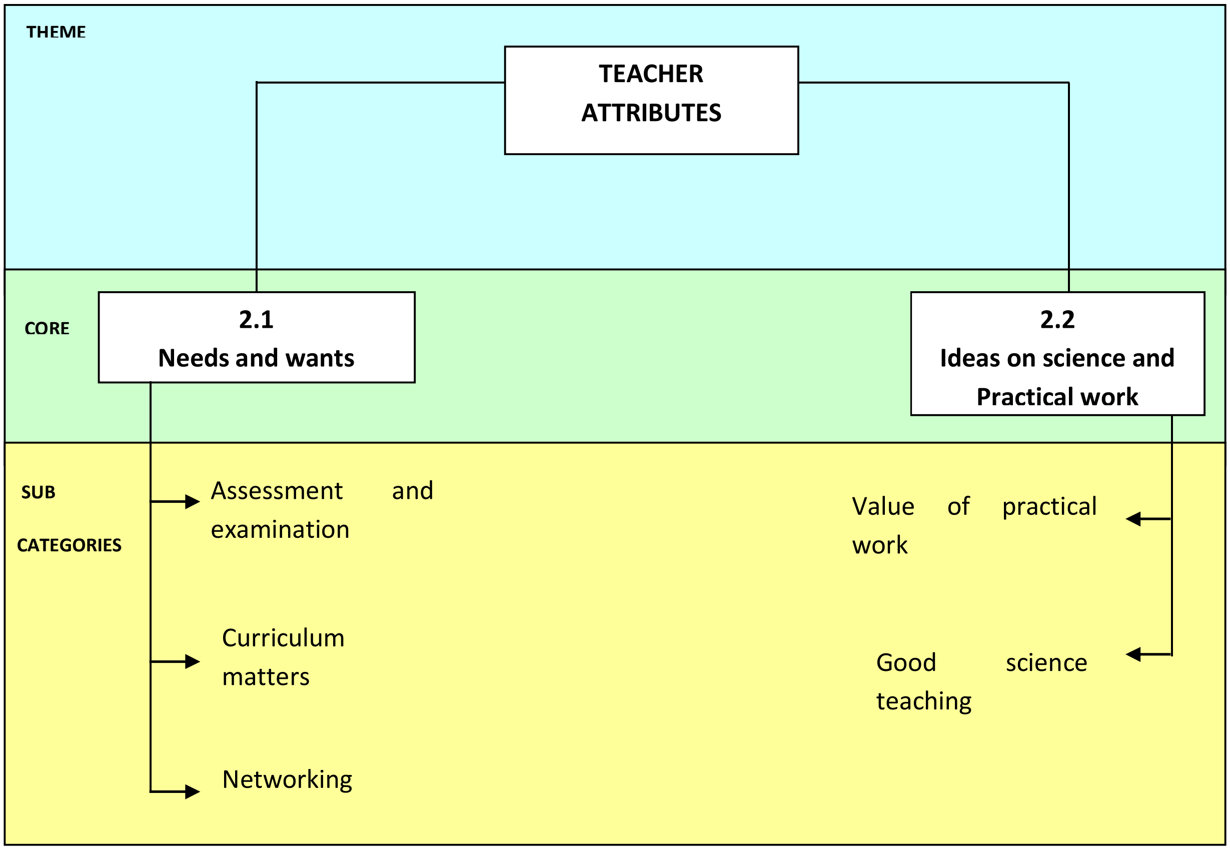

Figure 4.2: Theme 2: Teacher attributes influencing the enacted programme

4.10 Core category 2.1: Teachers' needs and wants

Three subcategories emerged as part of the core category of teachers' needs and wants. These subcategories focused on the assessment and examination, curriculum matters and networking. (Figure 4.2 above) The issues that emerged with respect to each subcategory will be discussed in turn.

4.10.1` Assessment and examination

The prominent role of examinations in teachers' professional decisions became evident when requests were made for support in teaching content of topics which feature significantly in the examinations as indicated in the suggestion below:

I would suggest the theory going into the higher-order calculations. If you could do more on Organic Chemistry, seeing that it is 55% of the question paper. I would say that you must tackle new things. Like Newton's Laws. (B3/43-44)

In the same vein, the application of practical work in class as a result of the workshop experience could be increased, according to some teachers, if these practical activities introduced during the workshop could be extended by an assessment component*:*

It would be a good thing to show us how to mark the [practical] investigations. (E11/6-7)

4.10.2 Curriculum matters

There was a perception that the sessions would be easier to transfer into class activities if the workshop experiences were to address closely the new Outcomes Based Education (OBE) curriculum. Teachers wanted activities to be more focused on the specific requirements of the OBE curriculum, including specific Learning Outcomes (LOs) and Assessment Standards (ASs):

I was expecting an OBE session, like for instance… we going to work with LO2 and the AS is this, so we going to do a practical on this AS. There is your outcomes and AS, and the activities we do here would be focused on. For example, Grade 4 till Grade 12. (E8/9-13) There is a gap there…and that is what we need to focus on… and now how you come to the mark? so we must focus on that..(E8/15-17)

There were suggestions that all practical worksheets should list the Assessment Standards and Learning Outcomes covered, and thus be more focused on the curriculum requirements.

I will suggest that you add Assessment Standards and the Learning Outcomes so that we can have a complete Prac. Because it isn't complete, we saw the Prac. We know how to do it. But we must be able to link it with what the WCED needs. (A3/9-12)

The issues raised by the teachers are important to them for a number of reasons. Firstly, the guidelines and components of the curriculum documents are very broad.[1] Teachers are expected to interpret the curriculum in their own way, which, if they are not science specialists or are under-qualified can be very difficult to do. Hence there was a request for more detailed guidance on assessment and the teaching of important topics that are prioritized in the examinations.

[1] This has subsequently changed as the most recent curriculum change – CAPS-is more prescriptive.

4.10.3 Networking

The implementation of practical work in class is seen to be promoted not only by the experiences with practical activities during the workshops, but also through networking. Networking and exchanging classroom experiences also support teachers' ability to conduct practical work. By identifying similar problems at the workshops, teachers networked around problem areas in practical work. They argue for the creation of a platform for networking, even outside the project workshops.

> *I think being together helps too you get ideas [on teaching through practical work] from other schools too. You see you're not the only one with problems and that there are other teachers too [have the same problems] I think we learn from each other. (D12/12-16)*

One suggestion for future workshops was to reserve allocated time for *'more exchange between teachers'* during workshops instead of the ad-hoc discussions which occurred informally during coffee breaks and meals in the programme.

A request for formally arranged meetings between participants on other occasions in the year was made.

> *I wish that it [meetings] could be more than once a year. I think being together helps too. It's the only way we can be together, you're bringing us together and we're sharing (D12/12-14)*

When asked specifically in an interview whether the specific teacher continued networking individually after the intervention, the distance between schools was mentioned as an obstacle.

> *Schools who are part of the program- there's huge distances between them. There are some teachers in the vicinity, like there's a lady in Robertson, we had contact with her where she was talking about practical work that she had problems with. There are attempts that has been made to reach out to schools, but I think it needs to be facilitated- more structured (C9/9-16)*

4.11 Core category 2.2: Ideas on science and practical work

Two subcategories emerged as part of the core category of ideas on science and practical work. These subcategories focused on the value of practical work and good science teaching. (Figure 4.2 above) The issues that emerged with respect to each subcategory will be discussed in turn.

Teachers' perceptions about the nature of science, and the role of practical work in the construction of scientific knowledge impacted on the ways that they could see themselves implementing practical work in their classes. The final issue that arose centred on the practicalities of science classroom teaching and learning.

4.11.1 Ideas on the value of practical work

In the interview, teachers were asked what they thought the value of practical work was. Several teachers pointed to experimentation being key to the nature of science. They identified experimental evidence as the essential building blocks for scientific knowledge.

> *Oh yes… I think that [practical work] is what sets the other subjects apart from Science. I always try to do the Practicals first. The children love it. I think it's very, very important. (B1/13-15)*

> *It's quite a deep thing for me; in the sense that I think Science comes from observation, and if there's no practical, there's no observation. (C1/17-19)*

> *As if you are sitting in the Science class and you are observing the teacher talking about something that you don't really see. That means you are taking out the essence of the whole thing-observation. Newton was sitting under the under the apple tree when he observed the apple falling from the tree. From there he could make certain deductions, so I could cite many other stories about what has happened in Science, and the birth of things; about the birth of many profound concepts in Science is from observation. So from there practical work for the learner is a core-issue. (C1/31-43)*

Sentiments were expressed that the prominence of practical work in making sense in science is not recognized sufficiently in the curriculum. The concerns were that there are only very few compulsory practical experiences for the learners in the curriculum documentation.

> *I'm a bit concerned about the WCED [Western Cape Education Department]. They took out a lot of pracs. We only need to do two pracs for the year! (A1/9-10)*

4.11.2 Ideas on good science teaching

There was some agreement that practical work in science teaching is very motivating ('*the children love it*') (B1/14), but can only be valuable in learning if it is linked with cognitive understanding, as indicated by the quotations below.

> *They [learners] like to see: It must be fun to do. But I think the understanding, we must add it in, link those things. (A2/7-8)*

However, some constraints at school reportedly limit the use of practical work by teachers, such as time constraints, or large class sizes.

> *At the school where I am teaching I am always pushed for time. (C2/26-27)*

> *I can't actually do practicals as I should, with so many pupils in your class. (D1/21-23)*

For other participants, however, these very same problems (time shortage and class sizes) have been alleviated by using the intervention experiences. One teacher noted that she had changed her approach to lesson planning and presentation by using the resources provided during the workshops. She realised that the prepared resources did not only save her time, but also allowed her to integrate practical work in her lessons.

> *[The programme] has helped me to progress with my way of thinking and with my way of planning in the classroom. Like the Department [of Education] gives you a package and they say this and this must be done. But what is happening now is, you are teaching me ways to do it more effectively, so that I can save time, because otherwise I wouldn't have made it, like with the pracs in class. Like I know I'm doing this chapter today: the things [materials] that you guys did in Worcester, I can go on that. I don't have to do things from the text-book… and that helps a lot to save time*. (B8/9-17)

Using alternative laboratory equipment seems to be stimulated through lack of resources, that is, innovation was prompted by a lack of equipment.

> *I have to be innovative, because sometimes you don't always get the stock that fits properly with this thing. (B1/35-36)* while B said 'for *example, in electricity pracs I sometimes use foil instead of resistors.9A1/26-27) Yes I try to change things. (A1/29)*

The practical component was seen as motivating and a way of stimulating interest in science. Science process skills such as observation and deductions are a core component of science, and this can only be developed when children are exposed to practical work.

Teachers saw practical work as a valuable component of science, and acknowledge the workshop activities for adding worth to their professional development.

4.12 Summary

This chapter presented the findings of the study in response to the three research questions indicated previously. It examined the relationship between the intended and the implemented programme. In addition, grounded theory was used as a method of analysis to explore the experienced programme and the achieved programme. Two main themes emerged which relate to teachers' perceptions of the intervention and aspects that influence their classroom practice. Generally, the teachers were very positive about their experiences in the programme and its contribution to their professional development as science teachers. They found the activities stimulating and, in some cases, quite challenging.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

As indicated previously, the study seeks to establish the relationship between the nature and coherence of a PD intervention programme and its influence on science teachers' content knowledge, skills and classroom practice.

As such it seeks to explore what the outreach intervention intended to achieve, how the intervention was implemented, how the teachers experienced the intervention, as well as what the perceived outcomes were in the science classes as a result of the teachers' participation.

The study adopted a qualitative approach which involved document analysis, interviewing the CPD project manager, workshop observation, gathering teachers' feedback on the different experiences they had during the workshop, as well as interviewing selected participating teachers in their own teaching environment. This provided opportunities to hear their views and perceptions.

In the discussion, I will refer to the emerging issues rather than to views of individual teachers, or of groups of teachers. What follows is a discussion of the key issues that emerge from the data analysis and observations by referring to the alignment between the six formats of the CPD programme.

5.2 Conceptual Framework

The study used an adapted version of a curriculum evaluative framework by Van den Akker (1998, 2003) and Hartley and Treagust (2006). Even though this original framework was developed for evaluating the implementation of curriculum innovations in schools in relation to teachers' understanding, their classroom activities and their learners' performance; this study explored the possibility of its suitability as a framework for evaluating the impact of a teacher professional development intervention. In this case, the intervention programme can be envisaged as incorporating the same aspects that are the intended (ideal and formal), implemented, experienced, achieved and enacted programmes. The impact of the teacher professional development intervention was measured by establishing the consistency between the different aspects.

In section 5.4, I will reflect on the suitability of the framework for evaluating this type of CPD intervention.

5.3 Nature and Coherence of programme

The intended programme includes the underpinning philosophy (the ideal programme), and the stated specific aims (the formal programme). The interview with the project manager suggests that the ideal intervention programme intended to encourage the development of 'first generation scientists, engineers and technologists' amongst youngsters from disadvantaged schools by providing them with role models of experimental scientists. The focus of this broad goal is on *outcomes* for learners. Equally, all but one of the six broad aims of the intervention programme emerging from project documents specify the *experiences* learners will have, and the *changes* they will undergo as a result of the intervention programme. Thus, the ideal programme consistently specifies intended effects of the intervention on the learners.

In contrast, when the project manager summarises the aims of the project (as an exponent of the formal programme), the intended impact is phrased in terms of the teachers. He specifically indicates that the three aims include an improvement of teachers' science knowledge and skills in conducting practical work, the strengthening of their skills in running science clubs, and the staging of a science competition which would demonstrate the extent to which the training provided was implemented by the teachers.

It is of importance that the expectations of the participating teachers are in line with the latter. Teacher expectations of participating in the project focus on their own learning, that is, changes in their own abilities, understandings and skills

Looking ahead, the data also indicates that the implemented intervention programme (as in the scheduled workshop activities) and the experienced programme (as in the reactions of the teachers to their participation in the workshops) largely focuses on outcomes on teachers, and only marginally on learner outcomes.

This ambivalence of focus exists in many teacher development programmes. The ultimate impact of teacher development interventions is normally envisaged in terms of the improved achievement of the learners; that is, in terms of Guskey's (2001) model, a Level 5 impact. However, the impact of teacher development interventions is often measured in terms of teacher outcomes, either as changes in teachers' understanding and skills (Guskey's Level 2 impact), or as changes in teacher classroom interactions (impact at Guskey's Level 4).

The relationship between the various formats of the programme is discussed below. Attempts will be made to identify reasons for any success, or lack of it, by pinpointing inconsistencies between the intended, implemented and experienced programmes.

5.3.1 The relationship between the intended and the implemented outreach programme.

The ideal programme emphasises the need for promoting science as an area of knowledge based on experimentation. This aspect of the Nature of Science (NOS) or any other aspect of the NOS such as the differences between data/observations and inferences/conclusions is not stressed in the implemented programme. It is of note that in the experienced programme, several teachers justify their involvement in the project by emphasising the specific nature of science as an experimental subject. Thus it seems that the underlying driver of the NOS is acknowledged implicitly by at least some participants. However, the emphasis in the workshops was not necessarily on open scientific investigations which capture the nature of science. Rather, the emphasis was on consolidating content knowledge, manipulating apparatus, and the recording data. Most of these activities consisted of teacher demonstrations and semi-closed student experiments. Thus, the activities were pitched at Levels 1 and 2 according to the classification framework by Hattingh *et al.* (2007). It is clear that the organisers view the purpose of practical work as a way of consolidating and refining knowledge and understanding of science concepts, and developing experimental procedures as highlighted by Mji and Makgato (2006).

This type of practical work in the implemented programme is slightly at odds with the intended programme which seems to emphasise open-ended investigations, the usual format for science competitions. However, this inconsistency may be explained by the lack of the teachers' experiences in doing practical work of any type.
Teachers were alerted to using alternative resources when traditional resources were lacking. They were also encouraged to be creative when faced with resource challenges. It was hoped that their involvement with the science clubs and competitions would take teachers further than Levels 1 and 2 and provide opportunities for them (and their students) to operate in those hybrid spaces between the curriculum, and individual and home interests as identified by Ramnarain and de Beer (in press, 2011). However, this was not easily evident in the science competition.

5.3.2. The relationship between the implemented and the experienced programme

Three aspects of delivery emerged from the data on the experienced intervention programme. These aspects are the quality of the presenters, the nature of the activities and operational matters. The teachers appreciated that concepts and practical work were linked as, in their opinion, this added to the value of the practical work. They also thought that it was useful to develop insights into how to deal with progression from lower to higher grades. For the more didactic minded teachers, the experience of working in groups informed them of a different way of learning that they could apply in the classroom. They indicated that they had developed new insights into how to use innovative, cheap and easily available resources in the classroom. The responses of the teachers indicated that the activities in the three-day workshop contributed to the development of their pedagogical content knowledge, their own conceptual understanding and experimental skills. All of these aspects illustrated very positive teacher outcomes and aligned well with the implemented programme.

5.3.3 The relationship between the experienced programme and the outcomes

Two broad categories emerged which address the outcomes of the intervention in the teachers' views. These are the impact on teachers themselves as well as on the extracurricular activities, and the development of science clubs and participation in science competitions. I will address each of these in turn.

5.3.3.1 Experienced programme: Impact on the teachers.

Participants' experiences highlighted four key areas related to the impact on teachers. These included an impact on classroom pedagogy (PCK), knowledge and skills, teacher confidence, and teacher motivation. Generally, all the impact on the teachers for all these aspects was perceived as very positive. Teachers reported that they could envisage and re-conceptualise the activities for their own contexts. Some expressed the view that the workshop was stimulating and challenging, which had a motivational effect on the way they saw their role as science teachers. This positive professional attitude carried through into classroom practice.

Some teachers felt empowered by the workshop experiences to do practical work in the class. This comes through in the interviews where teachers who never used equipment in the class were now doing just that, while others were confident to try new strategies. Also, the nature of the practical demonstrations presented at the science competition by the learners is evidence that the teachers did the workshop practicals in the classroom.

5.3.3.2 Experienced programme: Impact on science competitions and on managing science clubs

Teachers were informed that the workshops would provide them with practical knowledge and skills that would enable them to start science clubs at their schools, in line with the intended programme. However, the participants reported that no guidance was provided in terms of the operational aspects of starting and sustaining science clubs. During the workshop teachers were only provided with the date of the competition and strongly encouraged to participate. Participants thus identified an important inconsistency between the intended and the implemented invention programme.

Availability of time and personal interest seem to be important for mounting successful science clubs. Other established extracurricular activities for teachers and learners tended to impede on science club activities. A science club is not a normal feature at every school, thus there is no imperative to allocate resources, formal time and teacher support as part of the standard, accepted activities of the school. Sporting activities have a much higher status: schools are judged on their sporting achievement and acknowledged in the public domain. It could be quite an isolating task running a science club.

There was a four-month gap between the workshops and the science competition. Teachers were invited to call on the organisers for support. However, this did not happen until very close to the completion date. In lieu of school-based support, another formal intervention was needed to guide teachers in operational aspects of setting up and managing science clubs and preparing students for the science competition.

5.3.4 The relationship between the intended programmes and the outcomes.

As indicated in Chapter 4, the broad aims for the ideal programme are worded with an emphasis on outcomes for learners. However, when translating the intended outcomes into actions for the intervention, the intentions are phrased in terms of outcomes for the teachers (formal programme). In the following section, I will examine the alignment between the intended programme and the outcomes of the intervention (achieved and enacted programmes) for each of the six broad aims as specified in the project reports.

1. *To support teachers and learners in the learning and teaching of science and technology:*

   At the start of the intervention the project manager shared the broad aims of the project (the intended programme) with the teachers. However, the three- day intervention (the implemented programme) covers only a small component of the broader vision in which teachers are expected to try out what they have learnt in the classroom.

   The data shows that, apart from the three-day workshop, the intervention also provided for in-school support, for instance in conducting practical sessions in class or adjusting practical activities encountered in the workshop to the level of the learners. Since the project did not have full-time staff available for such support, the project could only respond to teachers' requests for help.

The teachers' perceptions (the experienced programme) provide strong evidence that participants feel that teachers gained considerably in the areas of PCK, conceptual understanding and practical skills related to specific concepts in science and technology. Examples of adjusted classroom practice provide illustrations of the application of this new knowledge in class. However, the data reveals that some teachers had developed additional skills and conceptual understandings as a result of the workshops.

2. *To raise awareness and participation of learners in science activities:*

There is strong evidence from the interviews (the experienced programme) that teachers increased their confidence in conducting practical work which, in turn, enabled them to do more practical work with their learners. The interview data indicates that all the teachers started doing practicals in a more sustained way with their learners, some to a greater degree than others. The ones who were successful indicated that the participation in the workshops (the implemented programme) provided them with the confidence to try out practicals in the classroom. Those who did it to a limited degree reported that organisational constraints of the school day and curricular demands were factors that impeded opportunities to do practicals.

The data also shows that the implemented programme supported such additional practical work by providing resources, including worksheets that were used in class, often without adaptation.

From the interviews it emerged that in several instances the school's participation in the science competition stimulated learners to read up on science concepts related to their projects, and to assist teachers with practical work in the classroom.

3. *To draw learners' attention to science and technology in their everyday lives and how it relates to their curriculum activities in school:*

This evaluation study did not find evidence of success in achieving this aim.

Although the implemented programme emphasised the use of everyday materials in the experiments, this aspect was not mentioned in the experienced programme by teachers as a feature that they use for linking science and technology to students' everyday life. Teachers may see the use of everyday materials solely as a response to the shortage of standard science equipment.

4. *To expose learners to the possibilities in* Science, Engineering and Technology (*SET) careers:*

   The project provides opportunities for learners to attend career days in science where professionals in science address them as potential role models. However, no mention was made of this opportunity by the teachers. This evaluation study did not find evidence of success in achieving this objective.

5. *To support the development of a culture of science learning in the region:*

   Some success has been reported in achieving this aim. The formal programme presents the running of science clubs and the staging of a science competition as ways of developing a culture of science learning in the region. From the interviews (the experienced programme) it becomes evident that most teachers have entered their student projects for the science competition. Starting and running science clubs was less successful. Teachers who have sufficient time available and value the worth of investigative science will be more likely to succeed at developing functioning science clubs. Similarly, and as expected, the motivated students who enjoy science as a subject participate in the clubs. They may not necessarily be the 'clever' ones. Rather, participating students are attracted by the unstructured, informal environment of the extra-curricular activities where they can explore topics of personal interest without too many constraints or restrictions.

   The evidence of the implemented programme shows that only minimal time and attention was devoted during the workshop to guiding teachers in how to develop science clubs. The assumption seems to have been that once the teachers themselves were familiar with conducting sample investigations, they would be able to take these as a basis for student projects in science clubs.

   In-school support, such as assisting teachers in the setting up of science clubs and the preparation for the science competition, was not part of the implemented programme. Instead, the teachers relied on the network they had built up during the three-day workshop.

6. *To provide potential role models in Science, Engineering and Technology (SET):*

   The project's underpinning philosophy sees trained and practicing scientists, engineers and technologists from disadvantaged communities as role models. The project has not run for sufficient time to measure such achievement. On a smaller scale, successful participants in science competitions could be seen as potential role models for other students. The motivating aspect of these events might encourage learners to choose science as a subject at school, which could enable them to further a career in science.

Evidently, science competitions took place and students of teachers participating in the intervention entered projects in these competitions. Thus, these students may be seen as role models as experimental scientists for other students. This in itself may be seen as an achievement of this objective. However, this evaluation project did not find evidence if these students are actually considered to be role models by their peers.

This evaluation has obtained little evidence of success for aims 3, 4 and 6. These aims include the intention of drawing learners' attention to the link between science and their everyday life, of apprising them of the opportunities in careers in SET, and, of providing students with potential role models in SET. All three aims have in common that the evidence of success should probably be collected from the interactions of teachers with the learners, in science lessons and science clubs. Then explanatory references to the link between curriculum content and everyday life, to the opportunities of SET careers, and the use of science competition participants as role models may be most explicitly apparent. This would require additional data collection on the enacted intervention programme about the ways teachers' experiences of the intervention influence teacher-student interactions. The lack of evidence of success for these objectives thus does not imply failure, but the fact that teachers do not mention these aspects as results of the intervention in the experienced programme emphasises the need for further evaluative research.

In addition, the data from the experienced intervention programme shows an important but unintended outcome. Teachers report the helpfulness of the establishment of an informal teacher network as a result of participating in the workshop. As reported earlier, this network, in part, compensates for the lack of guidance in the implemented intervention programme in managing and developing science clubs. Through this network, participants asked advice from, and provided support to, each other on issues of the management of science clubs, selection or modification of suitable student projects and loan of science equipment. More generally, teachers consulted within the network about suitable teaching strategies and learning materials such as worksheets and assessment items, building on the knowledge that each member had similar experiences during the workshop.

5.4 Reflections on the usefulness of the evaluation framework

5.4.1 A recap of the CIF evaluation model

This study has used CPD Intervention Format (CIF) Model as the evaluation framework for a teacher professional development intervention. This CIF Model is based on Van den Akker's (2003) framework for evaluating the implementation of curriculum innovations.

The professional development intervention programme is seen as appearing in various formats. As explained in the methodology chapter, the following formats of a CPD intervention programme can be identified:

1. Ideal programme format (the vision of the CPD intervention programme);
2. Formal programme format (as written up in the CPD intervention project plans, funding proposals, etc.);
3. Perceived programme format (programme staff's notions of aims, objectives, activities etc. of the CPD intervention);
4. Implemented programme format (activities during CPD workshops, in-school support, by programme staff);
5. Experienced programme format (teachers' experiences/reflections on the CPD intervention programme);
6. Achieved programme format (changes in teachers' understanding, skills, attitudes);
7. Enacted programme format (changes in teachers' behaviour in class/ science clubs).

Whereas the first six formats are mirrored in Van den Akker's framework, the last format has been added for this CPD evaluation framework in order to describe the format of teachers' application of the skills and understandings in their class. The essential aspect of this evaluation framework is that the impact of the CPD intervention is described in terms of the consistency across the various formats, as in Van den Akker's model.

5.4.2 Strengths in using the CIF model

The Simple Logic Model (W.K. Kellogg Foundation, 2004) for evaluating interventions is most commonly used and compares the stated objectives with the measured outcomes of the intervention. This is similar to what has been reported in section 5.3.4.1. The Simple Logic Model (SLM) is able to identify the match and discrepancies between the intended outcomes and the actual outcomes.

The CIF evaluation model describes not only the start and the finish of the intervention in terms of the intended and actual outcomes, but describes a series of different formats of the intervention, each representing a transition stage in the intervention. Because of the documentation of these various steps, the CIF model allows us to go further than the SLM. The CIF model can identify possible causes of any discrepancies, and thus it provides, in principle, the possibility of identifying measures to remedy any identified discrepancies. For instance, in this project the lack of structure in developing science clubs may be attributed to the lack of attention to this aspect in the implementation format, i.e. the workshops.

A second advantage of using the CIF model is the coherence it potentially provides for the planning of a CPD intervention. If the model is taken into account from the conceptualisation of the intervention, coherence across the various formats is built in as a design criterion.

A third advantage is that, contrary to the SLM, the CIF model can accommodate unexpected outcomes. These unexpected outcomes (such as the development of an informal teacher network in this intervention) are often very valuable in order to structure changes to the intervention. The CIF model is not only able to identify unexpected outcomes, but also trace the origin to a particular programme format. In this case the informal teacher network was necessitated in the enacted format, when teachers were required to actually set up science clubs, and prepare for the science competition.

5.4.3 Weaknesses in using the CIF evaluation model

A model that depends on identifying consistencies depends on the completeness and accuracy of the descriptions of the units being compared, in this case the descriptions of the different intervention formats. The CIF model therefore seems not particularly suitable for large interventions with a range of intended outcomes, implementation strategies and/or a large diversity of teachers participating in the intervention. In the current evaluation this is not a danger – the group of teachers is relatively homogeneous (apart from the primary-high school contrast) - and the intended outcomes are reasonably focused.

A second weakness could be the limited detail in the description of different intervention formats. For this current intervention, no data has been collected about the project staff's interpretation of the intended intervention programme (the perceived format of the intervention); and the evidence for the achieved intervention (about teachers' change in understanding and skills) has only been collected through self-reports from participants.

5.5. Recommendations from the study

In order to improve the consistency between the intended programme and the implemented programme, it should be clear in the minds of professional development providers if they are setting up professional development programmes with objectives for learner outcomes or teacher outcomes; as these two types of programmes will not necessarily be the same. In this study, the aims in the organisers' report were very broad and did not contextualize the workshop objectives. In order to increase consistency across the various formats of the intervention it would thus help if the purpose of the three-day workshop (the implementation programme) is more explicitly aligned with the intended programme at the conceptualization stage. In this way the facilitators would be aware of programme intentions and this could be communicated to teachers as well. The broad aims (focusing on the learners) would appeal to the funders, but the specific objectives (focusing on the teachers with learners' benefits in mind) would guide the smooth running of the workshop.

The issue of the language of delivery will always emerge as a challenge in professional development for teachers in South African schools. A discussion on this issue with participants before programme delivery might be useful in determining an appropriate approach. In this particular case, the professional development intervention intends to promote practical work, in part, by improving teachers' PCK, conceptual understanding, and experimental skills and by making suitable learning materials available. It may be worth considering the provision of (and work with) the background reading materials and the learner worksheets in both English and Afrikaans during the workshops.

The intervention was unusual in that it targeted both primary and high school teachers from the same area. The data suggests that this has specific advantages in providing all participants with a holistic view of the applicability of the type of practical work across the school levels, and the logic of progression. However, it might be useful if organisers consider the specific needs of primary and high school learners by considering grade-specific activities. It might be useful if subsequent interventions provide for joint, as well as separate, sessions to cater for general and specific needs where appropriate.

Organisers need to consider that there are some aspects in the promotion of experimental activities which can be easily incorporated into the normal running of the school, such as conducting practicals in the classroom during legitimate science periods. Other aspects, like the running of science clubs during extramural time can be more challenging. Professional development programmes could possibly be more effective if promoted activities are more easily accommodated within the general running of the school.

It would help if the school management team as well as education officials are included as an integral component of the professional development programme and participate in the decision-making processes of the programme outline. In this way, teachers who are trying out new things are supported instead of swimming against the tide.

The potential for formal networking, mentoring and cluster development among participating schools may also be maintained. Within clusters of schools, the formation of lead science and technology schools will be an incentive to sustain the changes brought about by this and similar interventions.

5.6 Limitations of the study and suggestions for further research

The study drew data from several sources, such as project documents, observations of workshop activities, interviews with the project manager and participating teachers, and whole group feedback sessions. The limitations of the study include the fact that it was a qualitative study, with a small sample of science teachers from four rural high schools as the only participants interviewed individually. This sample of teachers did not fully represent the range of teachers participating in the programme.

Another limitation is related to the semi-structured nature of the interviews with some questions that were rather open-ended. This sometimes resulted in 'drifting' teacher responses. Thus some responses were not focused, although subsequent probing was done.

Classroom observations and learner interviews, which would have completed the cycle, were not carried out, as the emphasis of the research was on the workshop component of the programme. All three aims of the formal programme have in common that evidence of success should probably be collected from the interactions of teachers with the learners, in science lessons and science clubs. This might be a focus for further study in order to ascertain whether participating teachers managed to sustain and develop the practical skills they learnt in the programme, as well as their levels of operation in organising practical work in the classroom.

5.7 Conclusion

The study intended to explore the relationship between the nature and coherence of a professional development programme and its effect on science teachers. The main purpose of the programme was to develop science teachers' conceptual knowledge and science practical skills. The project succeeded to a considerable extent in equipping teachers to conduct practical work. This was evidenced in the practicals performed at the science competition.

The project incorporated some aspects of professional development considered effective, such as active learning methodologies, and the emphasis on developing pedagogical content knowledge (PCK). Other aspects mentioned, such as ongoing, sustainable in-school support in the classroom, were not prioritised. However, this intervention can be ranked as a transmission mode model as classified by Kennedy (2005).

On-going support, more focussed on peer networking and mentoring as well as refresher workshops, will contribute to teachers sustaining their newly found skills and shift the ranking to a more transitional mode of teacher professional development. Incorporation of all role-players in a participatory approach, as suggested by Isaacs (2009), should increase the potential for sustainability.

Professional development programmes could possibly be more effective if they are more easily accommodated in the general running of the school. Organisers need to consider that there are some aspects which can be easily incorporated into the normal running of the school, such as conducting practicals in the classroom during legitimate science periods.

Other aspects, like the running of science clubs during extramural time can be more challenging. It would help if the school management team, as well as education officials, are included as an integral component of the professional development programme and participate in the decision making processes of the programme. Making changes to the school programme to incorporate student development programmes, for example, using an extended lunch time, needs the sanction and support of the school management team. Thus extramural activities become intramural activities. In this way, teachers who are trying out new things are supported instead of swimming against the tide.

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APPENDICES

Appendix A: Example of a letter sent to the Director of Education Research

Supervisory body: Cape Peninsula University of Technology

Faculty of Education

P O Box 652

Cape Town

8000

Personal contact: Tel: (021) 959-6584

Fax: (021) 959-6068

The Head: Education

For Attention: The Director of Education Research

Western Cape Education Department

Private Bag X9114

Cape Town

8000

Dear Sir

I have registered as a part-time student to complete a Masters in the Education Department of the Cape Peninsula University of Technology. My specific research topic is: "The effectiveness of an outreach invention to provide teachers with skills to implement practical and experimental work in class".

I need permission to conduct interviews with teachers who are participating in the Outreach Programme at the following schools: xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx.

I have been informed by the teachers that they prefer being interviewed in the school's premises. The interviews should not be longer than thirty minutes. I will negotiate with the teachers to find a convenient time to avoid disruption to their teaching periods.

Thanking you in anticipation.

Yours faithfully

Robert Solomon

Student; CPUT

Appendix B: Questionnaire for Outreach Project 2008

Questionnaire: Project Manager

1. What were your objectives for the Outreach Programme?

2. Who were your target groups?

3. Were there reasons for combining the primary and high schools at the workshops?

4. Why was the emphasis on practical work at the workshops?

5. What were the reasons for having a science competition for participating schools?

6. What was the relevance for wanting schools to start science clubs?

7. Did you have funders, if so, who were they and what were their requirements?

8. Can you reflect and comment on the following:

    a. The effectiveness of the presenters
    b. The implementation of the programme
    c. The response of and impact on the teachers
    d. How have you changed subsequent programmes based on lessons from this experience?

9. To what extent has this intervention contributed to sustaining:

    a. Science competitions
    b. Science clubs
    c. Teachers' practice

10. Do you have any other general comments?

Thank you

Appendix C: Observation sheet of workshop

Categories	**Description of events**	**Researcher's reflections/thoughts**
Methodology used by presenter		
Nature of the activities		
Operational aspects		
Teacher interaction		

Appendix D: Interview Schedule

Interview Schedule

The Out Reach Program tries to provide teachers with skills to implement practical and experimental work in class with learners and start up (Science clubs)

(Interview +- 30 minutes)

1 Ice breaker: Think back and relate to that one incident that attributes to you being a science teacher today.

Practicals

*Do you think that practical work in the science class room has value?

2(a) Have you always done **practicals** in the class?

NO! / SOMETIMES!

* What barriers have you encountered in conducting practicals?

* Are you doing practicals now?

* What has influenced you to do practicals now?

YES!

* Do you have a fixed set of practicals that you perform?

* Has your range of practical work changed? (have you added more practicals to? your repertoire)

* Have you been innovative with practical work? (not conventional pracs)

2(b) Try and hone in on one outstanding **practical** that was part of the program.

* Did it make an impact on you?

* Why did it make such an impact?

* Have you conducted this practical in class?

* Did you conducted it as a demonstration or practical in the class?

* What was the resulting outcome? (did it work for you/student?)

New topics

3(a) There have been many curriculum changes such as **new topics** introduced.

*Tell me about your experiences, focusing on any new topic in the curriculum?

*How do you deal with it? (your experiences)

(b) Were the new topics presented in the outreach program adequately covered?

(c) Do you think the topics chosen by the project fit your needs?

(d) Do you have any advice on how we can address the new topics in the curriculum?

Science competitions

4 Part of the program was the **science competitions** (Recall provide triggers)

(b)What are some of your memories you have of your students in the science competitions? e.g. (students reactions, kitchen science or timer reactions)

(c) What type of preparations with students did you have prior to the competition?

(d) Did preparation coincide with topics taught in your grades?

(e) What were students attitudes towards preparing for competition?

(f) Do you think students involved in the competition attitude change towards science? (why)

(g) Tell me about some of challenges/stumbling blocks that a science teacher in this area might encounter when trying to start up a science club?

General Questions

* Are the presenters adequately equipped to present the topics?
* What can the presenters do differently to improve the quality of presentations?

* What are your views on the value of the program?
* Has the programme impacted positively or negatively on the way you teach physics or chemistry?
* Which aspects of the program have been the most effective for you?

Thank you, the information was invaluable.

Open ended questions:

Any memories / good or bad? Any thoughts / ideas? You would like to share.